

SUMMARY

[0005a] According to a first aspect of the present invention, there is provided a prosthetic heart valve, including: a support structure having a first end, a second end, a central longitudinal axis extending from the first end to the second end, a plurality of struts and a plurality of rivets, wherein each of the struts has a first end portion, a second end portion, and a third portion extending from the first end portion to the second end portion, wherein each of the struts has openings in the first end portion, the second end portion, and the third portion, wherein each of the struts has a length dimension, a width dimension, and a thickness dimension, wherein the length dimension extends from the first end portion to the second end portion and is greater than the width dimension and the thickness dimension, wherein the width dimension is a cross-sectional dimension perpendicular to the length dimension and the thickness dimension and is greater than the thickness dimension, wherein the thickness dimension is a radial dimension relative to the central longitudinal axis, wherein each of the struts comprises a first width at first locations circumscribing the openings and a second width at second locations extending from one of the first locations to another one of the first locations, wherein the second width is less than the first width and is uniform throughout, wherein the rivets have first portions, second portions, and third portions, wherein the first portions of the rivets comprise a third width and extend through the openings of the struts, wherein the second portions of the rivets comprise a fourth width disposed on outer-facing surfaces of the struts, wherein the fourth width is greater than the second width and the third width, wherein the third portions of the rivets comprise a fifth width disposed on inner-facing surfaces of the struts, wherein the fifth width is less than the first width and greater than the third width, and wherein the struts are pivotable about the rivets to radially expand and compress the support structure; an actuator member coupled to the struts of the support structure and configured to selectively actuate expansion and compression of the support structure; and a plurality of leaflets coupled to the support structure and configured to allow unidirectional blood flow through the prosthetic heart valve.

[0005b] According to a second aspect of the present invention, there is provided a prosthetic heart valve, including: a support structure having a first end, a second end, a central longitudinal axis extending from the first end to the second end, a plurality of inner struts, a plurality of outer struts, and a plurality of rivets, wherein each of the inner struts and each of the outer struts has a plurality of openings formed therein, wherein each of the inner struts and each of the outer struts has a length dimension, a width dimension, and a thickness dimension, wherein the thickness dimension extends radially relative to the central longitudinal axis and is less than the width dimension and the length dimension, wherein the width dimension is a cross-sectional dimension perpendicular to the length dimension and the thickness dimension and is less than the length dimension, wherein each of the inner struts and each of the outer struts comprises a plurality of first segments circumscribing the

openings and having a first width and a plurality of second segments extending from and interconnecting adjacent first segments and having a second width, wherein the second width is less than the first width and is constant along the entire length of the second segment, wherein the rivets have first portions with a third width, second portions with a fourth width, and third portions with a fifth width, wherein the fourth width is greater than the third width and the second width, wherein the first portions extend between the second portions and the third portions through the openings of the inner struts and the outer struts, wherein the second portions are disposed on inner sides of the inner struts, wherein the third portions are disposed on outer sides of the outer struts, wherein the fifth width is less than the first width and greater than the third width, and wherein the inner struts and the outer struts are pivotable relative to each other about the rivets to radially expand and compress the support structure; an actuator member coupled to the support structure and configured to selectively actuate expansion and compression of the support structure; a plurality of leaflets coupled to the support structure and configured to allow unidirectional blood flow through the prosthetic heart valve; and a skirt comprising an inner surface and an outer surface, wherein the skirt is sandwiched between each of the inner struts and the outer struts of the support structure, wherein the inner struts circumscribe the inner surface of the skirt, and wherein the outer struts circumscribe the outer surface of the skirt.

[0005c] According to a third aspect of the present invention, there is provided a prosthetic heart valve, including: a support structure having a first end, a second end, a central longitudinal axis extending from the first end to the second end, a plurality of inner struts, a plurality of outer struts, and a plurality of mounts coupled to the inner struts or the outer struts, wherein each of the inner struts and the outer struts includes an inflow end portion, an outflow end portion, an intermediate portion disposed between the inflow end portion and the outflow end portion, a first opening formed in the inflow end portion, a second opening formed in the outflow end portion, and an intermediate opening formed in the intermediate portion, wherein each of the inner struts and each of the outer struts has a length dimension, a width dimension, and a thickness dimension, wherein the length dimension is greater than the width dimension and the thickness dimension, wherein the width dimension is a cross-sectional dimension perpendicular to the length dimension and the thickness dimension and is greater than the thickness dimension, wherein the thickness dimension is a radial dimension relative to the central longitudinal axis, wherein each of the inner struts and the outer struts comprises a first width at locations circumscribing the first opening, the second opening, and the intermediate opening and comprises a second width at a first intermediate location extending between the locations circumscribing the first opening and the intermediate opening and at a second intermediate location extending between the locations circumscribing the second opening and the intermediate opening, wherein the second width is less than the first width and is uniform, wherein adjacent pairs of inner and outer struts are coupled together by a plurality of rivets, wherein each rivet has a shaft portion, a first flange portion, and a second flange portion, wherein the first flange portion

extends from the shaft portion away from the central longitudinal axis, wherein the second flange portion extends from the shaft portions towards the central longitudinal axis and is spaced apart from the first flange portion, wherein the shaft portion has a third width and extends through the openings of the inner struts and the outer struts, wherein the first flange portion has a fourth width, wherein the fourth width is greater than the second width and the third width, wherein the second flange portion has a fifth width that is less than the first width and greater than the third width and wherein the inner struts and the outer struts are pivotable to each other about the rivets to radially expand and compress the support structure; an actuator member coupled to the mounts of the support structure and configured to selectively actuate expansion and compression of the support structure, wherein rotating the actuator member in a first direction relative to the mounts expands the support structure, and wherein rotating the actuator member in a second direction relative to the mounts compresses the support structure; a plurality of leaflets coupled to the support structure and configured to allow unidirectional blood flow through the prosthetic heart valve; and a skirt material coupled to the support structure, wherein all of the inner struts are disposed on a first side of the skirt material, and wherein all of the outer struts are disposed on a second side of the skirt material.

[0006] An endoluminal support structure or stent in accordance with certain embodiments of the invention solves certain deficiencies found in the prior art. In particular, the support structure can be repositioned within the body lumen or retrieved from the lumen.

[0007] A particular embodiment of the invention includes a support apparatus implantable within a biological lumen. The support apparatus can include a plurality of elongated strut members interlinked by a plurality of rotatable joints, wherein the rotatable joints can cooperate with the stent members to adjustably define a shaped structure between a compressed orientation and an expanded orientation.

[0008] More particularly, the shaped structure can be one of a cylindrical, a conical, or an hourglass shape. A rotatable joint can form a scissor mechanism with a first strut member and a second strut member. Furthermore, the strut members can be arranged as a series of linked scissor mechanisms. The apparatus can further include an actuator to urge the rotatable joints within a range of motion.

[0009] The apparatus can also include a prosthetic valve coupled to the shaped structure.

[0010] Another particular embodiment of the invention can include a medical stent implantable within a biological lumen. The medical stent can include a plurality of elongated strut members, including a first strut member and a second strut member, and an articulated joint connecting the first strut member and the second strut member.

[0011] In particular, the articulated joint can form a scissor mechanism with the first strut member and the second strut member. The articulated joint can bisect the first strut member and the second strut member. The articulated joint can interconnect a first end of the first strut member with a first end of the second strut member.

[0012] The plurality of strut members can be arranged as a series of linked scissor mechanisms. The strut members can also be non-linear. The strut members can be arranged to form one of a cylindrical, a conical, or an hourglass shape.

[0013] The stent can further include an adjustment mechanism to exert a force to urge the strut members about the articulated joint within a range of motion.

CLAIMS

1. A prosthetic heart valve, comprising:

a support structure having a first end, a second end, a central longitudinal axis extending from the first end to the second end, a plurality of struts and a plurality of rivets, wherein each of the struts has a first end portion, a second end portion, and a third portion extending from the first end portion to the second end portion, wherein each of the struts has openings in the first end portion, the second end portion, and the third portion, wherein each of the struts has a length dimension, a width dimension, and a thickness dimension, wherein the length dimension extends from the first end portion to the second end portion and is greater than the width dimension and the thickness dimension, wherein the width dimension is a cross-sectional dimension perpendicular to the length dimension and the thickness dimension and is greater than the thickness dimension, wherein the thickness dimension is a radial dimension relative to the central longitudinal axis, wherein each of the struts comprises a first width at first locations circumscribing the openings and a second width at second locations extending from one of the first locations to another one of the first locations, wherein the second width is less than the first width and is uniform throughout, wherein the rivets have first portions, second portions, and third portions, wherein the first portions of the rivets comprise a third width and extend through the openings of the struts, wherein the second portions of the rivets comprise a fourth width disposed on outer-facing surfaces of the struts, wherein the fourth width is greater than the second width and the third width, wherein the third portions of the rivets comprise a fifth width disposed on inner-facing surfaces of the struts, wherein the fifth width is less than the first width and greater than the third width, and wherein the struts are pivotable about the rivets to radially expand and compress the support structure;

an actuator member coupled to the struts of the support structure and configured to selectively actuate expansion and compression of the support structure; and

a plurality of leaflets coupled to the support structure and configured to allow unidirectional blood flow through the prosthetic heart valve.

2. The prosthetic heart valve of claim 1, wherein the openings formed in the struts include three or more openings formed in each of the struts, and each of the rivets extends through the openings of two adjacent struts.

3. The prosthetic heart valve of claim 1, wherein the first portions of the rivets are shaft portions sized such that the shaft portions extend through the openings of the struts, and wherein the second portions of the rivets are flange portions extending radially outwardly from end portions of the shaft portions.
4. The prosthetic heart valve of claim 1, wherein the actuator member is configured to reversibly and incrementally adjust the support structure between an expanded configuration and a compressed configuration.
5. The prosthetic heart valve of claim 1, further comprising a skirt, wherein the skirt is coupled to the struts by sandwiching the skirt between the struts.
6. The prosthetic heart valve of claim 5, wherein at least one strut is disposed on a first side of the skirt, and at least other strut is disposed on a second side of the skirt.
7. The prosthetic heart valve of claim 5, wherein one or more of the rivets extend through the skirt.
8. The prosthetic heart valve of claim 5, wherein the support structure further includes a first mount and a second mount spaced from the first mount, wherein the first and second mounts are coupled to the struts, and wherein the actuator member is rotatably coupled to the first and second mounts.
9. The prosthetic heart valve of claim 8, wherein actuator member is configured such that rotating the actuator member in a first direction relative to the first and second mounts expands the support structure and such that rotating the actuator member in a second direction relative to the first and second mounts compresses the support structure.
10. A prosthetic heart valve, comprising:
a support structure having a first end, a second end, a central longitudinal axis extending from the first end to the second end, a plurality of inner struts, a plurality of outer struts, and a

plurality of rivets, wherein each of the inner struts and each of the outer struts has a plurality of openings formed therein, wherein each of the inner struts and each of the outer struts has a length dimension, a width dimension, and a thickness dimension, wherein the thickness dimension extends radially relative to the central longitudinal axis and is less than the width dimension and the length dimension, wherein the width dimension is a cross-sectional dimension perpendicular to the length dimension and the thickness dimension and is less than the length dimension, wherein each of the inner struts and each of the outer struts comprises a plurality of first segments circumscribing the openings and having a first width and a plurality of second segments extending from and interconnecting adjacent first segments and having a second width, wherein the second width is less than the first width and is constant along the entire length of the second segment, wherein the rivets have first portions with a third width, second portions with a fourth width, and third portions with a fifth width, wherein the fourth width is greater than the third width and the second width, wherein the first portions extend between the second portions and the third portions through the openings of the inner struts and the outer struts, wherein the second portions are disposed on inner sides of the inner struts, wherein the third portions are disposed on outer sides of the outer struts, wherein the fifth width is less than the first width and greater than the third width, and wherein the inner struts and the outer struts are pivotable relative to each other about the rivets to radially expand and compress the support structure;

an actuator member coupled to the support structure and configured to selectively actuate expansion and compression of the support structure;

a plurality of leaflets coupled to the support structure and configured to allow unidirectional blood flow through the prosthetic heart valve; and

a skirt comprising an inner surface and an outer surface, wherein the skirt is sandwiched between each of the inner struts and the outer struts of the support structure, wherein the inner struts circumscribe the inner surface of the skirt, and wherein the outer struts circumscribe the outer surface of the skirt.

11. The prosthetic heart valve of claim 10, wherein the skirt comprises one or more openings, and wherein one or more of the rivets extend through the one or more openings of the skirt.

12. The prosthetic heart valve of claim 10, wherein the openings of the inner struts and the

outer struts include three or more openings formed in each of the inner struts and the outer struts, and wherein each of the rivets extends through the openings of two adjacent struts.

13. The prosthetic heart valve of claim 10, wherein the first portions of the rivets are shaft portions, and wherein the second portions of the rivets are flange portions extending radially outwardly from end portions of the shaft portions.

14. A prosthetic heart valve, comprising:

a support structure having a first end, a second end, a central longitudinal axis extending from the first end to the second end, a plurality of inner struts, a plurality of outer struts, and a plurality of mounts coupled to the inner struts or the outer struts, wherein each of the inner struts and the outer struts includes an inflow end portion, an outflow end portion, an intermediate portion disposed between the inflow end portion and the outflow end portion, a first opening formed in the inflow end portion, a second opening formed in the outflow end portion, and an intermediate opening formed in the intermediate portion, wherein each of the inner struts and each of the outer struts has a length dimension, a width dimension, and a thickness dimension, wherein the length dimension is greater than the width dimension and the thickness dimension, wherein the width dimension is a cross-sectional dimension perpendicular to the length dimension and the thickness dimension and is greater than the thickness dimension, wherein the thickness dimension is a radial dimension relative to the central longitudinal axis, wherein each of the inner struts and the outer struts comprises a first width at locations circumscribing the first opening, the second opening, and the intermediate opening and comprises a second width at a first intermediate location extending between the locations circumscribing the first opening and the intermediate opening and at a second intermediate location extending between the locations circumscribing the second opening and the intermediate opening, wherein the second width is less than the first width and is uniform, wherein adjacent pairs of inner and outer struts are coupled together by a plurality of rivets, wherein each rivet has a shaft portion, a first flange portion, and a second flange portion, wherein the first flange portion extends from the shaft portion away from the central longitudinal axis, wherein the second flange portion extends from the shaft portions towards the central longitudinal axis and is spaced apart from the first flange portion, wherein the shaft portion has a third width and extends through the openings of the inner

struts and the outer struts, wherein the first flange portion has a fourth width, wherein the fourth width is greater than the second width and the third width, wherein the second flange portion has a fifth width that is less than the first width and greater than the third width and wherein the inner struts and the outer struts are pivotable to each other about the rivets to radially expand and compress the support structure;

an actuator member coupled to the mounts of the support structure and configured to selectively actuate expansion and compression of the support structure, wherein rotating the actuator member in a first direction relative to the mounts expands the support structure, and wherein rotating the actuator member in a second direction relative to the mounts compresses the support structure;

a plurality of leaflets coupled to the support structure and configured to allow unidirectional blood flow through the prosthetic heart valve; and

a skirt material coupled to the support structure, wherein all of the inner struts are disposed on a first side of the skirt material, and wherein all of the outer struts are disposed on a second side of the skirt material.

15. The prosthetic heart valve of claim 14, wherein one or more of the rivets extend through the skirt material.

16. The prosthetic heart valve of claim 14, wherein the actuator member is configured to reversibly and incrementally adjust the support structure between an expanded configuration and a compressed configuration.

17. The prosthetic heart valve of claim 14, wherein the rivets are hollow.

18. The prosthetic heart valve of claim 17, wherein the first flange portion or the second flange portion of each rivet is formed by swaging.

19. The prosthetic heart valve of claim 14, wherein the skirt material comprises one or more openings, and wherein one or more of the rivets extend through the one or more openings of the skirt material.