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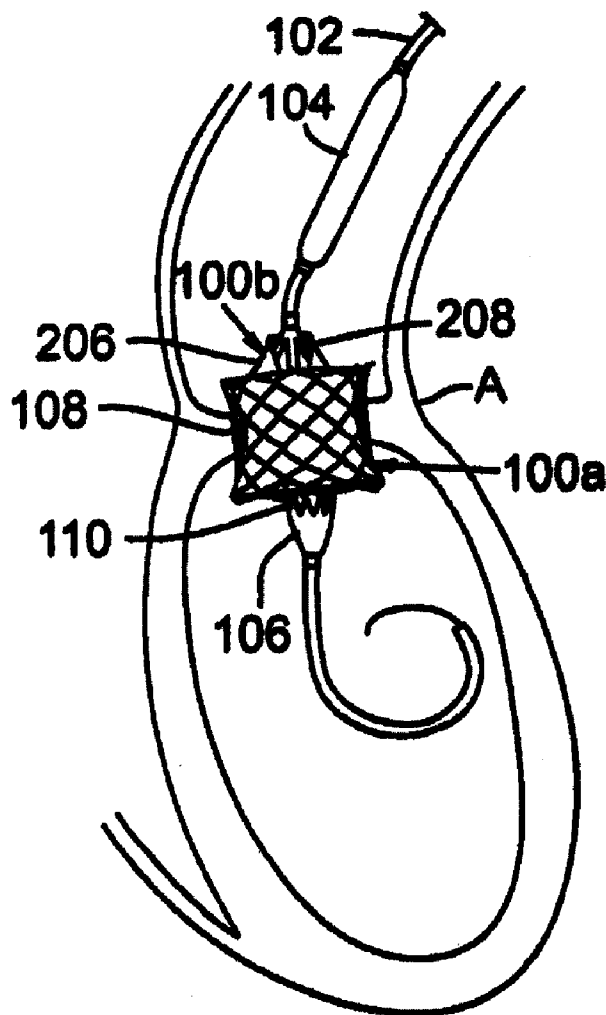
(19) **United States**(12) **Patent Application Publication**
Benichou et al.(10) **Pub. No.: US 2009/0281609 A1**(43) **Pub. Date: Nov. 12, 2009**(54) **TWO-STEP HEART VALVE IMPLANTATION****Publication Classification**(75) Inventors: **Netanel Benichou**, Hof-Carmel
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Bat-Shlomo (IL)(51) **Int. Cl.****A61F 2/06** (2006.01)**A61M 29/00** (2006.01)(52) **U.S. Cl. 623/1.11; 623/1.26; 604/96.01**

(57)

ABSTRACT

A two-part implantable heart valve and procedure are disclosed that allow expansion and positioning of a first part of the implantable heart valve having a temporary or transient valvular structure. A second part of the implantable heart valve is deployed within the first part and attaches thereto. The valvular structure of the second part then acts to function as the heart valve replacement. A tool or system is provided for determining an adequate percutaneous heart valve size for a given stenotic valve. A balloon can be inflated inside the stenotic valve to a desired pressure. When this pressure is reached an angiographic image is taken and the balloon diameter is measured at a waist area created by contact between the balloon and the stenotic valve. The diameter represents the minimum percutaneous heart valve diameter to be implanted.

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PORTLAND, OR 97204 (US)(73) Assignee: **Edwards Lifesciences**(21) Appl. No.: **12/392,995**(22) Filed: **Feb. 25, 2009****Related U.S. Application Data**(60) Provisional application No. 61/032,822, filed on Feb.
29, 2008.

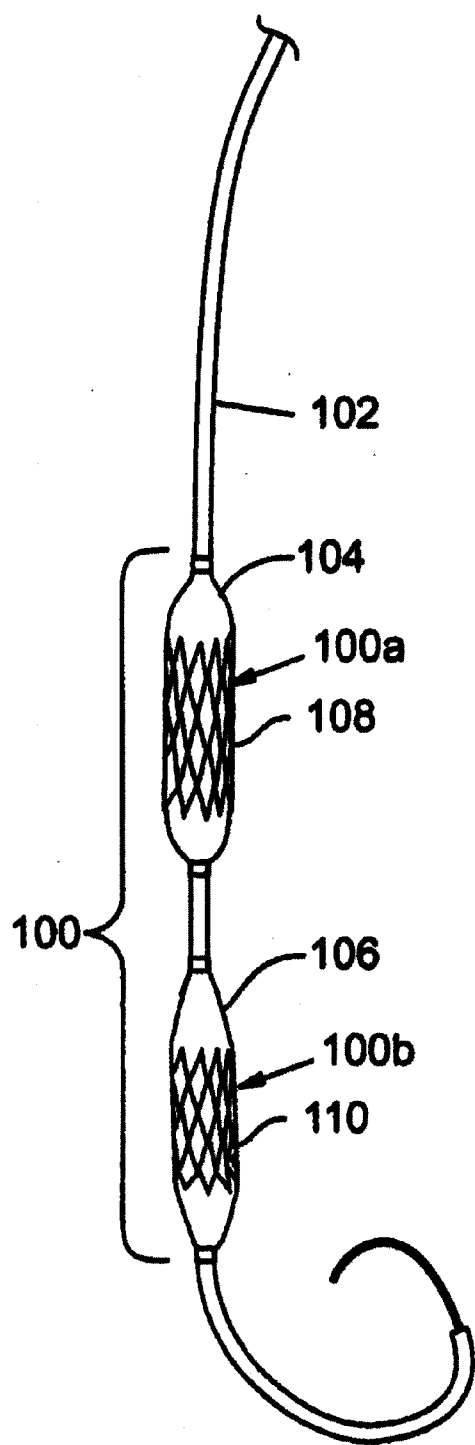


FIG. 1

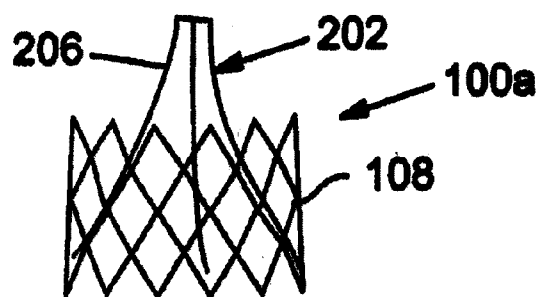


FIG. 2A

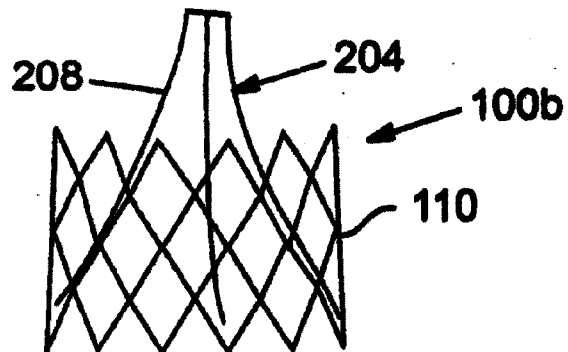


FIG. 2B

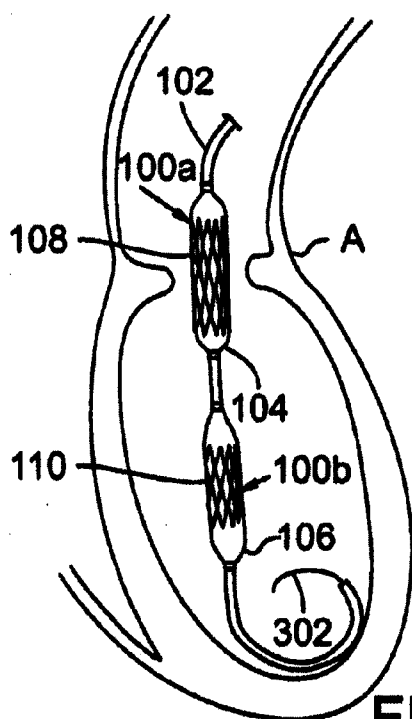


FIG. 3A

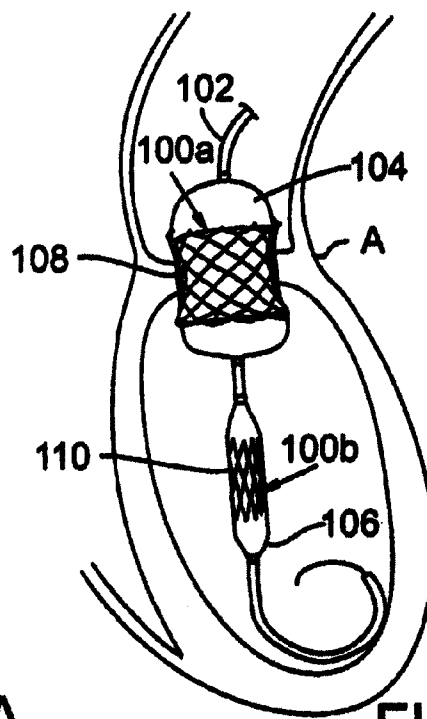


FIG. 3B

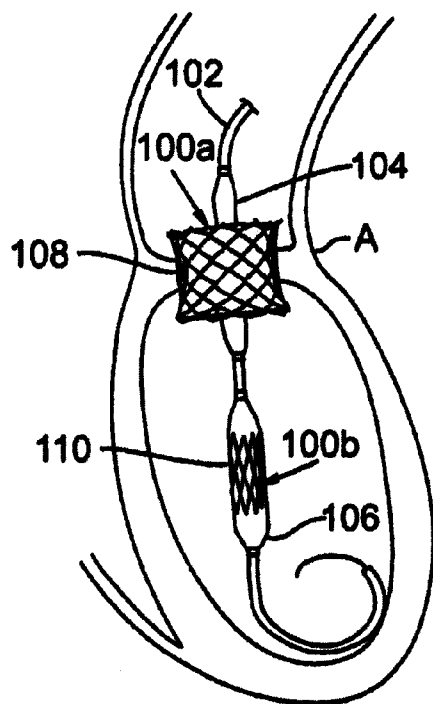


FIG. 3C

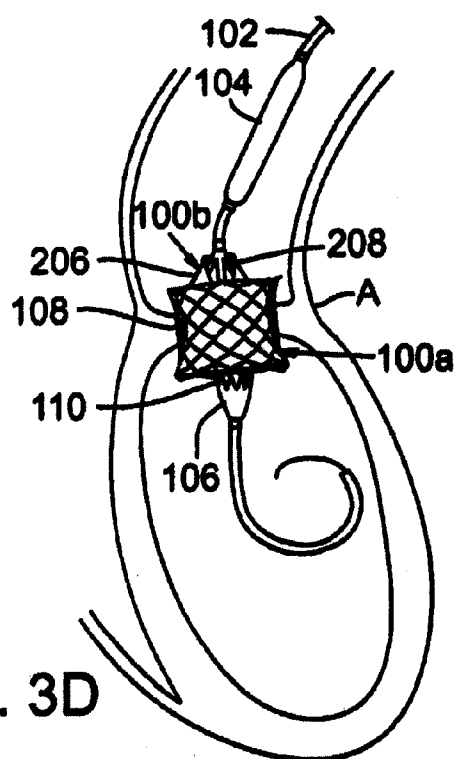


FIG. 3D

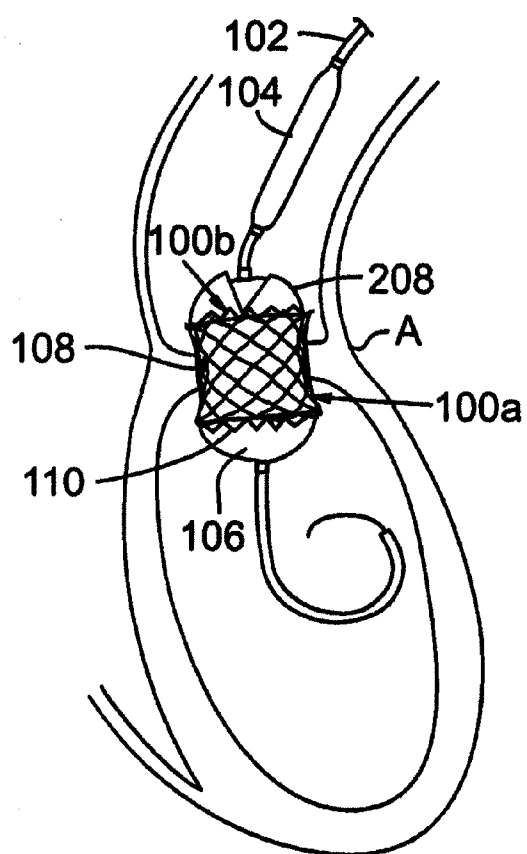


FIG. 3E

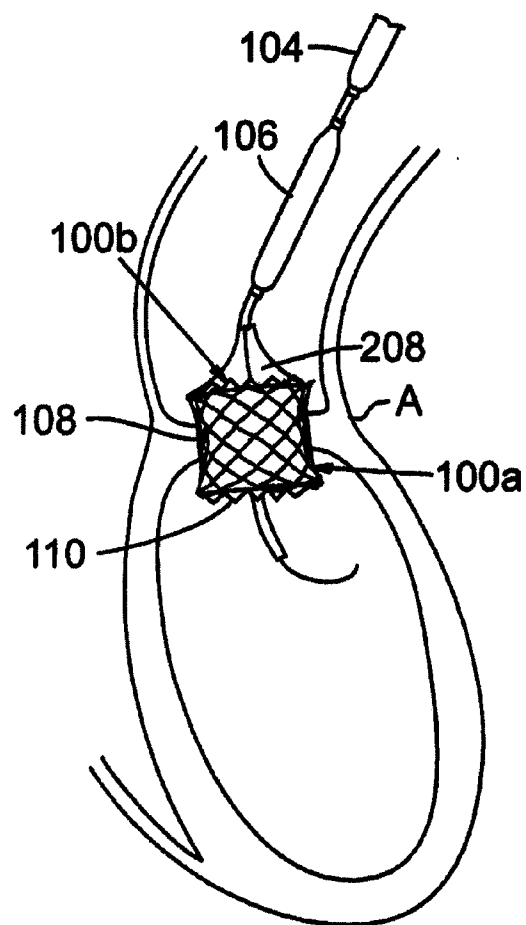


FIG. 3F

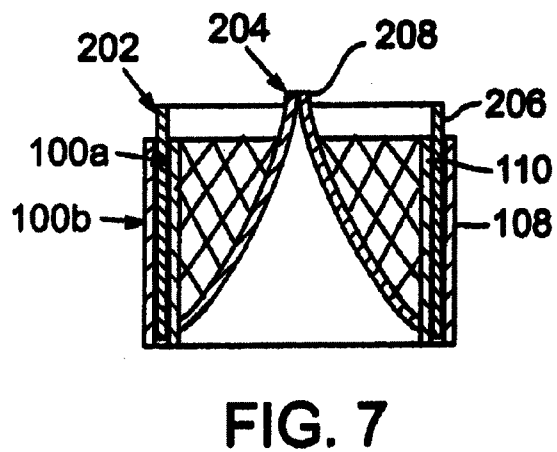
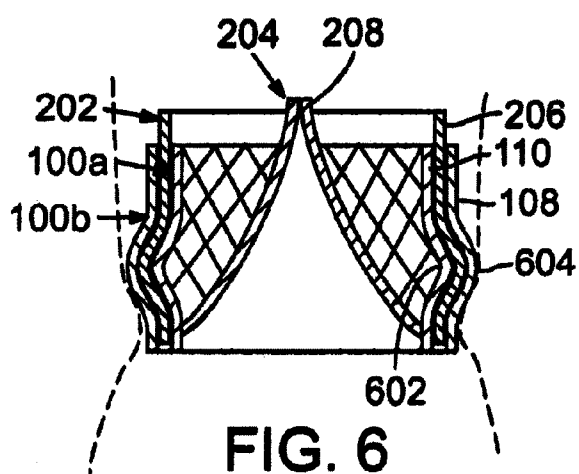
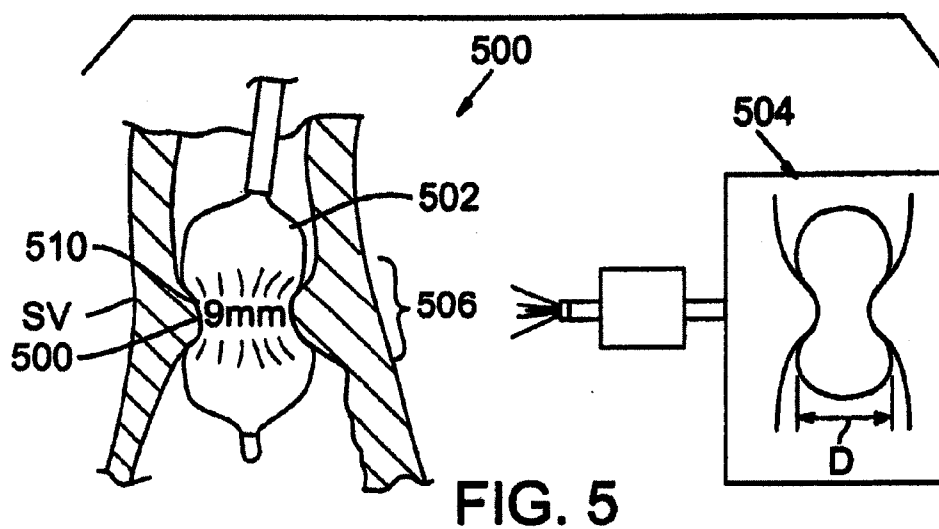
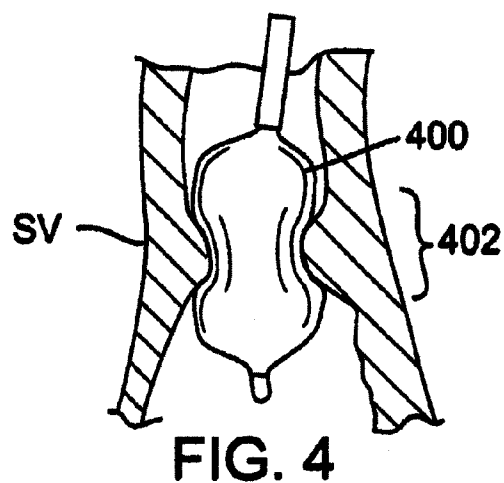
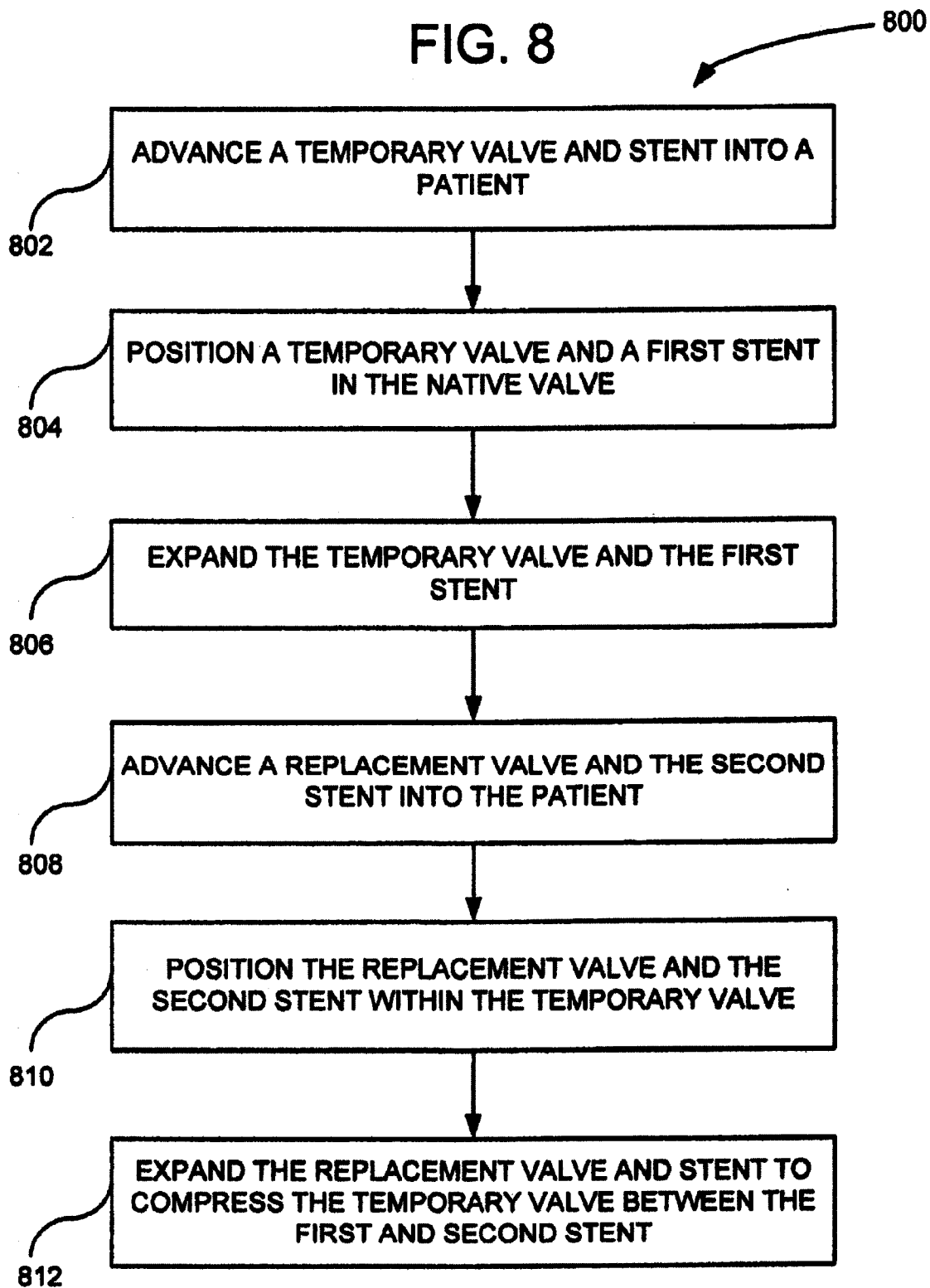


FIG. 8

TWO-STEP HEART VALVE IMPLANTATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Provisional Application No. 61/032,822, filed Feb. 29, 2008, which is hereby incorporated by reference.

FIELD

[0002] The present disclosure concerns an implantable device and, more particularly, to a valve prosthesis for cardiac implantation.

BACKGROUND

[0003] A percutaneous heart valve implantation (PHV) has been developed by Edwards Lifesciences PVT Ltd. and is described in U.S. Pat. No. 6,730,118, which is herein incorporated by reference in its entirety. A primary concept behind using a PHV is implantation inside the stenotic region of a calcified native valve without removing the native valve. The PHV stents the stenotic valve open and uses it as an attachment means for the PHV.

[0004] A major design parameter of the PHV is the folded or crimped profile. The crimped profile directly influences the ability to insert the PHV into the femoral artery or vein. Accordingly, a smaller profile allows for treatment of a wider population of patients, with enhanced safety.

[0005] Generally, the primary attachment mechanism of the PHV to the native valve is friction. This friction is generated by radial contact forces between the stenotic valve and the metallic frame of the PHV. A proper sizing should provide for secure attachment of the PHV to the native valve and provide good sealing to avoid, for example, paravalvular leaks.

[0006] Prior PHV implantation methods and apparatus include Schreck in U.S. Pat. No. 6,454,799, entitled, "MINIMALLY-INVASIVE HEART VALVES AND METHODS OF USE", which describes expandable heart valves for minimally invasive valve replacement surgeries. In a first embodiment, an expandable pre-assembled heart valve includes a plastically-expandable annular base having a plurality of upstanding commissure posts. A tubular flexible member including a prosthetic section and a fabric section is provided, with the prosthetic section being connected to the commissure posts and defining leaflets therebetween, and the fabric section being attached to the annular base. In a second embodiment, an expandable heart valve includes an annular tissue-engaging base and a subassembly having an elastic wireform and a plurality of leaflets connected thereto. The annular base and subassembly are separately stored and connected just prior to delivery to the host annulus. The leaflet subassembly is stored in its relaxed configuration to avoid deformation of the leaflets. The expandable heart valves can be implanted using a balloon catheter. The leaflets of the heart valves are secured to the commissure regions of the expandable stents using a clamping arrangement to reduce stress.

[0007] Spenser et al. in U.S. Patent Application No. 20030153974, entitled "IMPLANTABLE PROSTHETIC VALVE", describes a prosthesis device suitable for implantation in body ducts. The device has a support stent that is adapted to be initially crimped in a narrow configuration suitable for catheterization through a body duct to a target location and adapted to be deployed by exerting substantially

radial forces from within by means of a deployment device. The support stent includes a plurality of longitudinally rigid support beams of fixed length, and a valve assembly comprising a flexible conduit having an inlet and an outlet made of pliant material attached to the support beams to provide collapsible slack portions of the conduit at the outlet. When flow is allowed to pass through the valve prosthesis device from the inlet to the outlet, the valve assembly is kept in an open position, whereas a reverse flow is prevented due to the collapsible slack portions of the valve assembly that collapse inwardly to block the reverse flow.

[0008] Another known technique for implanting a prosthetic valve is a transapical approach where a small incision is made in the chest wall of a patient and the catheter is advanced through the apex (i.e., bottom tip) of the heart. Transapical techniques are disclosed in U.S. Patent Application Publication No. 20070112422, which is hereby incorporated by reference. Like the transvascular approach, the transapical approach includes a balloon catheter having a steering mechanism for delivering a balloon-expandable prosthetic heart valve through an introducer to the aortic annulus. The balloon catheter includes a deflecting segment just proximal to the distal balloon to facilitate positioning of the prosthetic heart valve in the proper orientation within the aortic annulus.

[0009] Yet another known technique for implantation of a prosthetic in the aortic valve is through the use of a two-balloon catheter. For example, such a system is shown in U.S. Pat. No. 6,908,481, entitled "VALUE PROSTHESIS FOR IMPLANTATION IN BODY CHANNELS." Typically, two balloons are fixed on a catheter shaft and are separated by a few millimeters. The first balloon carries a frame for scaffolding a stenosed orifice after initial dilatation and the second balloon carries an expandable valve. The first balloon is sufficiently strong to avoid bursting even at very high pressure. The second balloon does not need to be as strong as the first and can, therefore, be thinner, occupying less space and being easier to expand with lower pressure. The time interval between expansion of the first and second balloons must be short because there is a total aortic regurgitation back through the frame towards the left ventricle. Such a regurgitation is a hemodynamic condition that cannot be maintained for more than a few seconds.

[0010] In order to decrease the possibility of aortic regurgitation, U.S. Pat. No. 6,425,916, entitled "METHODS AND DEVICES FOR IMPLANTING CARDIAC VALVES" introduces a temporary valve. However, the temporary valve must be removed after the permanent valve is deployed, which requires an additional surgical step and potential complication.

SUMMARY

[0011] The present invention provides a two-part implantable heart valve and procedure, which allows expansion and positioning of a first part of the implantable heart valve using a temporary or transient valvular structure. The second part of the implantable heart valve is deployed within the first part. The valvular structure of the second part then acts to function as the heart valve replacement. The second part of the implantable heart valve displaces the temporary valve and compresses the temporary valve between a first frame associated with the first part and second frame associated with the second part to increase friction therebetween and reduce

paravalvular leakage. The temporary valve is, therefore, used as a part of the permanent heart valve replacement and need not be removed.

[0012] Advantageously, separating the two-part valve and delivering the parts in series reduces the crimped profile of the implantable valve so a wider population can be treated. In addition, the first part can be deployed using a strong pressure inflation of a balloon without the risk of damaging the primary valvular structure associated with the second part, which uses only light pressure inflation. Alternatively, either one or both of the parts can be self expanding.

[0013] A tool or system is provided for determining an adequate PHV size for a given stenotic valve. A balloon can be inflated inside the stenotic valve to a desired pressure. When the desired pressure is reached an angiographic image is taken and the balloon diameter is measured in a waist area created by contact between the balloon and the stenotic valve. The diameter represents the minimum PHV diameter to be implanted.

[0014] The foregoing and other features and advantages will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 is a simplified illustration of an embodiment of an implantable valve mounted in two parts on a delivery catheter.

[0016] FIGS. 2A and 2B are simplified illustrations of the two parts of the implantable valve of FIG. 1.

[0017] FIGS. 3A-3F illustrate possible steps for implantation of the valve of FIG. 1 with a two-balloon catheter.

[0018] FIG. 4 is a simplified illustration of a balloon inflated inside a stenotic valve during balloon valvuloplasty procedure.

[0019] FIG. 5 is a simplified illustration of a tool for correlating the size of a heart valve to a native valve.

[0020] FIG. 6 is a cross-sectional view of an embodiment including geometrically mating stents.

[0021] FIG. 7 is a cross-sectional view of an embodiment illustrating first and second stents with a temporary valve compressed therebetween

[0022] FIG. 8 is a flowchart of a method for implanting a heart valve using a two step approach with a temporary valve.

DETAILED DESCRIPTION

[0023] The following description is exemplary in nature and is not intended to limit the scope, applicability, or configuration of the invention in any way. Various changes to the described embodiments can be made in the function and arrangement of the elements described herein.

[0024] As used herein, the singular forms “a,” “an,” and “the” refer to one or more than one, unless the context clearly dictates otherwise.

[0025] As used herein, the term “includes” means “comprises.” For example, a device that includes or comprises A and B contains A and B but can optionally contain C or other components other than A and B. A device that includes or comprises A or B can contain A or B or A and B, and optionally one or more other components such as C.

[0026] FIG. 1 is a simplified illustration of an implantable valve 100 that can be made in two parts 100a and 100b in accordance with a first embodiment. A catheter 102 can have

two-balloons, a proximal balloon 104 and a distal balloon 106 fixed to catheter 102 in close proximity. In one embodiment, the two-balloon catheter 102 can include at least two lumens for successive and separate inflation of each balloon. The embodiments below are generally described with reference to the aortic valve, but each embodiment can be used with other cardiac valves.

[0027] The proximal balloon 104 can carry the first part 100a, which can be a combination including a first frame structure 108, also called a stent, and a first valvular structure 202, also called a valve (FIG. 2A). The valvular structure 202 can be a “temporary” or “transient” valve, which can have a durability estimated to last between a few minutes and a few days. The valvular structure 202 can be made of any biocompatible synthetic material, such as polyester, polytetrafluoroethylene or polyurethane. Additionally, biocompatible synthetic materials that dissolve can be used. Alternatively, a natural tissue, such as pericardial tissue (e.g. bovine, porcine or equine pericardium), or other biological tissue, can be used. Proximal balloon 104 can be mounted within first frame structure 108 in its deflated state, prior to the introduction of first part 100a.

[0028] The first part 100a functions to stent open the native aortic valve using a strong first frame structure 108, which is provided to scaffold the dilated stenosed aortic valve. The size and shape of first frame structure 108 can be designed to ensure that it resists the recoil of the dilated valve so that it can be securely embedded in the remains of the native aortic valve. For example, the first frame structure 108 can be designed with stronger, thicker struts relative to that of the second part 100b, which can increase the diameter of the first frame in the crimped state. The first frame structure 108 can include a form of connectors, such as hooks or barbs, to help secure first frame structure 108 to the native aortic valve.

[0029] Once deployed, the valvular structure 202 of first part 100a can function hemodynamically as a replacement for the native heart valve leaflets until second part 100b can be deployed. Since valvular structure 202 can be a temporary valve, it does not need to be as durable as a typical valve prosthesis and, therefore, it can be made to occupy less space. For example, the valvular structure 202 can have relatively thin leaflets so that it has a reduced diameter in the crimped state.

[0030] First part 100a then provides a basis for anchoring second part 100b upon deployment of second part 100b. Beneficially, the deployment of first part 100a into the native aortic valve is provided with a sealing agent to prevent paravalvular leaks, which are leaks between first part 100a and the native valve.

[0031] In one embodiment, the distal balloon 106 carries second part 100b, which includes a combination of a second frame structure 110 (or a second stent) and a “main” or “long-term” replacement valve 204 (FIG. 2B), which is a second valvular structure. The second valvular structure can be highly durable and exhibit excellent hemodynamic performance. The valve 204 can be made from biological matter, such as natural tissue, pericardial tissue (e.g., bovine, porcine or equine pericardium), a harvested natural valve, or other biological tissue. Alternatively, the valve can be made from biocompatible synthetic materials (e.g., biocompatible polymers), which are well known in the art. Distal balloon 106 does not need to be as strong as proximal balloon 104 and, therefore, can be made thinner, to occupy less space, making it easier to expand with lower pressure balloon inflation.

[0032] One difference between first part **100a** and second part **100b** is that second frame structure **110** does not need to be as strong as first frame structure **108**, thus making it easier to expand with low balloon pressure inflation, which does not risk damaging the second valvular structure **204**. Accordingly, second frame structure **110** can be sized and shaped with thinner struts than first frame structure **108**. As a result, the second frame structure **110** can have a smaller diameter than the first frame structure **108**, when both are in a crimped state. However, the comparatively larger crimped volume of the first frame structure **108** is offset, to some degree, by being associated with a thinner valvular structure **202**. More particularly, valvular structure **202** can be thinner than valvular structure **204** and, therefore, has a smaller diameter than valvular structure **204**, when both are in the crimped state. Thus, the overall diameter in the crimped state of each part **100a** and **100b** is reduced because a larger stent **108** is combined with a smaller valve **202** and a larger valve **204** is combined with a smaller stent **110**.

[0033] Second part **100b** is deployed such that it mounts to first part **100a**. It should be understood that any type of fastening configuration or means can be used to attach second frame structure **110** to first frame structure **108**. In one embodiment, the means of attachment between the two frames can be the use of friction. In this embodiment, the outer surface of second frame structure **110** can be made having a "rougher" surface to enhance the frictional relationship between the two frames. In another embodiment, hooks or barbs disposed on the surface of second frame structure **110** can be used to interlock into the cells created by the struts of first frame structure **108**. In yet another embodiment of the attachment means can include the formation of a geometrical shape onto one or both of first and second frame structures **108** and **110** that provide a fixation in a mechanical male to female type connection. FIG. 6 described further below shows such a mechanical connection.

[0034] FIGS. 3A-3F are simplified illustrations showing a method of deploying the two-part implantable valve **100** in a cardiac valve (the aortic valve is used for illustrative purposes, but the method also applies to other cardiac valves). In FIG. 3A, catheter **102** is advanced through body lumens along guidewire **302** to the native aortic valve A until distal balloon **106** with second part **100b** is disposed in the left ventricle and proximal balloon **104** with first part **100a** is positioned in the aortic valve A.

[0035] As shown in FIG. 3B, proximal balloon **104** is inflated under relatively high pressure to expand first frame structure **108** of first part **100b**. In one embodiment, first frame structure **108** can be expanded to a diameter greater than the aortic valve annulus, thereby compressing the native leaflets and/or stretching the aortic annulus during deployment. Such over expansion enhances the fixation of first frame structure **108** within the annulus. Over-expansion of first frame structure **108** also decreases residual gaps between the annulus and first part **100a**, thereby reducing or eliminating undesirable leakage around the perimeter.

[0036] The expansion of proximal balloon **104** and the positioning of first part **100a** are typically performed within a few seconds. In one embodiment, as shown in FIG. 3C, because during the balloon inflation the aortic orifice A is obstructed by proximal balloon **104** and the cardiac output is zero, proximal balloon **104** can be immediately deflated (e.g., within less than 5 or 6 seconds). Beneficially, as soon as the deflation has begun, the closing and opening states of leaflets

206 of valvular structure **202** (FIG. 2A) are allowed to function so that the valve becomes operational. Proximal balloon **104** can also be pulled back briskly in the aorta to allow leaflets **206** to function as soon as possible. Because the deployment of first part **100a** is completed quickly, aortic regurgitation towards the left ventricle is reduced, thus reducing the possibility of inducing a massive pulmonary edema and a drop to zero of the cardiac output.

[0037] As shown in FIG. 3D, as proximal balloon **104** is withdrawn into the aorta, distal balloon **106** carrying second part **100b** is moved into position within the aortic valve and within first frame structure **108** and leaflets **206**. As shown in FIG. 3E, after second part **100b** is properly positioned, distal balloon **106** is inflated to expand second part **100b**. The inflation of distal balloon **106** causes second frame structure **110** to push and compress the first valvular structure **202** between the first frame structure **108** and the second frame structure **110**.

[0038] As shown in FIG. 3F, when second frame structure **110** is properly attached to first frame structure **108**, distal balloon **106** is deflated and removed. Beneficially, as soon as the deflation has begun, the closing and opening states of leaflets **208** of valvular structure **204** (FIG. 2B) are allowed to function.

[0039] In an alternative embodiment, first frame structure **108** and/or second frame structure **110** can be self-expanding at the aortic valve. For example, first part **100a** is expanded using proximal balloon **104**, as generally shown in FIGS. 3A-3C. The second part **100b**, having the main valve attached thereto, is advanced to a location within first frame structure **108** and is allowed to self-expand. Alternatively, both frame structures **108** and **110** can be self-expandable and deployed accordingly. Examples of self-expanding implantable valves and associated delivery methods suitable for use can be found in U.S. Application Publication No. 2004/0186563, filed Mar. 18, 2003, which is incorporated by reference herein in its entirety.

[0040] In another alternative embodiment, it will be appreciated that a double balloon catheter **102** is not necessary to deploy the two-part valve **100** and can be deployed using two separate catheters. For example, in one embodiment, first part **100a** can be deployed using a first catheter. Subsequently, second part **100b** can be deployed using a second catheter.

[0041] The two-part implantable valve **100** has been described for purposes of illustration, as being advanced percutaneously through the aorta in a retrograde direction for implantation at the site of a native aortic valve. However, a variety of alternative procedures can also be used. For example, the two-part implantable valve **100** can be advanced in an antegrade direction, such as by using a transseptal route. Furthermore, it will be appreciated that the general principles of the procedures shown in FIGS. 3A-3F can be applied in alternative minimally invasive approaches, such as, for example, by passing the prosthetic valve through a small incision in the chest wall (the transapical approach).

[0042] FIG. 6 shows a cross-sectional view of an example of the frames and valvular structures after deployment. In this particular embodiment, the first frame structure **108** can be made having a first geometrical feature **602**, such as a detent. The second frame structure **110** can also include a second geometrical feature **604**, such as an indentation, channel or groove that corresponds and mates with first geometrical feature **602**. Upon deployment of second part **100b** into first part **100a**, first geometrical feature **602** is made to seat in

second geometrical feature **604** to secure the frames together. In between the first frame structure **108** and the second frame structure **110**, the temporary valve **202** can be compressed, which can also provide a good seal to reduce paravalvular leakage.

[0043] FIG. 7 shows another cross-sectional view, similar to FIG. 6, but without a geometrical feature for mating the two frame structures. The valvular structure **202**, including the leaflets **206** are compressed between the first and second stents, **108**, **110**, to create a seal extending from a bottom to the top of the stent **110**. The compressed valvular structure increases friction and reduces paravalvular leakage.

[0044] Advantageously, the two-part implantable valve **100** allows for a soft and mobile valvular structure **204** in second part **100b**, which is capable of opening and closing freely in the blood stream without risk of being damaged by the balloon inflation. First part **100a** provides a stent structure capable of withstanding a strong pressure inflation of the expanding balloon, without undue concern over the risks to valvular structure **202** due to its temporary nature.

[0045] The following relates to the determination method for matching a given stenotic heart valve and the appropriate percutaneous valve size (diameter).

[0046] A estimate of the adequate PHV size can be based on ultrasound measurement of the annulus, on angiographic images and on the physician's expertise. In this technique, before PHV implantation, a balloon valvuloplasty can be performed. The purpose of the balloon valvuloplasty is to prepare the implantation site and to make estimates for the proper PHV size.

[0047] FIG. 4 is a simplified illustration of a balloon **400** inflated inside a stenotic valve SV during a balloon valvuloplasty procedure. As shown, balloon **400** can create a narrowed region **402** or "waist" when being inflated in the contact area with the diseased valve.

[0048] As previously mentioned, the axial retention force for securing the PHV to the native stenotic valve SV can be created by the radial contact forces applied by the stenotic valve SV on the outer surface of the PHV support frame. The minimal radial force that holds the PHV, divided by the surface area of a cylinder, representing the solid outer area of the PHV support frame, can provide the minimal pressure (P_m) to hold the PHV in position.

[0049] The basic assumption of the sizing method is that the minimal pressure (P_m) can be determined by in vitro and in vivo tests. Accordingly, it is assumed that the pressure P_m is known quantity.

[0050] FIG. 5 is a simplified representation of a tool **500** for determining an adequate PHV size for a given stenotic valve SV. In one embodiment, a balloon **502** is inflated inside the stenotic valve SV to a pressure of P_m . When this pressure is reached, an angiographic image **504** can be taken and the balloon diameter D in the waist area **506** can be measured. Diameter D represents the minimum PHV diameter to be implanted.

[0051] At pressure P_m , balloon **502** can develop a waist **506** to ensure that balloon wall **510** at waist area **506** is not loaded and that the total pressure P_t at waist area **506** can be applied on the native stenotic valve SV.

[0052] In one embodiment, for ease of implementation, a table can be created and made available for the physician that correlates between diameter D of waist area **506** and the adequate PHV size. The measuring procedure described above can be performed: 1) as a part of a balloon valvulo-

plasty procedure performed prior to a PHV implantation; or 2) after the balloon valvuloplasty procedure.

[0053] Balloon **502** can be a compliant balloon or a non-compliant balloon. If a non compliant balloon is used, then its inflated diameter can be larger than waist diameter D in order to ensure balloon wall **510** is not resisting the pressure at waist area **506** and that total pressure P_t is held by the native stenotic valve SV.

[0054] If a compliant balloon is used, the curve of pressure vs. diameter of balloon **502** should be known and the pressure that the native valve SV actually resists can be calculated accordingly.

[0055] Balloon **502** can be inflated by a liquid that contains a contrast dye so that the shape of balloon **502** is visible under fluoroscopy.

[0056] FIG. 8 shows a flowchart **800** of a method for implanting the two-stent structure. In process block **802**, a temporary valve and stent are advanced into the patient, such as using one or more delivery catheters in a transvascular or transapical approach. In process block **804**, the temporary valve and stent are positioned in the native valve. The stent and valve are then expanded (process block **806**) into the native valve. Such expansion can be effected through a balloon or the stents can be self expanding. In any event, the temporary valve becomes operational so that the patient has cardiac output. In process block **808**, a replacement valve and a second stent are advanced into the patient. The second stent and the replacement valve are positioned within the temporary valve. For example, the first and second stent can have their top and bottom edges aligned or corresponding geometrical configurations can be aligned. Once the second stent is aligned, in process block **812**, the second stent is expanded either using a balloon or through self expansion. In any event, the second stent compresses the temporary valve against the first stent so that the temporary valve is sandwiched there between.

[0057] In view of the many possible embodiments to which the principles of the disclosed invention can be applied, it should be recognized that the illustrated embodiments are only preferred examples of the invention and should not be taken as limiting the scope of the invention. Rather, the scope of the invention is defined by the following claims. We therefore claim as our invention all that comes within the scope of these claims.

We claim:

1. A method of implanting a cardiac valve, comprising:
 - advancing a radially-expandable temporary valve and a radially-expandable first stent into a patient in a collapsed position;
 - positioning the temporary valve and the first stent between leaflets of a native cardiac valve;
 - expanding the temporary valve and the first stent into the native cardiac valve so that the temporary valve becomes operational;
 - advancing a radially-expandable replacement valve and a radially-expandable second stent into the patient in a collapsed position;
 - positioning the radially-expandable replacement valve and radially-expandable second stent within the temporary valve; and
 - expanding the radially-expandable replacement valve and radially-expandable second stent so as to compress the temporary valve between the first stent and the second stent.

2. The method of claim 1, wherein the second stent has a top end and a bottom end and the temporary valve, in its compressed state between the first and second stents, extends either from the top end to the bottom end of the second stent or extends within the top end to the bottom end of the second stent so as to minimize paravalvular leakage.

3. The method of claim 1, wherein the first and second stents are advanced into a patient using a common delivery catheter and wherein the delivery catheter is deployed percutaneously or transapically.

4. The method of claim 1, wherein the first and second stents have mating geometrical configurations to assist with proper positioning of the first and second stents.

5. The method of claim 4, wherein the mating geometrical configurations include an indent located on the first stent for receiving a detent located on the second stent.

6. The method of claim 1, wherein expanding the temporary valve and the first stent includes inflating a first balloon on a delivery catheter and expanding the replacement valve and the second stent includes inflating a second balloon on the delivery catheter, the second balloon being spaced apart from the first balloon on the delivery catheter.

7. The method of claim 1, wherein the temporary valve is made of:

- a) a biocompatible synthetic material, including one or more of the following: polyester, polytetrafluoroethylene, or polyurethane; or
- b) biocompatible synthetic material that dissolves; or
- c) natural tissue, including pericardial tissue or other biological tissue.

8. The method of claim 1, further including determining a size of the replacement valve by inflating a test balloon inside the cardiac valve to a desired pressure and taking an angiographic image of the test balloon to determine its diameter.

9. The method of claim 1, wherein the temporary valve, in its compressed state between the first and second stents, serves as a friction barrier.

10. The method of claim 1, wherein the temporary valve is thinner than the replacement valve so as to minimize a crimp profile of the temporary valve.

11. The method of claim 1, wherein the first stent has a larger crimp profile than the second stent and the temporary valve has a smaller crimp profile than the replacement valve.

12. An apparatus for implanting a cardiac valve, comprising:

- a catheter having first and second balloons spaced apart along a length thereof;
- a first stent positioned on the first balloon;
- a second stent positioned on the second balloon, the second stent having a smaller diameter than the first stent when each of the stents is in a crimped state;
- a first valve coupled to the first stent, the first valve being a temporary valve that is designed to be compressed between the first and second stents upon deployment of the stents and their respective valves; and
- a second valve coupled to the second stent, the second valve being a replacement valve that has a larger diameter than the first valve when each of the valves is in a crimped state;

wherein the apparatus has a minimized overall crimped profile by grouping the larger first stent with the smaller first valve and the smaller second stent with the larger second valve.

13. The apparatus of claim 12, wherein the first stent and second stent are formed from struts, wherein the struts of the first stent are thicker than struts of the second stent.

14. The apparatus of claim 12, wherein the first valve and second valve include leaflets, wherein the leaflets of the first valve are thinner than leaflets of the second valve.

15. The apparatus of claim 12, wherein the first balloon is thinner than the second balloon.

16. The apparatus of claim 12, wherein the first stent has a geometrical feature that mates with a geometrical feature of the second stent.

17. The apparatus of claim 16, wherein the mating geometrical features include an indent located on the first stent for receiving a detent located on the second stent.

18. The apparatus of claim 12, further including a tool for taking an angiographic image of a test balloon for determining a size of the first and second stents.

19. The apparatus of claim 12, wherein the first stent includes barbs to secure the first stent to the native valve.

20. A method of implanting a cardiac valve, comprising: deploying a temporary valve and a first stent in the native valve; and

deploying a replacement valve and a second stent by inserting the replacement valve and the second stent into the temporary valve and by expanding the replacement valve and second stent so as to compress the temporary valve between the first and second stents.

21. The method of claim 20, wherein deploying the temporary valve and the first stent includes inflating a first balloon to a first pressure and expanding the replacement valve and the second stent includes inflating a second balloon to a second pressure, which is less than the first pressure.

22. The method of claim 20, wherein the second stent has a top end and a bottom end and the temporary valve, in its compressed state, extends either from the top end to the bottom end of the second stent or extends within the top end and the bottom end of the second stent so as to prevent paravalvular leakage.

23. The method of claim 20, wherein the first and second stents are advanced using a common delivery catheter having first and second balloons coupled in series.

24. The method of claim 20, wherein the first and second stents have mating geometrical configurations to assist with proper positioning of the first and second stents.

25. The method of claim 20, wherein the temporary valve is made of biocompatible synthetic material, including one of the following:

polyester, polytetrafluoroethylene, or a polyurethane.

26. The method of claim 20, wherein the temporary valve is made of a synthetic or biocompatible material that dissolves over time.

27. The method of claim 20, wherein the temporary valve is made of natural tissue, such as pericardial tissue (e.g. bovine, porcine or equine pericardium), or other biological tissue.

28. The method of claim 20, wherein the first stent has a larger crimp profile than the second stent and the temporary valve has a smaller crimp profile than the replacement valve.