

We claim:

1. A medical assembly, comprising:
 - a prosthetic heart valve that is radially expandable and compressible between a radially compressed configuration and a radially expanded configuration; and
 - a delivery apparatus comprising:
 - a handle,
 - at least one first actuator extending from the handle and coupled to a proximal end portion of the prosthetic heart valve, wherein the at least one first actuator is configured to apply a distally directed force to the proximal end portion of the prosthetic valve;
 - at least one second actuator extending from the handle and coupled to a distal end portion of the prosthetic valve, wherein the at least one second actuator is configured to apply a proximally directed force to the distal end portion of the prosthetic valve;
 - a sensor;
 - a first motion-transmitting member having a distal end portion coupled to the at least one first actuator and a proximal end portion coupled to the sensor; and
 - a second motion-transmitting member having a distal end portion coupled to the at least one second actuator and a proximal end portion coupled to the sensor;
 - wherein the prosthetic heart valve is radially expandable from the radially compressed configuration to the radially expanded configuration upon actuating the at least one first actuator and the at least one second actuator to apply the distally directed force and the proximally directed force, respectively, to the prosthetic heart valve;
 - wherein the sensor senses relative movement between the first and second motion-transmitting members upon actuation of the at least one first actuator and the at least one second actuator to determine the diameter of the prosthetic heart valve as it is expanded.
2. The medical assembly of claim 1, wherein the sensor is a linear displacement sensor.

3. The medical assembly of claim 2, wherein the linear displacement sensor comprises a linear variable differential transformer (LVDT), an optical linear encoder, a linear potentiometer, an optical sensor, a capacitive sensor, or combinations thereof.

4. The medical assembly of any of claims 1-3, further comprising a load cell disposed within the handle and coupled to a proximal end portion of the at least one second actuator, wherein the load cell is configured to measure tensile force in the second actuator as the prosthetic valve expands.

5. The medical assembly of claim 4, wherein the load cell is selected from the group consisting of: a compression load cell, a strain gauge load cell, a piezoelectric load cell, a pneumatic load cell, a hydraulic load cell, or combinations thereof.

6. The medical assembly of any of claims 1-5, further comprising a control unit in communication with the sensor and when dependent on claims 4-5, the load cell, wherein the control unit is configured to calculate at least one of the real-time radial force and the real-time diameter of the prosthetic valve.

7. The medical assembly of claim 6, wherein the control unit comprises a display configured to display to a user at least one of the real-time radial force and the real-time diameter of the prosthetic valve.

8. The medical assembly of claims 6 or 7, wherein the control unit is configured to control the first and second actuators to expand the prosthetic valve according to a preprogrammed expansion algorithm.

9. The medical assembly of any of claims 1-8, wherein the prosthetic heart valve has at least one push-pull actuator assembly comprising a first member attached to the proximal end portion of the prosthetic heart valve and a second member attached to a distal end portion of the prosthetic heart valve, and wherein the at least one first actuator is releasably coupled to the first member and the at least one second actuator is releasably coupled to the second member.

10. The medical assembly of any of claims 1-9, wherein the at least one second actuator extends through the at least one first actuator.

11. The medical assembly of any of claims 1-10, wherein the first and second motion-transmitting members comprise first and second wires.

12. The medical assembly of any of claims 1-11, wherein the first and second motion-transmitting members extend the majority of the lengths of the first and second actuators, respectively.

13. The medical assembly of claim 12, wherein the distal end portions of the first and second motion-transmitting members are affixed to the first and second actuators, respectively, at respective locations adjacent the prosthetic heart valve.

14. A delivery apparatus for a prosthetic heart valve, comprising:
a handle;

at least one first actuator and at least one second actuator extending from the handle, the first actuator being configured to apply a distally directed force to a proximal end portion of a prosthetic heart valve and the second actuator being configured to apply a proximally directed force to a distal end portion of the prosthetic heart valve to radially expand the prosthetic heart valve;

a sensor;

a control unit in communication with the sensor;

a first motion-transmitting member having a distal end portion coupled to the at least one first actuator and a proximal end coupled to the sensor;

a second motion-transmitting member having a distal end portion coupled to the at least one second actuator and a proximal end coupled to the sensor;

wherein the sensor senses relative movement between the first and second motion-transmitting members upon actuation of the at least one first actuator and the at least one second actuator and the control unit determines the real-time diameter of the prosthetic heart valve as it expands from a radially compressed configuration to a radially expanded

configuration based on the relative movement between the first and second motion-transmitting members.

15. The delivery apparatus of claim 14, wherein the sensor is a linear displacement sensor.

16. The delivery apparatus of claims 14 or 15, further comprising a load cell operatively coupled to the second actuator, the load cell configured to measure tension in the second actuator as the prosthetic valve expands.

17. The delivery apparatus of any of claims 14-16, wherein the control unit is configured to calculate the real-time radial force of the prosthetic valve based on the tension of the second actuator.

18. The delivery apparatus of claim 17, wherein the control unit further comprises a display configured to display to a user at least one of the real-time radial force and the real-time diameter of the prosthetic valve.

19. The delivery apparatus of any of claims 14-18, wherein the first and second motion-transmitting members comprise first and second wires extending the majority of the lengths of the first and second actuators.

~~20. A delivery apparatus for a prosthetic heart valve, comprising:
— a handle;
— at least one first actuator and at least one second actuator extending from the handle, the first actuator being configured to apply a distally directed force to a proximal end portion of a prosthetic heart valve and the second actuator being configured to apply a proximally directed force to a distal end portion of the prosthetic heart valve to radially expand the prosthetic heart valve;
— a load cell operatively connected to at least one of a proximal end portion of the first actuator and a proximal end portion of the second actuator and configured to measure a load on at least one of the first actuator and the second actuator; and~~

~~— a control unit in communication with the load cell and configured to calculate the radial force applied by the prosthetic heart valve against surrounding tissue based on the load measured by the load cell.~~

~~21. The delivery apparatus of claim 20, further comprising:~~

~~a sensor in communication with the control unit;~~

~~— a first motion transmitting member having a distal end portion coupled to the at least one first actuator and a proximal end coupled to the sensor;~~

~~— a second motion transmitting member having a distal end portion coupled to the at least one second actuator and a proximal end coupled to the sensor;~~

~~— wherein the sensor senses relative movement between the first and second motion transmitting members upon actuation of the at least one first actuator and the at least one second actuator and the control unit determines the real-time diameter of the prosthetic heart valve as it expands from a radially compressed configuration to a radially expanded configuration based on the relative movement between the first and second motion transmitting members.~~

22. A prosthetic heart valve assembly, comprising:

~~— a prosthetic heart valve movable between a radially compressed configuration and a radially expanded configuration; and~~

~~— a delivery apparatus comprising:~~

~~— a handle comprising a light source and a receiving element,~~

~~a first actuator extending from the handle and coupled to a first portion of the prosthetic heart valve, wherein the first actuator is configured to apply a distally directed force to the first portion of the prosthetic valve,~~

~~a second actuator extending from the handle and coupled to a second portion of the prosthetic valve, wherein the actuator is configured to apply a proximally directed force to the second portion of the prosthetic valve,~~

~~a sensor coupled to a distal end portion of the first actuator, the sensor comprising a housing;~~

~~a first optical fiber extending through the housing and having a proximal end portion coupled to the light source and a distal end portion coupled to the second actuator, and~~

~~a second optical fiber having a proximal end portion coupled to the receiving element and a distal end portion extending into the housing,~~

~~wherein the prosthetic heart valve is radially expandable from the radially compressed configuration to the radially expanded configuration upon applying the distally directed force and the proximally directed force to the prosthetic heart valve with the first and second actuators, respectively; and~~

~~wherein the sensor senses relative movement between the first optical fiber and the housing upon actuation of at least one of the first actuator and the second actuator to determine the diameter of the prosthetic heart valve as it is expanded.~~

~~23.—The assembly of claim 22, wherein the housing defines a recess, and wherein the sensor further comprises an optical coupler disposed within the recess and configured to couple light emitted by the first fiber into the second fiber.~~

~~24.—The assembly of claim 23, wherein the optical coupler comprises a reflective metal.~~

~~25.—The assembly of claim 23, wherein the optical coupler comprises a cut portion of the second fiber.~~

~~26.—The assembly of any of claims 22-25, wherein the first fiber comprises a plurality of alternating marked portions and exposed portions, the exposed portions being configured to emit light and the marked portions being configured to prevent light from being emitted.~~

~~27.—The assembly of claim 26, wherein as the first fiber moves relative to the housing the alternating marked and exposed portions produce a light pattern.~~

28. — ~~The assembly of claim 27, wherein the sensor is configured to determine the diameter of the prosthetic valve as it is expanded based at least in part on the light pattern.~~

29. — ~~The assembly of any of claims 22-25, wherein the first fiber comprises a plurality of marked portions, first filtered portions, and second filtered portions arranged in a selected order, the marked portions configured to prevent light from being emitted by the first fiber, the first filtered portions configured to allow a first wavelength of light to be emitted, and the second filtered portions configured to allow a second wavelength of light to be emitted.~~

30. — ~~The assembly of claim 29, wherein as the first fiber moves relative to the housing in a first direction the marked portions, first filtered portions, and second filtered portions produce a first light pattern, wherein as the first fiber moves relative to the housing in a second direction the marked portions, first filtered portions, and second filtered portions produce a second light pattern, and wherein the sensor determines the direction of movement of the second actuator based on at least one of the first and second light patterns.~~

31. — ~~The assembly of claim 30, wherein the sensor is configured to determine the diameter of the prosthetic valve as it is expanded based at least in part on the first and second light patterns.~~

32. — ~~The assembly of any of claims 22-31, further comprising a control unit operatively coupled to the sensor, wherein the control unit is configured to calculate the real-time diameter of the prosthetic valve.~~

33. — ~~The assembly of any of claims 22-32, wherein the sensor further comprises a sealing member coupled to a distal end portion of the housing and configured to prevent bodily fluids from entering the housing, the sealing member defining a lumen into which the distal end portion of the first fiber extends.~~

34. — ~~A delivery apparatus for a prosthetic heart valve, comprising:
a handle;~~

~~a light source configured to emit light;~~
~~a receiving element configured to receive light;~~
~~at least one first actuator and at least one second actuator extending from the handle,~~
~~the first actuator being configured to apply a distally directed force to a first portion of a~~
~~prosthetic heart valve and the second actuator being configured to apply a proximally~~
~~directed force to a second portion of the prosthetic heart valve to radially expand the~~
~~prosthetic heart valve;~~
~~a sensor;~~
~~a control unit in communication with the sensor;~~
~~a first optical fiber configured to produce a light pattern as the first fiber moves~~
~~relative to the sensor, the first fiber extending through the sensor and having a distal end~~
~~portion coupled to the second actuator and a proximal end portion coupled to the light source;~~
~~a second optical fiber having a distal end portion coupled to the sensor and a proximal~~
~~end portion coupled to the receiving element;~~
~~wherein actuation of the second actuator causes corresponding movement of the first~~
~~optical fiber relative to the sensor such that the sensor senses the light pattern and the control~~
~~unit determines a real-time diameter of the prosthetic heart valve as it moves between a~~
~~radially compressed configuration and a radially expanded configuration based at least in part~~
~~on the light pattern.~~

~~35.—The apparatus of claim 34, wherein the distal end portion of the first fiber~~
~~comprises a plurality of alternating marked portions and exposed portions configured to~~
~~produce the light pattern.~~

~~36.—The apparatus of claim 34, wherein the distal end portion of the first fiber~~
~~comprises a plurality of marked portions, first filtered portion, and second filtered portions~~
~~disposed in a selected order, wherein movement of the second actuator in a first direction~~
~~produces a first light pattern and movement of the second actuator in a second direction~~
~~opposite the first direction produces a second light pattern.~~

37.—The apparatus of claim 36, wherein the control unit determines a real time diameter of the prosthetic heart valve based at least in part on at least one of the first light pattern and the second light pattern.

38.—The apparatus of any of claims 34-37, wherein the first fiber comprises a core and a cladding, and wherein the distal end portion of the first fiber comprises a portion of the first fiber wherein the cladding has been removed and the core has been abraded.

39.—The apparatus of any of claims 34-37, wherein the distal end portion of the first fiber comprises a polymer member.