

Blood vessel prosthesis and delivery apparatus

The invention relates to a prosthesis for a blood vessel, and a delivery apparatus for delivering the prosthesis to the blood vessel, particularly, but not necessarily exclusively, for use in the treatment of aneurysms or dissections of the blood vessel.

Aneurysms are permanent distensions of the wall of a blood vessel, e.g. an artery, which disrupt the haemodynamics of the blood vessel. The aneurysm may halt the flow of blood at certain regions of the blood vessel, increasing the risk of clot formation, which may in turn cause cerebral embolism. Furthermore, a reduction in the structural wall integrity of the blood vessel may occur, which can cause a reduction in the effectiveness of the blood vessel and put a higher strain on the heart muscle, increasing the risk of heart failure or vessel rupture.

Dissections are tears in the blood vessel's intima or delaminations of the collagen/elastin wall architecture of the blood vessel. Dissections can result in a false lumen, i.e. inner cavity, within the blood vessel. The false lumen may provide areas in which blood can pool, increasing the risk of clot formation and subsequent cerebral embolism. Severe dissection may even result in a breach of the blood vessel integrity and possible bleeding from the blood vessel e.g. into the thoracic cavity, which may cause death in a short period of time.

Traditional treatment for dissections and aneurysms include surgical resection, removing the offending tissue (depending on the extent of the damage to the blood vessel), or the insertion of a tubular prosthesis or stent graft within the lumen of the blood vessel to remove the mechanical loading on the damaged blood vessel wall and to provide a haemodynamically compatible conduit for the transport of blood. Prostheses are traditionally made from Dacron ® or high density Polytetrafluoroethylene (PTFE).

More recently, endovascular methods of prosthesis introduction have reduced health risks to the patient by allowing percutaneous introduction of the prosthesis via the femoral artery. Operations can therefore be conducted under local anaesthetic, and cardiac arrest and/or cardiac bypass procedures may be eliminated, reducing the overall cost of the treatment.

Prostheses and stent grafts have been designed for positioning at bifurcation regions of blood vessels, i.e. regions in which the blood vessel branches. For example, PCT Application nos. WO00042948, WO03082153 and WO05122957 and US patent no. US5984955 disclose bifurcated prostheses/stent grafts for positioning primarily at the iliac bifurcation of the aorta. The prostheses comprise a main conduit, a first branch conduit extending therefrom, and a removable or retractable second branch conduit. The main conduit is designed to locate within the aorta and the first and second branch conduits are designed to locate within respective iliac arteries.

Journal article: K. Inoue et al., Aortic Arch Reconstruction by Transluminally Placed Endovascular Branched Stent Graft", *Circulation*. 1999; 100 describes a stent graft which includes conduits for aortic branches and a method of introduction.

The prostheses/ stent grafts described above are generally sited percutaneously using a catheter delivery system which allows introduction to and guidance through the vasculature. Control of the device is made through pushrods or hypotubes which can extract the device from a casing and locate it in position.

Notably, none of these prostheses and stent grafts, or the delivery systems thereof, are intended for, or are indeed appropriate for, positioning at the branch region of the ascending aorta where the aortic root meets the right and left coronary arteries, which feed the heart muscle with oxygenated blood. The anatomy of the aortic root and the coronary arteries is complex. This location is particularly prone to aneurysms and dissections.

According to a first aspect of the present invention, there is provided

a prosthesis delivery apparatus for delivering a prosthesis to the branch region of the ascending aorta and the right and left coronary arteries, the apparatus comprising:

a prosthesis comprising a main conduit and first and second branch conduits,

a first guide wire for inserting in the ascending aorta such that it extends through the ascending aorta into the right coronary artery; and

a second guide wire for inserting in the ascending aorta such that it extends through the ascending aorta into the left coronary artery;

wherein the prosthesis is arranged such that:

the first and second branch conduits are movable along the first and second guide wires to the branch region, and

the first branch conduit is moveable from a first position in which it projects inside the main conduit, to a second position in which it projects out from the main conduit for location in the right coronary artery, the first branch conduit being arranged to turn inside out as it moves from the first position to the second position, and

the second branch conduit is movable from a first position in which it projects inside the main conduit to a second position in which it projects out from the main conduit for location in the left coronary artery, the second branch conduit being arranged to turn inside out as it moves from the first position to the second position.

According to a second aspect of the present invention, there is provided:

a method for delivering a prosthesis to the branch region of the ascending aorta and the right and left coronary arteries, the prosthesis comprising a main conduit and first and second branch conduits, the method comprising the steps of:

inserting a first guide wire in the ascending aorta such that it extends through the ascending aorta into the right coronary artery;

inserting a second guide wire in the ascending aorta such that it extends through the ascending aorta into the left coronary artery.

moving the prosthesis to the branch region by moving the first branch conduit along the first guide wire and the second branch conduit along the second guide wire; and

moving the first branch conduit along the first guide wire from a first position in which it projects inside the main conduit to a second position in which it projects out from the main conduit, to locate the first branch conduit in the right coronary artery, the first branch conduit turning inside out as it moves from the first position to the second position;

moving the second branch conduit along the second guide wire from a first position in which it projects inside the main conduit to a second position in which it projects out from the main conduit, to locate the second branch conduit in the left coronary artery, the second branch conduit turning inside out as it moves from the first position to the second position.

Preferably, the prosthesis is mounted on the first and second guide wires, by inserting the first and second guide wires through the first and second branch conduits respectively, prior to moving the branch conduits toward the branch region.

According to a third aspect of the present invention, there is provided:

a prosthesis for locating at the branch region of the ascending aorta and the right and left coronary arteries, the prosthesis comprising a main conduit and first and second branch conduits, the first branch conduit being for locating in the right coronary artery and the second branch conduit being for locating in the left coronary artery, wherein:

the first branch conduit is movable from a first position in which it projects inside the main conduit to a second position in which projects out from the main conduit in order for it to locate in the right coronary artery, the first branch conduit being arranged to turn inside out as it moves from the first position to the second position, and

the second branch conduit is movable from a first position in which it projects inside the main conduit to a second position in which projects out from the main conduit in order for it to locate in the

left coronary artery, the second branch conduit being arranged to turn inside out as it moves from the first position to the second position.

This arrangement of the branch conduits described above permits the prosthesis to take a compact shape during delivery to the branch region of the blood vessel. Thus, the possibility of obstruction of the prosthesis during delivery is reduced. Furthermore, by arranging the branch conduits to turn inside out, moving the branch conduit from the first to the second position may be straightforward, and construction of the branch conduits may be uncomplicated. The prosthesis may be manufactured in one-piece.

Preferably, the prosthesis used in the delivery apparatus according to the first aspect of the present invention and/or of the prosthesis used in the method according to the second aspect of the present invention, is a prosthesis according to the third aspect of the invention.

The prosthesis may be used to treat aneurysms or dissections of the ascending aorta proximal to the aortic valve and the left ventricle of the heart.

According to a fourth aspect of the present invention, there is provided:

- a prosthesis delivery apparatus for delivering a prosthesis to a branch region of a blood vessel, the branch region having first and second blood vessel branches, the apparatus comprising:

- a prosthesis comprising a main conduit and first and second branch conduits,

- a first guide wire for inserting in the blood vessel such that it extends through the blood vessel into the first blood vessel branch; and

- a second guide wire for inserting in the blood vessel such that it extends through the blood vessel into the second blood vessel branch;

- wherein the prosthesis is arranged such that the first branch conduit is movable along the first guide wire toward the first blood vessel branch for location in the first blood vessel branch and the second branch conduit is movable along the second guide wire toward the second blood vessel branch for location in the second blood vessel branch.

According to a fifth aspect of the present invention, there is provided:

a method for delivering a prosthesis to a branch region of a blood vessel, the branch region having first and second blood vessel branches, the prosthesis comprising a main conduit and first and second branch conduits, the method comprising the steps of:

inserting a first guide wire in the blood vessel such that it extends through the blood vessel into the first blood vessel branch;

inserting a second guide wire in the blood vessel such that it extends through the blood vessel into the second blood vessel branch;

moving the first branch conduit along the first guide wire toward the first blood vessel branch for location in the first blood vessel branch and moving the second branch conduit along the second guide wire toward the second blood vessel branch for location in the second blood vessel branch.

Preferably, in the fourth and fifth aspects of the present invention, the prosthesis is mounted on the first and second guide wires by inserting the first and second guide wires through the first and second branch conduits respectively, prior to moving the branch conduits toward the first and second blood vessel branches.

According to a sixth aspect of the present invention, there is provided:

a prosthesis for locating at a branch region of a blood vessel, the branch region having a first blood vessel branch, the prosthesis comprising a main conduit and a first branch conduit, the first branch conduit being for locating in the first blood vessel branch, wherein the first branch conduit is movable from a first position in which it projects inside the main conduit to a second position in which projects out from the main conduit in order for it to locate in the first blood vessel branch, the first branch conduit being arranged to turn inside out as it moves from the first position to the second position.

Preferably, in the sixth aspect of the present invention, the prosthesis comprises a second branch conduit, the second branch conduit being for locating in a second blood vessel branch of the branch region.

Preferably, the second branch conduit is movable from a first position in which it projects inside the main conduit to a second position in which it projects out from the main conduit in order for it to locate in the second blood vessel branch, the second branch conduit being arranged to turn inside out as it moves from the first position to the second position.

This arrangement of the branch conduit(s) permits the prosthesis to take a compact shape during delivery to the branch region of the blood vessel. Thus, the possibility of obstruction of the prosthesis during delivery is reduced. Furthermore, by arranging the branch conduit(s) to turn inside out, moving the branch conduit(s) from the first to the second position may be straightforward, and construction of the branch conduit(s) may be uncomplicated. The prosthesis may be manufactured in one-piece, for example.

In the various aspects of the invention, preferably, the main conduit comprises a first end which defines an opening, a second end which defines an opening, and a sidewall extending between the first and second ends. Preferably, the first and second branch conduits are mounted to opposing flanks of the sidewall of the main conduit. Preferably, the first and second branch conduits and the main conduit are one-piece.

The main conduit may be substantially cylindrical. The cross-section of the main conduit, in a plane substantially perpendicular to the longitudinal axis of the main conduit, may therefore be substantially circular. In this description, the term 'mounted to opposing flanks' is intended to mean that the first and second branch conduits are mounted to the sidewall at positions which are more than 90 degrees apart, preferably more than 150 degrees apart, about the circumference of the circle or other cross-sectional shape. The first and second branch conduits may be mounted at positions of the sidewall that are offset in a direction parallel to the longitudinal axis of the main conduit.

According to a seventh aspect of the present invention, there is provided:

a prosthesis for locating at a branch region of a blood vessel, the branch region having first and second blood vessel branches, the prosthesis comprising:

a main conduit and first branch and second branch conduits, the main conduit having a first end which defines an opening, a second end which defines an opening, and a side wall extending between the first and second ends, the first and second branch conduits being for locating in the first and second blood vessel branches respectively,

wherein the first and second branch conduits are mounted to opposing flanks of the sidewall of the main conduit, and

the main conduit and first and second branch conduits are one-piece.

Preferably, the prosthesis used in the delivery apparatus according to the fourth aspect of the present invention, and/or the prosthesis used in the method according to the fifth aspect of the present invention, is a prosthesis according to the sixth or seventh aspect of the invention.

In the fourth, fifth, sixth and seventh aspects of the present invention, preferably, the blood vessel is an artery, preferably the aorta, most preferably the ascending aorta. Preferably, the first and second blood vessel branches are the left and right coronary arteries. Thus, the prosthesis may be used to treat aneurysms or dissections of the ascending aorta proximal to the aortic valve and the left ventricle of the heart.

In the various aspects of the invention, preferably, one or more first actuators are provided to move the first and second branch conduits from the first to the second position. Preferably, the first actuators are push rods. The push rods may be slidably mounted on the guide wires. Thus, since the guide wires are located in the blood vessel branches, the push rods may push the branch conduits in the appropriate directions for location in the blood vessel branches (e.g. the left and right coronary arteries), simply by sliding along the guide wires.

Preferably, first and second push rods are provided as first actuators, the first push rod being arranged to push the first branch conduit and the second push rod being arranged to push the second branch conduit. Preferably, the first and second push rods are slidably mounted on the first and second guide wires respectively. The first and second guide wires may extend through a portion of, or all of, the first and second push rods respectively. For example, the guide wires may extend

through the first and second push rods at positions within the prosthesis, but be separated from the push rods at positions outside the prosthesis. The guide wires may extend out of the push rods via one or more side holes.

Preferably, one or more second actuators are provided to push the prosthesis, e.g. the main conduit of the prosthesis, toward the branch region of the blood vessel, which in turn causes the first and second branch conduits to move along the first and second guide wires respectively. Preferably, the second actuator can also move the prosthesis in the opposite direction, i.e. in a direction away from the branch region. Thus, the first and second actuators may work against each other, e.g. so that the main conduit of the prosthesis can be held stationary whilst the branch conduits are moved from the first position to the second position. The second actuators may be one or more push rods. The first actuator push rods may be arranged to extend through one or more conduits provided by the second actuator push rods.

Preferably, the first and/or second guide wire comprises an identifying mark or shape. Thus, the appropriate guide wire can be chosen for each blood vessel branch.

Preferably, the prosthesis is expandable from a contracted state to an expanded state. Accordingly, the prosthesis may be placed in a contracted position during delivery to the branch region, so that it is less likely to be obstructed during delivery. Then, once positioned at the branch region, it may be expanded to a desired size for use.

Preferably, a delivery casing is provided for holding the prosthesis in a contracted state during delivery of the prosthesis to the branch region. Preferably, the prosthesis is arranged to expand automatically upon removal of the delivery casing. The delivery casing may be a sleeve that surrounds the prosthesis to maintain it in a contracted state. The delivery casing may be elongated and may act as the second actuator for pushing the prosthesis to the branch region of the blood vessel.

The prosthesis may be resiliently biased when positioned in the contracted state such that, upon removal of the delivery casing, the prosthesis expands automatically. The prosthesis may be formed of PTFE, or Nylon etc. The prosthesis may be resiliently biased by e.g. shape memory alloy elements, e.g. formed of Nitinol, embedded therein.

By locating in the blood vessel branches (e.g., the right and left coronary arteries), the first and second branch conduits may be used to anchor the prosthesis in position; prevent occlusion of the opening between the blood vessel branches, into which they locate, and the blood vessel (e.g., the ascending aorta); and/or help maintain the main conduit in the expanded state.

A fixing means may be provided for fixing the first and second branch conduits in position in the respective first and second blood vessel branches. The fixing means may be integral with the branch conduits. For example, the fixing means may be one or more stents attached to e.g. an end of the branch conduits. Balloons may be provided on the first actuators, e.g. push rods, to expand the stents in order to fix the branch conduits in position. The first actuators, e.g. push rods, may be used to hold the branch conduits in position prior to fixing, to prevent e.g. retraction of the branch conduits from the blood vessel branches. Alternatively, separate fixing means may be provided to fix the branch conduits in position, e.g. after the push rods have been retracted. For example, independent stents or endovascular staples may be used.

A fixing means may be provided at one or both ends of the main conduit. The fixing means may be used to anchor the respective ends of the main conduit against the blood vessel wall in order to prevent blood ingress between the main conduit and the blood vessel wall. The fixing means may be integral with the respective ends of the main conduit. For example, the fixing means may be one or more stents attached to the ends, the stents being expandable e.g. by balloons. Alternatively, separate fixing means may be provided to fix the main conduit in position, e.g. after the first actuator push rods have been retracted. For example, independent stents, or endovascular staples may be used.

Preferably, the prosthesis and/or the guide wires are configured for insertion into the blood vessel percutaneously. Thus, an endovascular method of prosthesis delivery may be provided.

By having open first and second ends of the main conduit, blood may flow between the blood vessel and the main conduit. The guide wires and/or actuators (e.g. push rods) may extend through the main conduit via the opening of the first end. Preferably, the second end of the main conduit is for locating adjacent the aortic valve. The second end of the main conduit may comprise an artificial aortic valve.

Preferably, the first and second branch conduits are connected to the side wall of the main conduit such that blood may flow between the first and second branch conduits and the main conduit. By connecting the branch conduits to the side wall, rather than the second end for example, an appropriate configuration may be achieved for positioning the prosthesis e.g. at the branching of the aortic root and the right and left coronary arteries. In particular, this arrangement may permit the branch conduits to project in directions substantially opposite from each other, and substantially perpendicular to the longitudinal axis of the main conduit. Thus, the prosthesis may conform to the complex anatomy of the bifurcation of the aortic root and the right and left coronary arteries.

An example embodying the present invention is now described with reference to the accompanying drawings, in which:

Fig. 1a shows guide wires of a delivery apparatus according to a first embodiment of the present invention extending through a blood vessel to a branch region of the blood vessel;

Fig. 1b and 1c show a prosthesis according to the present invention mounted on the guide wires of Fig. 1a and moved towards the branch region of the blood vessel;

Figs. 2a to 2d show successive steps performed during the location of branch conduits of the prosthesis of Figs. 1b and 1c into blood vessel branches of the branch region of the blood vessel;

Fig. 3 shows a delivery apparatus according to a second embodiment of the present invention; and

Figs. 4a to 4e show a branch conduit of a prosthesis according to a third embodiment of the present invention.

A first embodiment of a delivery apparatus according to the present invention, for delivering a prosthesis to a branch region of a blood vessel, is shown in Figs. 1a to 1c and Figs. 2a to 2d. In this embodiment, the blood vessel is the ascending aorta 1 of a human, and the branch region is the region at the aortic root 11, where the right and left coronary arteries 12, 13 connect to the aorta 1, adjacent to the aortic valve 15.

The delivery apparatus comprises first and second guide wires 21, 22, a prosthesis 3, a prosthesis delivery casing 4, and first and second push rods 51, 52. The prosthesis 3 is formed from haemodynamically compatible material and comprises a main conduit 33 having a first end 331, a second end 332 and side wall 34 extending between the first and second ends 331, 332. The first and second ends 331, 332 are open. The prosthesis 3 comprises first and second branch conduits 31, 32, which are connected at respective first ends 311, 321 to opposite flanks of the side wall 34. The first ends 311, 321 of the branch conduits 31, 32 are open to permit blood flow between the branch conduits 31, 32 and the main conduit 33. The second ends 312, 322 of the branch conduits 31, 32 are also open, to permit blood flow between the branch conduits 31, 32 and the coronary arteries 12, 13.

The steps undertaken to deploy the prosthesis 3, using the delivery apparatus, are described below.

Firstly, with reference to Figs. 1a to 1c, the first guide wire 21 is percutaneously inserted into the aorta 1 such that it extends through the aorta 1 and a first end 212 of the first guide wire 21 is positioned in the right coronary artery 12. The first guide wire 21 may be placed in this position using a catheter (not shown), which is subsequently removed.

Next, the second guide wire 22 is percutaneously inserted into the aorta 1 such that it extends through the aorta 1 and a first end 222 of the second guide wire 22 is positioned in the left coronary artery 13. The second guide wire 22 may also be placed in this position using a catheter (not shown), which is subsequently removed.

Next, the prosthesis 3, surrounded by the delivery casing 4, is mounted on the first and second guide wires 21, 22 and pushed by a push rod 53 along the guide wires 21, 22, past the aortic branch arteries 14, toward the aortic root 11, as shown in Figs 1b and 1c.

As can be seen in Fig. 2a, which shows a cross-section of the prosthesis 3 mounted on the first and second guide wires 21, 22, during delivery to the aortic root region 11, the first and second branch conduits 31, 32 are in a first position in which they project into the interior of the main conduit 33. Furthermore, the main conduit 33 is held in a contracted state by the delivery casing 4. The delivery casing 4 is a removable sleeve that surrounds and compresses the main conduit 33. Accordingly, the prosthesis 3 may take a compact shape during delivery to the aortic root region 11, reducing the chance of the prosthesis 3 being obstructed on the way.

In the first position, the first and second branch conduits 31, 32 are inclined from the sidewall 34. The first and second branch conduits 31, 32 project toward the first end opening 333 of the main conduit 3. As shown in Fig. 2a, the first and second guide wires 21, 22 extend into the main conduit 33 via the first end opening 333 of the main conduit 33, and through the first and second branch conduits 31, 32 via the open second ends 312, 322 of the first and second branch conduits 31, 32. The first and second guide wires 21, 22 then project from the prosthesis 3 via the first ends 311, 321 of the first and second branch conduits 31, 32, whereupon they extend between the sidewall 34 and the delivery casing 4, and then through an opening 42 of the delivery casing 4.

Once the prosthesis 3 has reached the aortic root region 11, deployment of the prosthesis 3 takes place as described below with respect to Figs. 2b to 2d.

Firstly, the delivery casing 4 is partially removed from the prosthesis 3, so that the first ends 311, 321 of the first and second branch conduits 31, 32 are exposed, as shown in Fig. 2b. The main conduit 33 of the prosthesis 3 comprises shape memory alloy elements, such that, upon removal of the delivery casing 4, the main conduit 33 expands automatically. Once the first ends 311, 321 of the first and second branch conduits 31, 32 are exposed, first and second push rods 51, 52, which have engagement surfaces 511, 521, that abut the second ends 312, 322 of the first and second branch

conduits 31, 32, are manually controlled to push the second ends 312, 322 of the branch conduits through the open first ends 311, 321 of the first and second branch conduits 31, 32. This causes the branch conduits 31, 32 to evert, i.e. turn inside out, whereupon they are placed in a second position, as shown in Fig. 2c, in which they project outward from the main conduit 33 of the prosthesis 3. In the second position, the branch conduits 31, 32 project in a direction substantially perpendicular to the longitudinal axis of the main conduit 33, indicated generally by line A

As the first and second branch conduits 31, 32 are moved from the first position to the second position, by the push rods 51, 52, they are forced into the right and left coronary arteries respectively. This helps anchor the prosthesis 3 in position, ensures that the fluid path between the aorta 1 and the coronary arteries 12, 13 is kept open, and helps maintain the main conduit 33 in the expanded state.

Next, the delivery casing is removed fully from the prosthesis, such that the entire main conduit 33 can expand to substantially the size of the inner wall diameter of the aorta 1. The push rods 51, 52 are also retracted. To secure the prosthesis 3 in position, a stents (not shown) can be used.

Thus, the prosthesis 3 may reduce mechanical loading on the aorta 1 at the aortic root region 11, and may provide a haemodynamically compatible conduit for the transport of blood between the aorta and the right and left coronary arteries.

Subsequently, the first and second guide wires 21, 22 can be removed.

In Fig. 2a, it can be seen that the first and second branch conduits 31, 32 are mounted to opposite flanks of the sidewall 34 at points level with one another, i.e. the mounting points are generally aligned in a direction parallel to the longitudinal axis A of the main conduit 33. However, the mounting points may be offset in a direction parallel to the longitudinal axis A of the main conduit 33. This may be particularly useful to enable compact packing of the prosthesis 4; it may mean that the branch conduits 31, 32 do not obstruct each other if the prosthesis 4 is compressed.

Fig. 3 shows a delivery apparatus according to a second embodiment of the present invention. The delivery apparatus is similar to and functions in generally the same way as the apparatus of the first embodiment of the invention, except that the prosthesis in this second embodiment comprises two guide tubes 35, 36. The guide tubes 35, 36 are provided to make mounting of the prosthesis, on the guide wires 21, 22, simpler. The same numbering is used to indicate features common to Fig 3 and Figs. 1a to 2d.

As shown in Fig. 3, the guide tubes 35, 36 each fit into the first and second branch conduits 31, 32 respectively, when the branch conduits 31, 32 are in their first positions.

The guide tubes 35, 36 extend through the branch conduits 31, 32 and through the first ends 311, 321 of each branch conduit 31, 32, whereupon they extend between the sidewall 34 and the delivery casing 4 and through the opening 42 of the delivery casing 4, and then project from the prosthesis 4.

Since the guide tubes 35, 36 project from the prosthesis 4, the guide wires 21, 22 can easily be inserted into the guide tubes 35, 36, whereupon the guide tubes 35, 36 serve to channel the guide wires 21, 22 between the delivery casing 4 and the sidewall 34, through the branch conduits 31, 32 and through the main conduit 33 of the prosthesis. Thus, mounting of the prosthesis on the guide wires, is made easier.

The guide tubes 35, 36 are connected to the prosthesis 4; however, alternatively, the guide tubes 35, 36 can be connected to the push rods 51, 52.

Figs. 4a to 4e show a branch conduit 32' a push rod 52' of a delivery apparatus according to a third embodiment of the present invention. The branch conduit 32' is similar to the branch conduits 31, 32 of the previous embodiments of the invention, and it functions in generally the same way, except that it comprises an integral stent 61, located at its second end 322'. The branch conduit 32' can be used as an alternative to the branch conduits 31, 32 of the previous embodiments. The stent 61 is provided as a fixing means, to fix the branch conduit 32' in position once it is located in the appropriate blood vessel branch. The push rod 52' is similar to the push rods 51, 52 of the previous embodiments of the

invention, and functions in generally the same way as in these previous embodiments, except that it comprises an inflatable balloon 62. The balloon 62 is provided to expand the stent 61.

The steps taken to deploy the branch conduit 32' can be seen in Figs. 4a to 4e. In Fig. 4a, the branch conduit 32' is located in its first position, i.e. in a position in which it is located inside the main conduit of the prosthesis. From the position shown in Fig. 4a, the branch conduit 32' is forced along the guide wire 22 to its second position, as shown in Fig. 4b, by the push rod 52'. The branch conduit 32' everts as it moves from the first to the second position, but the stent 61 does not evert. Once the branch conduit 32' is in the second position, the balloon 62 is inflated, which forces the stent 61 to expand, as shown in Fig. 4c. This causes the stent 61 to press the branch conduit 32' against the side walls of the blood vessel, fixing the branch conduit 32' in position. Once the branch conduit 32' is fixed in position, the balloon 62 is deflated as shown in Fig. 4d. Then, the push rod 52', including the balloon 62, is retracted, as shown in Fig. 4e.

Claims:

1. Prosthesis delivery apparatus for delivering a prosthesis to the branch region of the ascending aorta and the right and left coronary arteries, the apparatus comprising:
 - a prosthesis comprising a main conduit and first and second branch conduits,
 - a first guide wire for inserting in the ascending aorta such that it extends through the ascending aorta into the right coronary artery; and
 - a second guide wire for inserting in the ascending aorta such that it extends through the ascending aorta into the left coronary artery;wherein the prosthesis is arranged such that:
 - the first and second branch conduits are movable along the first and second guide wires to the branch region, and
 - the first branch conduit is moveable from a first position in which it projects inside the main conduit, to a second position in which it projects out from the main conduit for location in the right coronary artery, the first branch conduit being arranged to turn inside out as it moves from the first position to the second position, and
 - the second branch conduit is movable from a first position in which it projects inside the main conduit to a second position in which it projects out from the main conduit for location in the left coronary artery, the second branch conduit being arranged to turn inside out as it moves from the first position to the second position.
2. The delivery apparatus of claim 1, comprising one or more actuators for moving the first and second branch conduits from the first to the second position.
3. The delivery apparatus of 2 comprising one or more actuators for moving the first branch and second branch conduits along the first and second guide wires to the branch region.
4. The delivery apparatus of claim 2 and 3, wherein the same actuators are used to move the first branch and second branch conduits along the first and second guide wires to the branch region and to move the first and second branch conduits from the first to the second position.

5. The delivery apparatus of claims 2, 3 or 4, wherein the actuators are push rods.
6. The delivery apparatus of claim 5, wherein the push rods are slidably mounted on the guide wires.
7. The delivery apparatus of any one of the preceding claims, wherein the first and/or second guide wire comprises an identifying mark or shape.
8. The delivery apparatus of any one of the preceding claims, wherein the first and/or second guide wire is configured for insertion into the ascending aorta percutaneously.
9. The delivery apparatus of any one of the preceding claims, wherein the prosthesis is configured for insertion into the ascending aorta percutaneously.
10. The delivery apparatus of any one of the preceding claims wherein the prosthesis is expandable from a collapsed state to an expanded state.
11. The delivery apparatus of claim 10, comprising a delivery casing for holding the prosthesis in a collapsed state during delivery of the prosthesis to the branch region.
12. The delivery apparatus of claim 11, wherein the prosthesis is arranged to expand automatically upon removal of the delivery casing.
13. The delivery apparatus of any one of the preceding claims, further comprising one or more stents for securing the prosthesis in place at the branch region.
14. A prosthesis for locating at the branch region of the ascending aorta and the right and left coronary arteries, the prosthesis comprising a main conduit and first and second branch conduits, the

first branch conduit being for locating in the right coronary artery and the second branch conduit being for locating in the left coronary artery, wherein:

the first branch conduit is movable from a first position in which it projects inside the main conduit to a second position in which projects out from the main conduit in order for it to locate in the right coronary artery, the first branch conduit being arranged to turn inside out as it moves from the first position to the second position, and

the second branch conduit is movable from a first position in which it projects inside the main conduit to a second position in which projects out from the main conduit in order for it to locate in the left coronary artery, the second branch conduit being arranged to turn inside out as it moves from the first position to the second position.

15. The prosthesis of claim 14, wherein the main conduit comprises a first end which defines an opening, a second end which defines an opening and a side wall extending between the first and second ends of the main conduit, the first and second branch conduits being mounted to the side wall of the main conduit.

16. The prosthesis of claim 14 or 15, wherein the first and/or second branch conduits are configured to be moveable along respective first and second guide wires.

17. The prosthesis of any one of claims 14 to 16, wherein the first and/or second branch conduits have an engagement surface at one end for engaging one or more actuators for moving the branch conduits from the first to the second position.

18. The prosthesis of any one of claims 14 to 17, wherein the prosthesis is expandable from a collapsed state to an expanded state.

19. A prosthesis assembly comprising the prosthesis of claim 18 and a removable delivery casing for holding the prosthesis in the collapsed state.

20. The prosthesis of any one of claims 14 to 19 wherein the first and second branch conduits are mounted to opposing flanks of the sidewall of the main conduit.
21. The prosthesis of any one of claims 14 to 20, wherein the main conduit, and first and second branch conduits are one-piece.
22. The prosthesis of any one of claims 14 to 21, wherein the first and/or second branch conduit comprises a fixing means for fixing the branch conduit in the coronary artery.
23. The prosthesis of claim 22, wherein the fixing means for fixing the first and/or second branch conduit is a stent.
24. The prosthesis of any one of claims 14 to 23, wherein the main conduit comprises one or more fixing means for fixing the first and/or second end of the main conduit to the wall of the ascending aorta.
25. The prosthesis of claim 24, wherein the fixing means for fixing the first and/or second end of the main conduit is a stent.
26. A delivery apparatus substantially as described herein with reference to the Figures.
27. A prosthesis substantially as described herein with reference to the Figures.
28. A method for delivering a prosthesis to the branch region of the ascending aorta and the right and left coronary arteries, the prosthesis comprising a main conduit and first and second branch conduits, the method comprising the steps of:
- inserting a first guide wire in the ascending aorta such that it extends through the ascending aorta into the right coronary artery;
 - inserting a second guide wire in the ascending aorta such that it extends through the ascending aorta into the left coronary artery.

moving the prosthesis to the branch region by moving the first branch conduit along the first guide wire and the second branch conduit along the second guide wire; and

moving the first branch conduit along the first guide wire from a first position in which it projects inside the main conduit to a second position in which it projects out from the main conduit, to locate the first branch conduit in the right coronary artery, the first branch conduit turning inside out as it moves from the first position to the second position;

moving the second branch conduit along the second guide wire from a first position in which it projects inside the main conduit to a second position in which it projects out from the main conduit, to locate the second branch conduit in the left coronary artery, the second branch conduit turning inside out as it moves from the first position to the second position.

29. The method of claim 28, wherein one or more actuators are used for moving the first branch and second branch conduits along the first and second guide wires to the branch region.

30. The method of claim 28 or 29, wherein one or more actuators are used for moving the first and second branch conduits from the first to the second position.

31. The method of claim 29 and 30, wherein the same actuators are used to move the first branch and second branch conduits along the first and second guide wires toward the branch region and to move the first and second branch conduits from the first to the second position.

32. The method of claims 29, 30 or 31, wherein the actuators are push rods.

33. The method of claim 32, wherein the push rods are slidably mounted on the guide wires.

34. The method of any one of claims 28 to 33, wherein the first and/or second guide wire comprises an identifying mark or shape.

35. The method of any one of claims 28 to 34, wherein the first and/or second guide wire is inserted into the ascending aorta percutaneously.

36. The method of any one of claims 28 to 35, wherein the prosthesis is inserted into the ascending aorta percutaneously.
37. The method of any one of claims 28 to 36, wherein the prosthesis is expanded from a collapsed state to an expanded state at the branch region.
38. The method of claim 37, wherein a delivery casing is provided for holding the prosthesis in a collapsed state during delivery of the prosthesis to the branch region.
39. The method of claim 38, wherein the prosthesis expands automatically upon removal of the delivery casing.
40. The method of any one of claims 28 to 39, wherein one or more stents are used to secure the prosthesis at the branch region.