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(54) PERCUTANEOUS ENDOVASCULAR APPARATUS FOR REPAIR OF ANEURYSMS AND ARTERIAL BLOCKAGES

(71) Applicant: TMT SYSTEMS, Milford, CT (US)

(72) Inventor: Timur P. Sarac, Orange Village, OH (US)

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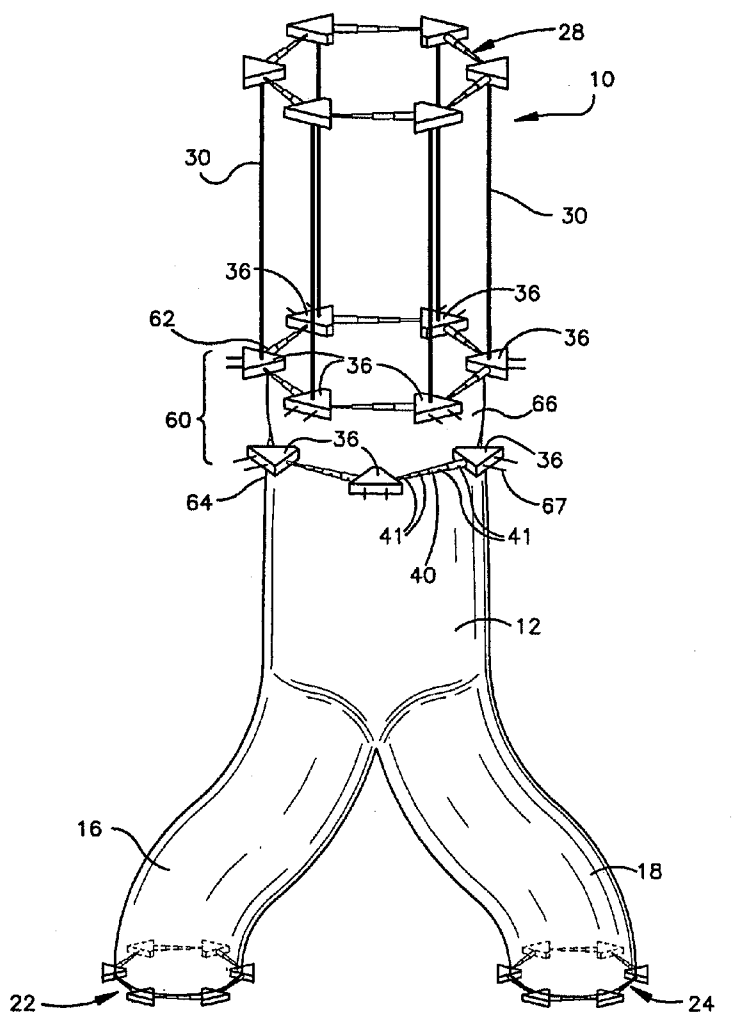
(57) ABSTRACT

An endovascular apparatus is provided for treating the effects of vascular disease including aneurysms and arterial blockages using a percutaneous, minimally invasive technique. In one embodiment the endovascular apparatus includes a tubular sleeve having a cranial end, a first caudal branch, and a second caudal branch such that the tubular sleeve is shaped like an upside down "Y." The apparatus further includes at least one expandable attachment device attached to the tubular sleeve for securing the endovascular apparatus to an interior wall of a vessel.



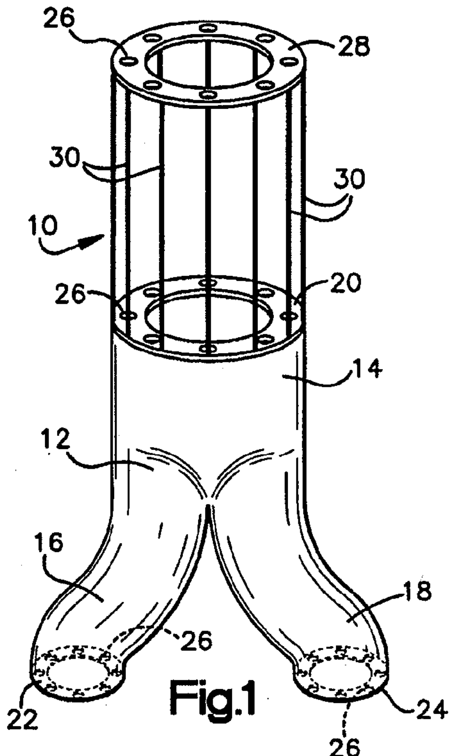


Fig.1

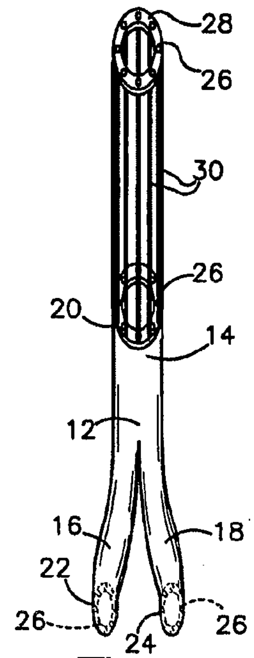


Fig.2A

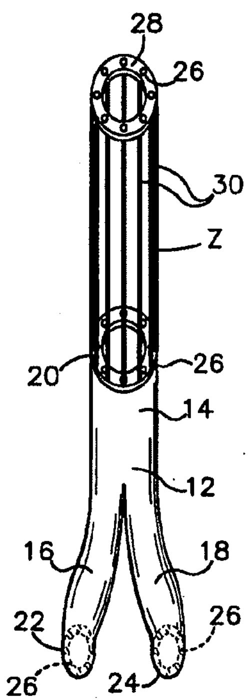


Fig.2B

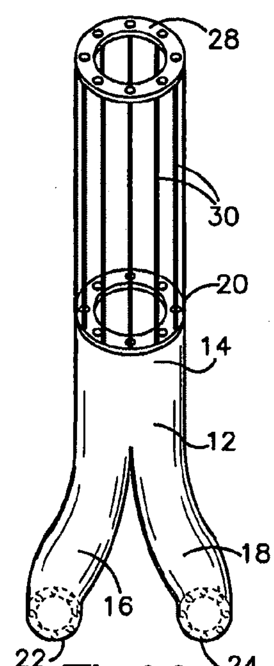


Fig.2C

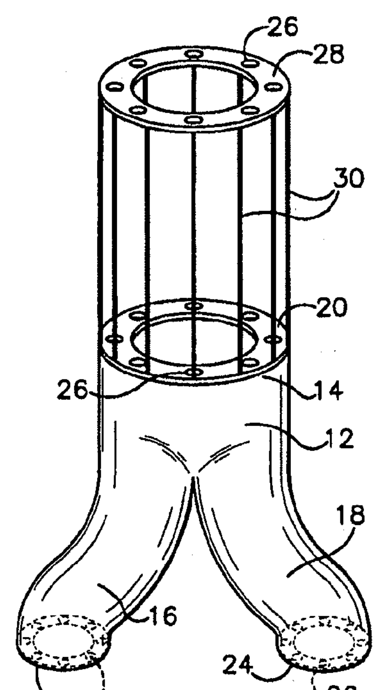


Fig.2D

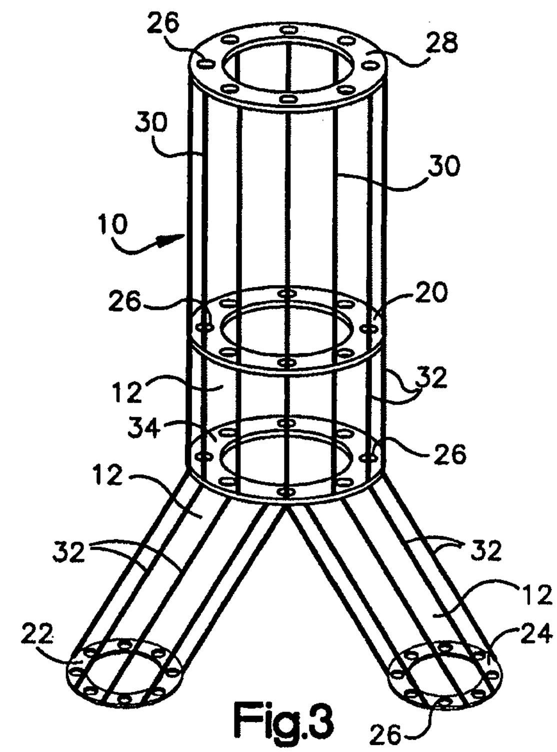



Fig.3

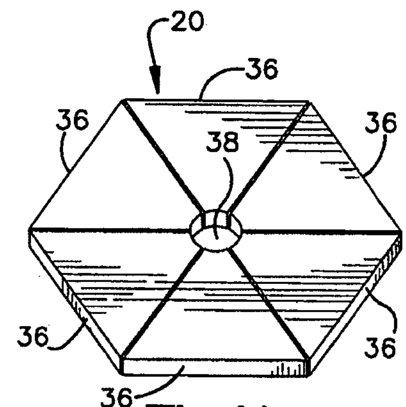
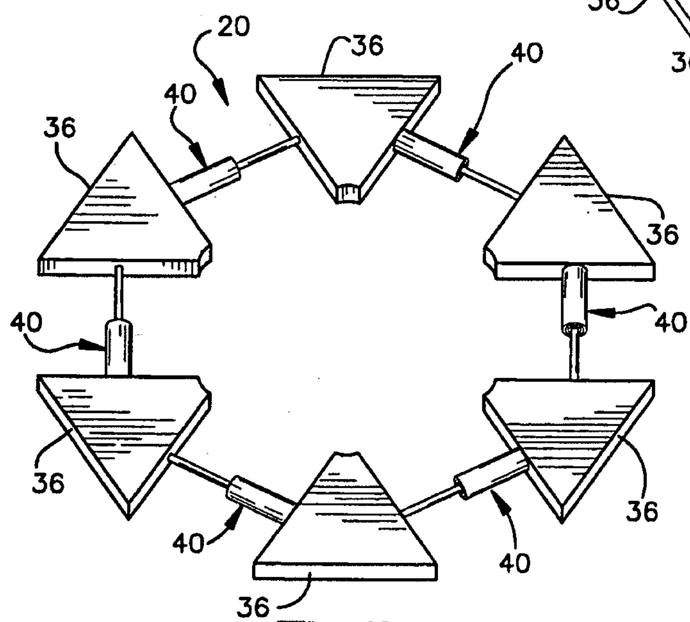



Fig.4A

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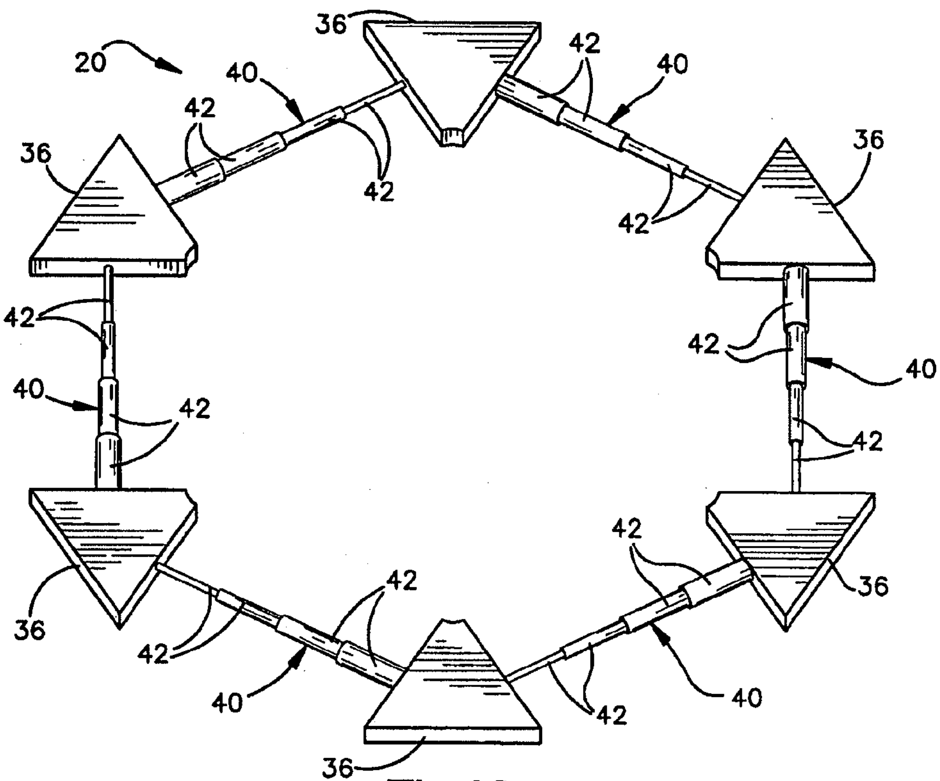



Fig.4C

Fig.5

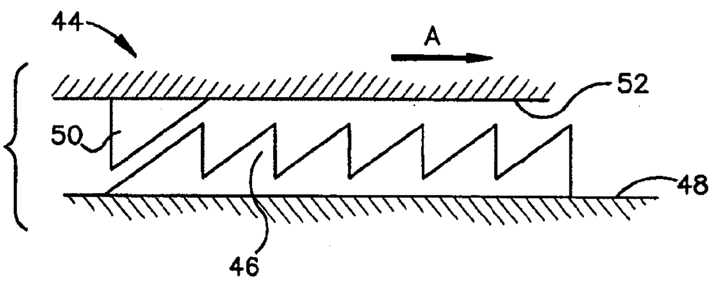
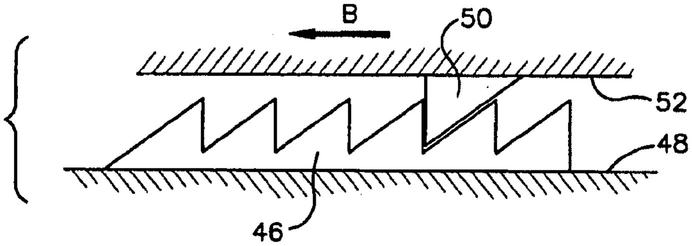
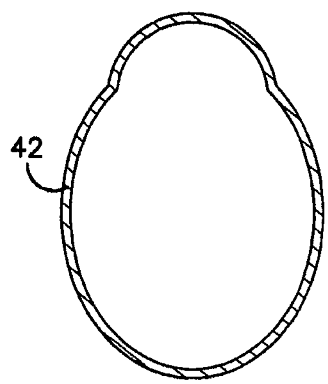



Fig.6



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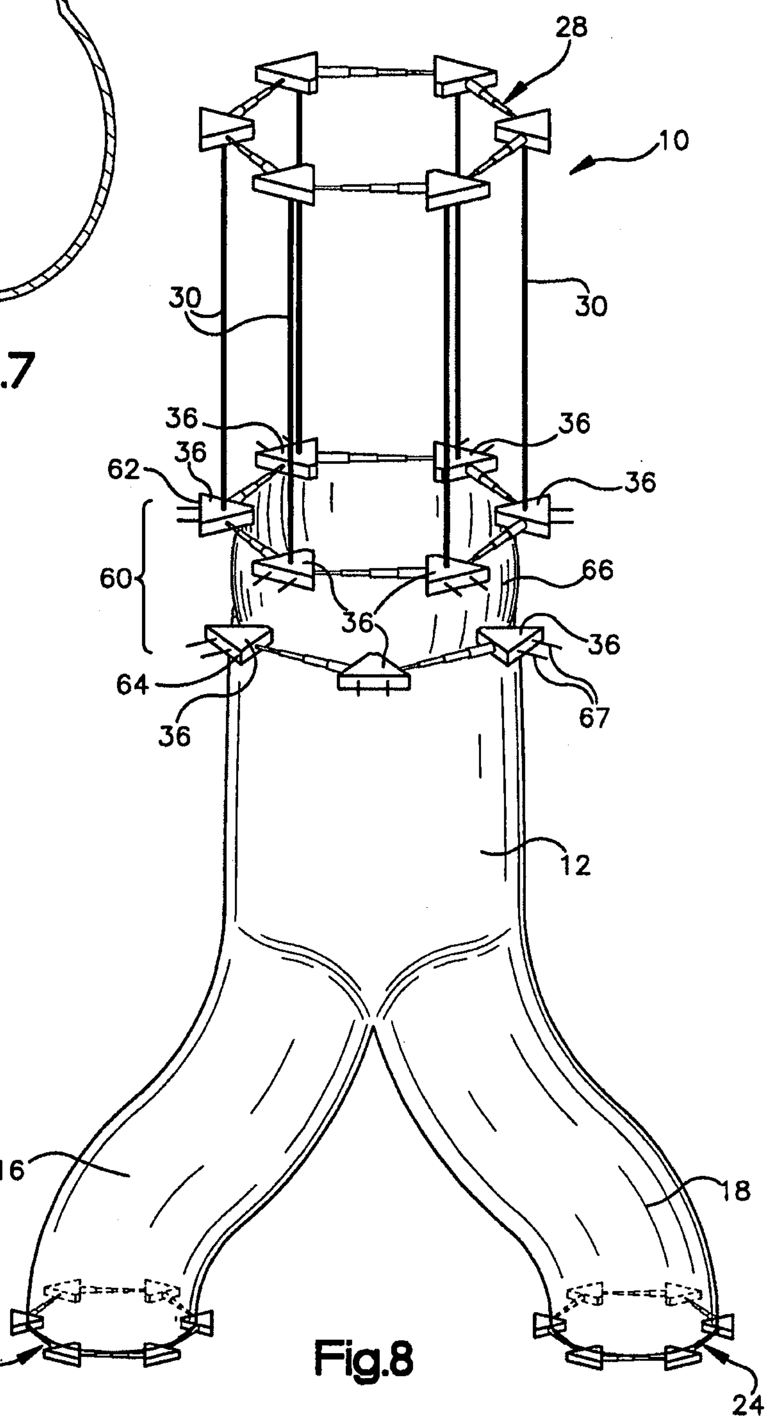



Fig.8

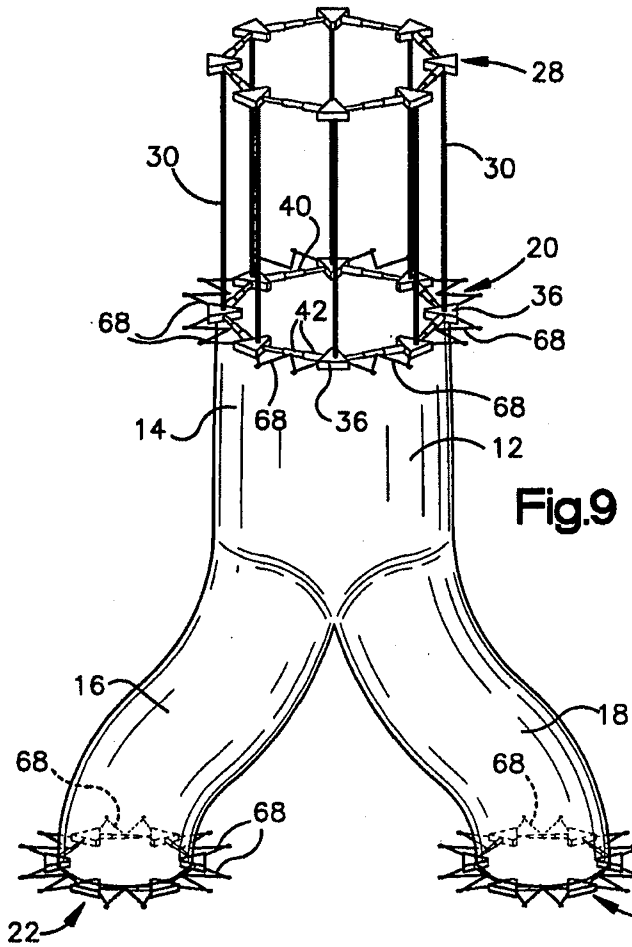



Fig.9

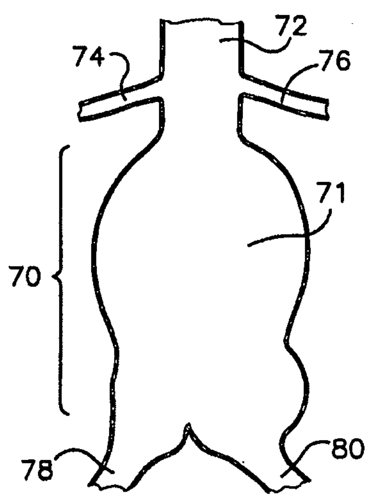
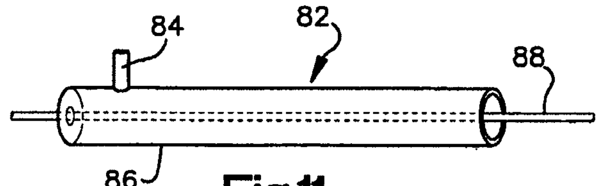



Fig.10

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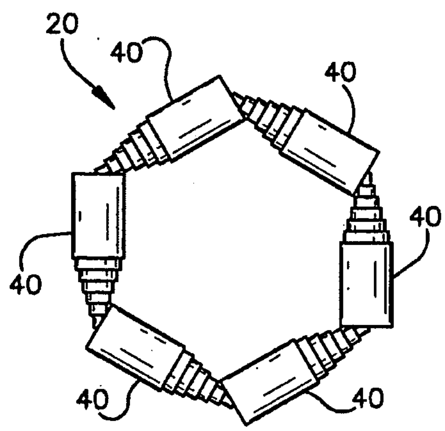



Fig.12A

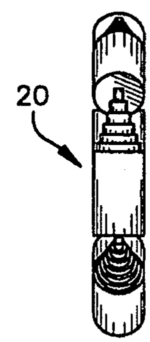



Fig.12C

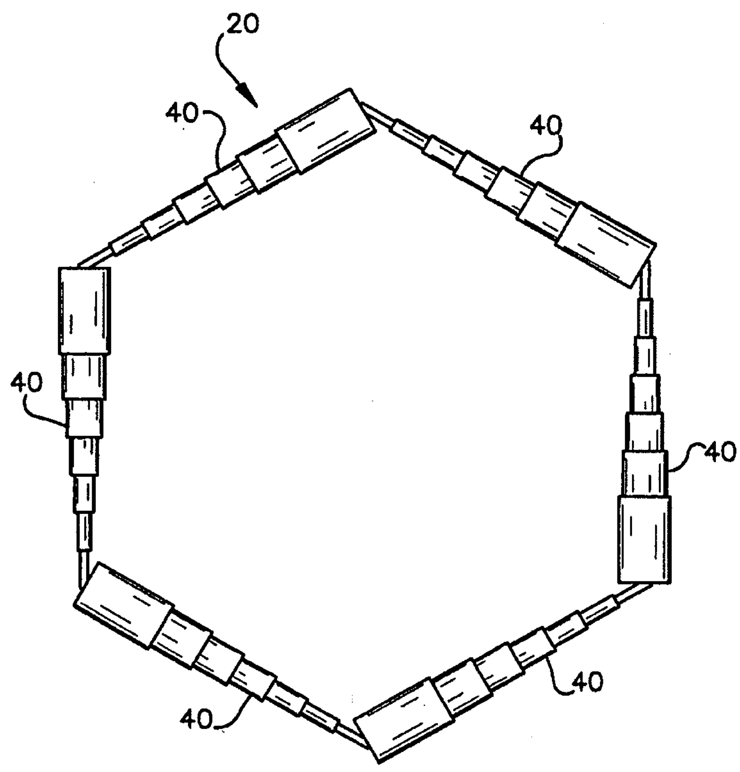



Fig.12B

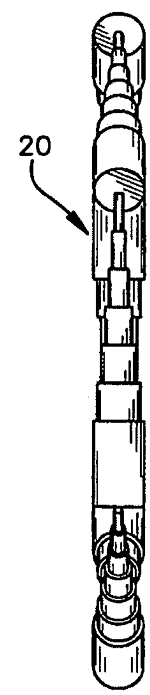
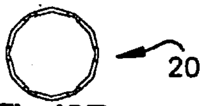



Fig.12D

Fig.13A



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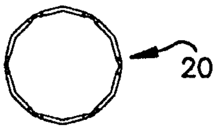

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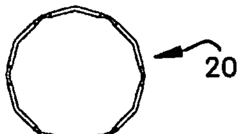

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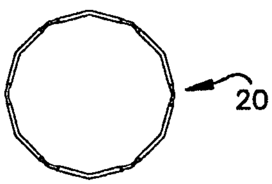


Fig.13E

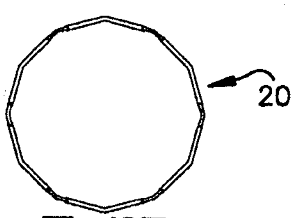


Fig.13F

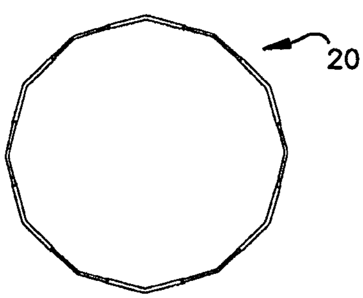


Fig.13G

Fig.13H

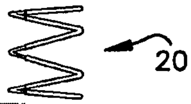
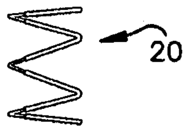


Fig.13I



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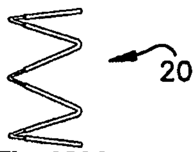

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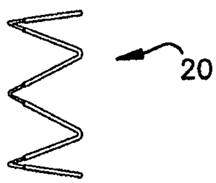

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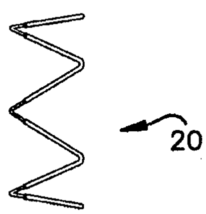

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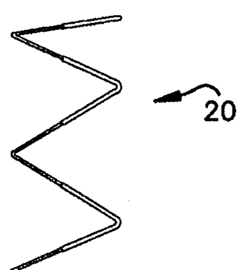


Fig.13N

Fig.13O

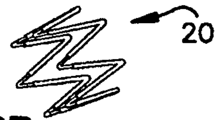
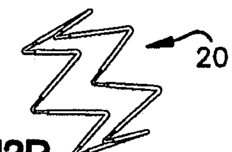


Fig.13P

Fig.13Q



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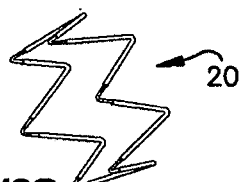
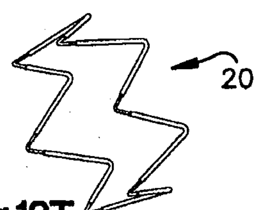


Fig.13S



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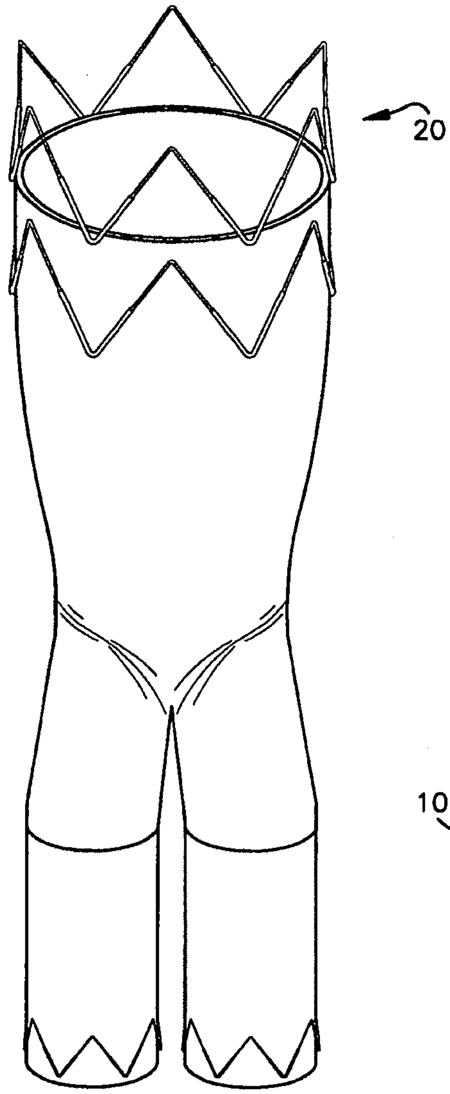


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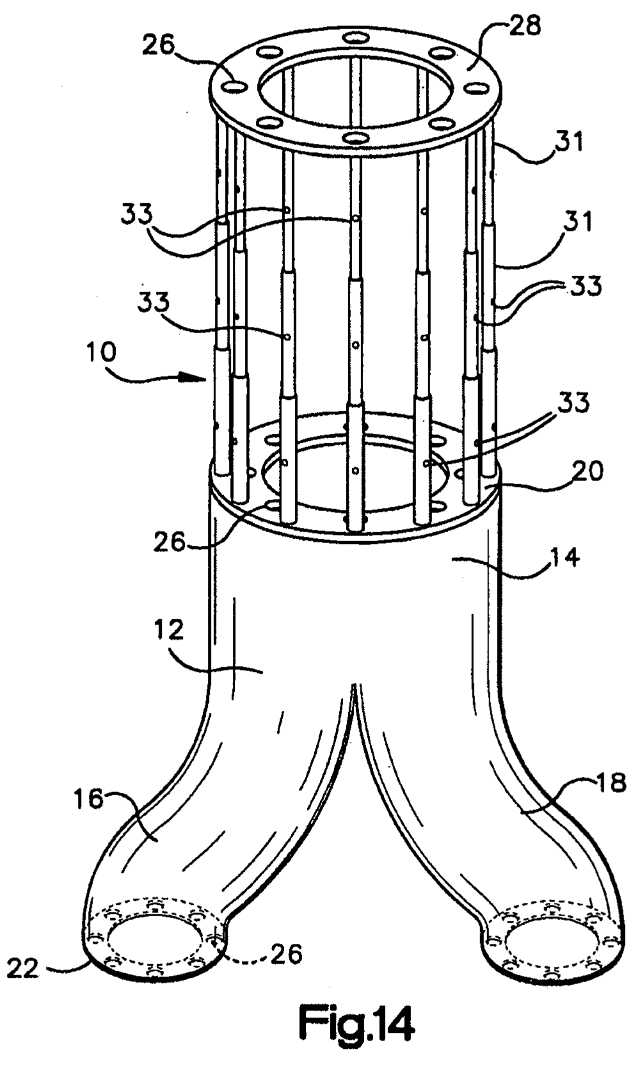


Fig.14

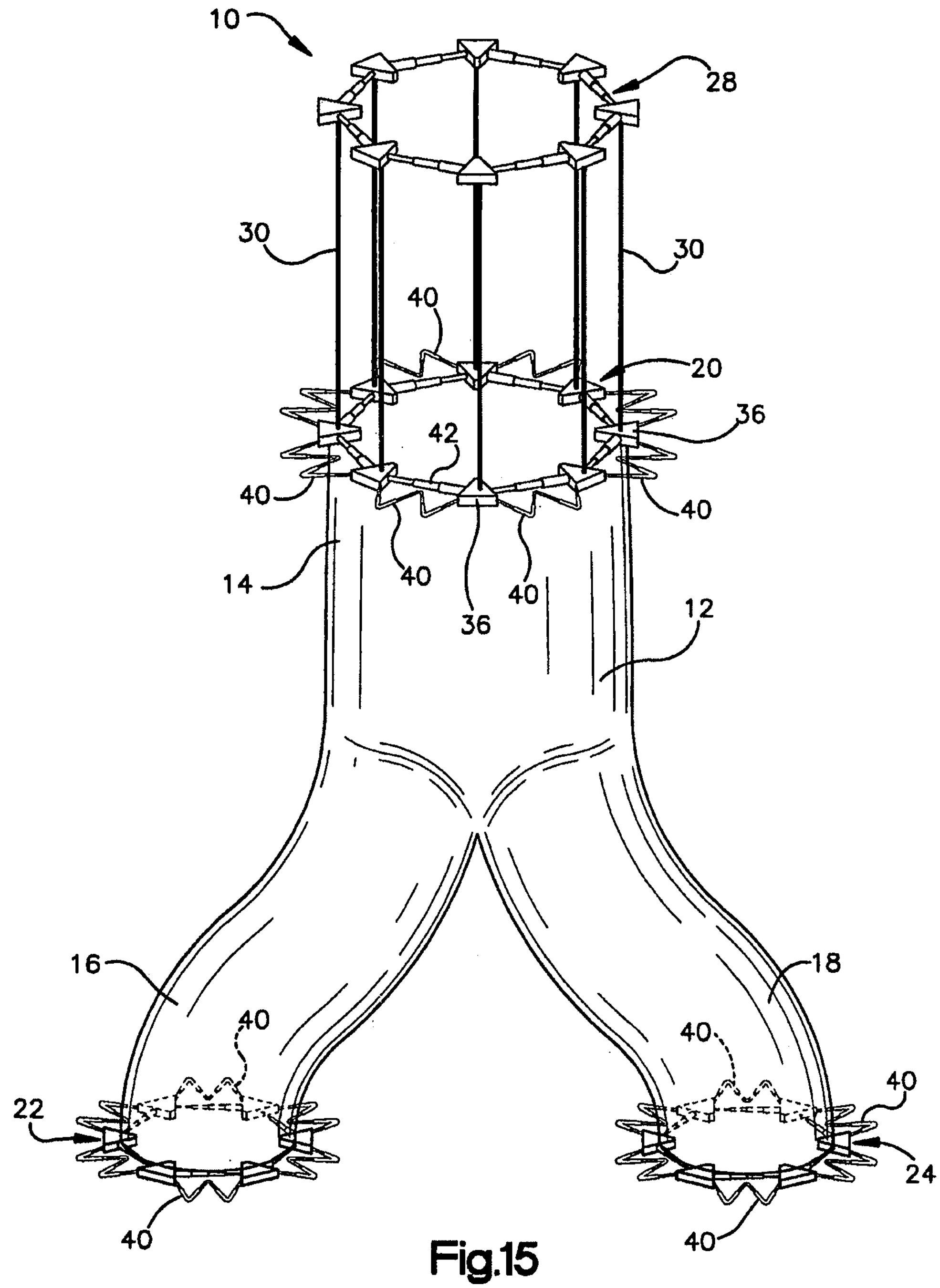


Fig.15

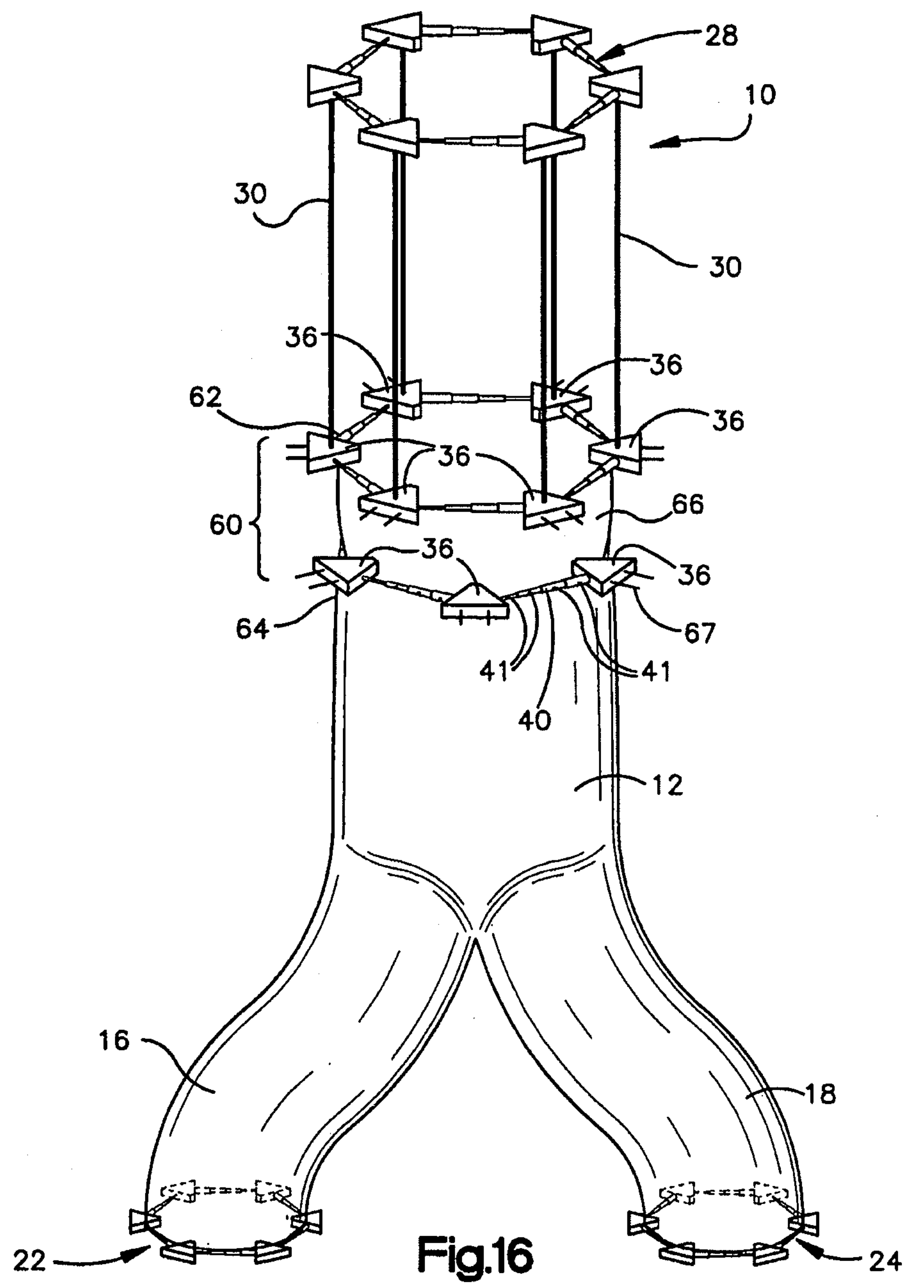
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Fig.16

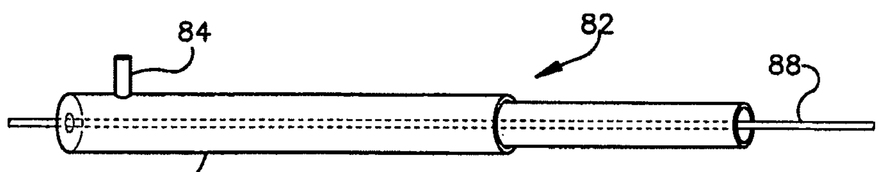
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Fig.17

# PERCUTANEOUS ENDOVASCULAR APPARATUS FOR REPAIR OF ANEURYSMS AND ARTERIAL BLOCKAGES

## CROSS-REFERENCE TO RELATED APPLICATIONS

**[0001]** This application is a continuation of U.S. patent application Ser. No. 11/484,331, filed Jul. 10, 2006, which is a continuation-in-part of U.S. patent application Ser. No. 10/624,864, filed Jul. 22, 2003, which in turn claims priority to U.S. Provisional Application No. 60/397,745, filed Jul. 22, 2002. Each of the aforementioned priority applications are hereby incorporated by reference in its entirety.

## BACKGROUND OF THE INVENTION

**[0002]** Field of the Invention

**[0003]** The present invention relates generally to an endovascular apparatus for the treatment of aneurysms or arterial blockages, and more particularly, to an endovascular apparatus having an expandable attachment device for securing the endovascular apparatus to an interior wall of a lumen.

**[0004]** Description of the Related Art

**[0005]** An abdominal aortic aneurysm is an abnormal enlargement or "ballooning out" of the arterial wall of the aorta in a region that passes through the abdominal cavity, usually below the renal arteries and above the common iliac arteries. The aneurysm may also extend into the common iliac arteries. Such aneurysms are typically brought on by the weakening of the arterial wall from vascular disease. Although abdominal aortic aneurysms often do not cause pain, unless treated, an aneurysm may rupture causing a fatal hemorrhage in a patient.

**[0006]** In the past aortic aneurysms were treated almost exclusively by surgical repair. Specifically, the aneurysm would be resected and replaced by an artificial artery known as a prosthetic graft. Because of the substantial risks associated with such an invasive surgery, however, other treatments for aortic aneurysms have been proposed including endovascular grafting.

**[0007]** Endovascular grafting involves the placement of a prosthetic graft within the lumen of the artery such that the graft spans the length of the aneurysm. In this manner the aneurysm can be excluded from the circulatory system rather than resected. Using a catheter as a deployment device, the endovascular graft can be introduced into the vascular system percutaneously. Once the graft has been positioned at the site of the aneurysm it can be attached to the vascular wall both above and below the aneurysm using expandable attachment devices to prevent movement of the graft after deployment.

**[0008]** To introduce an endovascular graft percutaneously, the graft must be collapsible into a small profile for negotiating the vascular system. Upon reaching the site of the aneurysm the graft and its attachment devices can be expanded into a desired shape using an inflating balloon catheter or other actuator. A variety of expandable attachment devices have been proposed for securing an endovascular graft to an interior wall of a vessel most of which use stents with hooks or barbs to penetrate the intima of the vessel. None of the proposed attachment devices, however, have been found to be ideally suited for use with an endovascular graft.

**[0009]** Accordingly an endovascular apparatus having a new expandable attachment device is desired. The new attachment device ideally should be small with a low profile and should expand to many times its initial diameter. It also should exert enough radial force when expanded to fix into the aorta and thereby reduce blood leaks around the apparatus.

## SUMMARY OF THE INVENTION

**[0010]** In a first aspect, an expandable attachment device for securing an endovascular apparatus to an interior wall of a lumen is provided. The expandable attachment device may include a plurality of telescoping arms that are joined together to form an expandable ring. This ring may function similarly to stents. The expandable attachment device may be attached to an endovascular apparatus for the treatment of aneurysms or blockages, such as a graft or stent, or to a heart valve and may include barbs, hooks, or other fasteners about its perimeter for attaching to the interior wall of a lumen. Because the attachment device can be collapsed to a size that can be fed through a vessel, the attachment device and an associated endovascular apparatus can be deployed percutaneously in a patient. Once positioned at the site of an aneurysm or arterial blockage, the telescoping attachment device can be expanded to hold the endovascular apparatus in place adjacent the inner lumen wall.

**[0011]** In a second aspect, an endovascular apparatus is provided for treating aneurysms or arterial blockages using a minimally invasive technique. The apparatus includes a tubular sleeve having a cranial end and at least one caudal branch. If the tubular sleeve includes a first caudal branch and a second caudal branch then the tubular sleeve is shaped like an upside down "Y." Accordingly, for the treatment of abdominal aortic aneurysms the cranial end may be positioned in the infrarenal aorta, the first caudal branch may be positioned in one of the common iliac arteries, and the second caudal branch may be positioned in the other common iliac artery. The tubular sleeve may be made from materials conventionally used to make endovascular grafts including synthetic fabrics or films, DACRONT™ or expanded polytetrafluoroethylene (ePTFE) so as to define a lumen and so as to be collapsible during percutaneous insertion into a patient's vascular system.

**[0012]** The endovascular apparatus further includes an expandable attachment device attached to the cranial end of the tubular sleeve for securing the apparatus to an interior wall of a vessel above an aneurysm. The expandable attachment device comprises a plurality of telescoping arms that are attached to form an expandable ring. Each telescoping arm is similar to an expandable presentation pointer. Alternatively, each telescoping arm may function like an accordion. Accordingly, during percutaneous insertion of the endovascular apparatus into a patient, the attachment device can be collapsed into a small profile. Once the apparatus is positioned at the site of the aneurysm or blockage, the expandable attachment device can be expanded to hold the endovascular apparatus in place adjacent the inner lumen wall. Fixation components may be positioned around the perimeter of the attachment device and may be partially embedded in the inner wall of the vessel to secure the attachment device.

**[0013]** The plurality of telescoping arms may be made from materials suitable for use in the human body including stainless steel, plastic, or an alloy of nickel and titanium generally known as NITINOL™. NITINOL is commonly used in the manufacture of medical devices that are to be deployed in a compressed state through a catheter because of its unique thermal memory properties. For example, a NITINOL part may be manufactured in a first condition and then cooled and compressed into a second condition. When heated to the body temperature of the patient the NITINOL part will expand to its original first condition.

**[0014]** In another aspect one or more expandable attachment devices may be attached to the one or more caudal branches of the tubular sleeve for securing the one or more caudal branches to the interior of the vessel wall.

**[0015]** In one aspect, an endovascular apparatus comprises tubular sleeve having a central lumen with a cranial end portion, a first caudal branch, and a second caudal branch. An M-stent is attached to the cranial end portion of the tubular sleeve extending circumferentially around the tubular sleeve to hold the sleeve open and secure the sleeve to a wall of a vessel.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0016]** FIG. **1** is a schematic illustration of an endovascular apparatus according to a first aspect;

**[0017]** FIGS. **2**A-D show the endovascular apparatus of FIG. **1** in various states or expansion;

**[0018]** FIG. **3** is a schematic illustration of an endovascular apparatus according to a second aspect;

**[0019]** FIG. **4**A is a top view of an expandable attachment device according to a first aspect in a fully collapsed state;

**[0020]** FIG. **4**B is a top view of the expandable attachment device of FIG. **4**A in a partially expanded state;

**[0021]** FIG. **4**C is a top view of the expandable attachment device of FIG. **4**A in a fully expanded stated;

**[0022]** FIG. **5** is a locking mechanism according to a first aspect in a first position;

**[0023]** FIG. **6** is the locking mechanism of FIG. **5** in a second position;

**[0024]** FIG. **7** is a cross section of a segment of a telescoping arm according to a first aspect;

**[0025]** FIG. **8** is an endovascular apparatus according to a third aspect;

**[0026]** FIG. **9** is an endovascular apparatus according to a fourth aspect;

**[0027]** FIG. **10** is an illustration of a typical abdominal aortic aneurysm located in the infrarenal aorta;

**[0028]** FIG. **11** is a catheter for percutaneous introduction of an endovascular apparatus into a body lumen;

**[0029]** FIG. **12**A is a schematic top view of an expandable attachment device according to a second aspect in a partially expanded state;

**[0030]** FIG. **12**B is a schematic top view of the expandable attachment device of FIG. **12**A in a fully expanded stated;

**[0031]** FIG. **12**C is a schematic side view of the expandable attachment device of FIG. **12**A;

**[0032]** FIG. **12**D is a schematic side view of the expandable attachment device of FIG. **12**B;

**[0033]** FIGS. **13**A-G are schematic top views of an expandable attachment device according to a third aspect in various states of expansion;

**[0034]** FIGS. **13**H-N are schematic side views of the expandable attachment device of FIGS. **13**A-G;

**[0035]** FIGS. **13**O-T are schematic isometric views of the expandable attachment device of FIGS. **13**A-G;

**[0036]** FIG. **13**U is a schematic illustration of another embodiment of the invention.

**[0037]** FIG. **14** is a schematic illustration of the endovascular apparatus of FIG. **1** having telescoping support columns;

**[0038]** FIG. **15** is a schematic illustration of an endovascular apparatus according to another aspect;

**[0039]** FIG. **16** is a schematic illustration of an expandable attachment device according to another aspect; and

**[0040]** FIG. **17** is a schematic illustration of a telescoping catheter for percutaneous introduction of an endovascular apparatus into a body lumen.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0041]** An endovascular apparatus **10** according to a first aspect is shown in FIG. **1**. The endovascular apparatus **10** includes a tubular sleeve **12** having a cranial end **14**, a first caudal branch **16**, and a second caudal branch **18**. In other embodiments, termed "uni-iliac" devices, the tubular sleeve **12** may include only a single caudal branch. The tubular sleeve may be made from DACRON, ePTFE, peritoneum, fascia, or other common graft material so as to form a flow path for by-passing an aneurysm.

**[0042]** The endovascular apparatus **10** further includes a first expandable attachment device **20** attached to the cranial end **14** of the tubular sleeve **12**, a second expandable attachment device **22** attached to the first caudal branch **16** of the tubular sleeve **12**, and a third expandable attachment device **24** attached to the second caudal branch **18** of the tubular sleeve **12**. The expandable attachment devices **20**, **22**, **24** may include holes **26** which may be sewn or sutured to the tubular sleeve **12**. Alternatively, in lieu of holes **26**, the expandable attachment devices can be woven into the sleeve.

**[0043]** In another embodiment, the endovascular apparatus **10** may include a fourth expandable attachment device **28** that is attached to the first expandable attachment device **20** by support columns **30**. The fourth expandable attachment device **28** may be positioned above a patient's renal arteries, superior mesenteric artery or celiac artery. The support columns **30**, which may be made from NITINOL or stainless steel, may provide columnar support and strength for the endovascular apparatus **10** while permitting blood flow to arteries located between the first expandable attachment device **20** and the fourth expandable attachment device **28**.

**[0044]** The support columns **30** may be either wires or tubes. If tubular, the support columns **30** may also be telescoping. For example, in another embodiment depicted in FIG. **14**, the support columns **31** may comprise a plurality of incrementally sized segments that are slideably engaged and fit within one another. Thus, in this embodiment the endovascular apparatus **10** may be inserted percutaneously into a vessel with the support columns **31** contracted such that the axial distance between the first expandable attachment device **20** and the fourth expandable attachment device **28** is reduced. During deployment of the endovascular apparatus **10** the support columns **31** may be expanded, thereby permitting the first expandable attachment device **20** to be positioned below the renal arteries while the fourth expandable attachment device is positioned above the renal arteries. In yet another embodiment, shown in FIG. **14**, the tubular support columns **30**, **31**, whether telescoping or not telescoping, may contain an adhesive and include ports or apertures **33** such that the adhesive can escape the support columns **30**, **31** upon deployment to assist in securing the endovascular apparatus **10** to the wall of a vessel.

**[0045]** As illustrated in FIGS. **2**A-**2**D, the endovascular apparatus **10** is collapsible for easy insertion and navigation through a patient's vascular system using a catheter. Particularly, as illustrated in FIG. **2**A, the attachment devices **20**, **22**, **24**, and **28** may be radially collapsed into a profile that is small enough to fit in a catheter sheath. When the attachment devices **20**, **22**, **24**, **28** are deployed from the sheath at body temperature, the devices may be expanded by a balloon or other actuator to a size and shape in which they are able to retain the sleeve **12** against the wall of a vessel.

**[0046]** The endovascular apparatus **10** according to a second aspect is shown FIG. **3** in which the tubular sleeve **12** is supported by support columns **32**. The support columns **32** may attach the first expandable attachment device **20** to a fifth expandable attachment device **34** Likewise, the support columns **32** may attach the second and third expandable attachment devices **22**, **24** to the fifth expandable attachment device **34** which may be located at the juncture of the first caudal branch **16** and the second caudal branch **18** of the tubular sleeve **12**. In addition the support columns **32** may be sewn or sutured to the exterior of the tubular sleeve **12**. This may provide continued columnar support throughout the endovascular apparatus **10** to prevent migration within the vessel. The support columns **32** may be telescoping as described with respect to FIG. **14**.

**[0047]** Referring to FIG. **4**A, an expandable attachment device **20** according to a first aspect is shown in a fully collapsed state. The attachment device **20** includes a plurality of fixation components **36** positioned about the perimeter of the device **20**. A port **38** is located at the center of the attachment device **20**. The port **38** is sized so as to receive a balloon or other actuator during deployment. The balloon may be inflated to expand the attachment device **20** after insertion into a vessel. FIG. **4**B shows the attachment device **20** in a partially expanded state. FIG. **4**C shows the attachment device **20** in a fully expanded state. While in a preferred embodiment, the fixation component can have angular corners, in other embodiments, the fixation component can have curved, rounded, or ovoid edges. Similarly, the entire corner or edge of each fixation component need not be the same shape throughout the length of the edge or corner.

**[0048]** Referring to FIG. **4**C, a telescoping arm **40** is used to attach each fixation component **36** to an adjacent fixation component **36**. The telescoping arm **40** may be pivotably attached to a fixation component **36** at one or both ends of the arm **40**. A telescoping arm **40** is made up of a plurality of segments **42**. The segments **42** may be in slideable contact with one another and may be incrementally sized so as to fit within one another. For example, each telescoping arm **40** may be constructed from what is referred to generally as "nested tubes." When the telescoping arms **40** are fully extended the attachment device **20** may resemble a polygon having fixation components **36** located at its vertices. The fixation components **36** may include barbs or prongs **67** (shown in FIG. **8**) for fixation to a vessel wall. In another embodiment shown in FIG. **16**, the telescoping arms **40** may contain an adhesive and include ports or apertures **41** such that the adhesive can escape the telescoping arms upon deployment to assist in securing the endovascular apparatus **10** to the wall of a vessel.

**[0049]** As one of ordinary skill might appreciate, the attachment device may take variety of shapes depending upon the configuration of the telescoping arms **40** and the fixation components **36**. For example, referring to FIGS. **12**A-D, the telescoping arms **40** may be positioned in a single plane. Alternatively, referring to FIGS. **13**A-T, the telescoping arms **40** may be positioned in multiple planes in, for example, what is referred to herein as an "M configuration." One possible advantage of the M configuration is that it may produce superior radial force for holding the attachment device in position. In addition, the M configuration may produce the same ratio of expansion (i.e., the ratio of the final outer diameter of the attachment device in its expanded state to the initial outer diameter of the attachment device in its collapsed state) as the "single plane configuration" using fewer parts.

**[0050]** FIG. **13**U depicts multiple "M configuration" attachment devices on an endovascular apparatus.

**[0051]** To keep the telescoping arms **40** in their final extended state after deployment in a vessel, a one-way latch may be used to lock adjacent segments **42**. FIG. **5** shows one possible latch **44**, in a first position, for locking the telescoping arms **40**. The latch **44** may consist of a one or more grooves **46** associated with a first segment **48** and a tooth **50** associated with a second, adjacent segment **52**. As the telescoping arm **40** is expanded, the second segment **52** moves in a first direction A relative to the first segment **48**. The tooth **50** and the grooves **46** are aligned so as to engage when the telescoping arm **40** is extended. Once the tooth **50** engages a groove **46**, as shown in FIG. **6**, the second segment **52** may not move in a second direction B relative to the first segment **48**. Accordingly, the telescoping arm **40** is free to extend but may not collapse once extended. Of course other one-way latches may be used to lock the segments **42** of the telescoping arms **40**. FIG. **7** illustrates one possible cross-section of a segment **42** of the telescoping arm **40**. This "rail" design permits room for sliding and positioning of a one-way latch, like the one shown in FIG. **5**, between segments **42** shown in FIG. **4**.

**[0052]** FIG. **8** shows the endovascular apparatus **10** according to a third aspect. In the embodiment shown in FIG. **8**, the endovascular apparatus **10** includes a double-expandable attachment device **60** in the place of the first expandable attachment device **20**. The double-expandable attachment device **60** comprises an upper expandable attachment device **62** and a lower expandable attachment device **64** which are separated by and attached to an o-ring seal **66**. The upper attachment device **62** is angularly offset from the lower attachment device **64** so that the fixation components **36** of each are offset. The fixation components **36** may include prongs or barbs **67** to aid in securing the expandable attachment devices **62**, **64** to the vessel wall. This design provides for secure attachment to the vessel wall with reduced leakage around the perimeter of the attachment device **60**. The lower expandable attachment device **64** may be attached to the tubular sleeve **12**. The upper expandable attachment device **62** may be attached to the fourth expandable attachment device **28** by support columns **30**.

**[0053]** Referring to FIG. **9**, the endovascular apparatus **10** according to fourth aspect is shown. In this embodiment a plurality of "M springs" **68** are attached to the cranial end **14**

of tubular sleeve **12** as graft expanders in order to hold the tubular sleeve **12** open. In this manner the M springs **68** may reduce leakage around the perimeter of the tubular sleeve **12**. M springs **68** may also be used to hold the caudal ends **16**, **18** of the tubular sleeve **12** open. In the embodiment shown in FIG. **9**, the M springs **68** are not attached to the segments **52** of the telescoping arms **40** and are located on the exterior of the tubular sleeve **12**. In another embodiment, the M springs **68** may be located on the interior of the tubular sleeve **12** or attached to the fixation components **36**. Of course, in place of the "M springs" **68**, springs in the shape of a "V" may be used. Alternatively, in another embodiment depicted in FIG. **15**, the M springs **68** may be replaced by telescoping arms **40** in an "M configuration."

**[0054]** FIG. **10** illustrates a typical abdominal aortic aneurysm **70** located in the infrarenal aorta **71**. The infrarenal aorta **71** is that portion of the aorta **72** located below the renal arteries **74**, **76**. As shown in FIG. **10**, abdominal aortic aneurysms typically occur below the renal arteries **74**, **76** and above the common iliac arteries **78**, **80**. In some cases, the aneurysm includes the common iliac arteries **78**, **80**. The endovascular apparatus **10** may be used to treat or repair an abdominal aortic aneurysm **70**, like the one shown in FIG. **10**, by excluding the weakened aneurysmal aortic wall from pressurized and pulsatile flow. In addition, the endovascular apparatus **10** may be used to treat aneurysms or blockages located in other body lumens such as the thoracic aorta, iliac arteries, subclavian arteries, urinary tract, bile tract, intestinal tract, etc.

**[0055]** The endovascular apparatus **10** may be deployed at the site of an aneurysm percutaneously using a catheter **82** like the one shown in FIG. **11**. The catheter **82** may have an IV port **84**, a sheath **86** and an introducer **88** which can be withdrawn within the sheath **86**. Using the catheter **82**, the device can be introduced percutaneously through either of the femoral arteries. As shown in FIG. **17**, using a "nested tube" design similar to the one utilized by the telescoping arms **40** of the attachment device **20**, the catheter **82** may also be made to be telescoping.

**[0056]** During deployment the first expandable attachment device **20** may be positioned just below the renal arteries **74**, **76** and seated with an expandable balloon or other actuator. The fourth expandable attachment device **28** may be positioned superior to the renal arteries **74**, **76**, the mesenteric artery, or the celiac artery and seated with an expandable balloon. After the first attachment device **20** is seated, the second expandable attachment device **22** may be positioned in a first iliac artery **78** and seated with an expandable balloon or other actuator. The third expandable attachment device **24** may be positioned such that it rests at a second iliac artery **80**. To position and seat the third attachment device **24**, access may be obtained percutaneously through the second iliac artery **80**.

**1-18**. (canceled)

**19**. An endovascular apparatus comprising:

a tubular sleeve having a central lumen with a cranial end portion longitudinally separated from a caudal end portion, the cranial end portion including a cranial end opening and the caudal end portion including at least one caudal end opening; and

an expandable attachment device extending circumferentially around the cranial end portion of the tubular sleeve, the expandable attachment device including:

a plurality of tubular segments including first and second segment openings and a tubular segment body, the tubular segment body including an acute angle forming a caudally-pointing tubular segment apex attached to the cranial end portion, the first and second segment openings being mutually circumferentially spaced and being oriented substantially in the cranial direction, and

a plurality of received segments including first and second segment ends and a received segment body, the received segment body including an acute angle forming a cranially-pointing received segment apex longitudinally spaced cranially from the cranial end opening, the first and second segment ends being mutually circumferentially spaced and being oriented substantially in the caudal direction,

wherein each first segment end is telescopically received into a second segment opening, and each second segment end is telescopically received into a first segment opening in an M configuration;

wherein the expandable attachment device includes alternating telescopically arranged tubular and received segments, with each tubular segment being circumferentially spaced from the circumferentially adjacent tubular segments by a circumferentially interposed received segment.

**20**. The endovascular apparatus of claim **19**, wherein the caudal end portion of the tubular sleeve includes a first caudal branch laterally separated from a second caudal branch, the first and second caudal branches each including a branch opening oriented in a caudal direction.

**21**. The endovascular apparatus of claim **20**, wherein the expandable attachment device is a first expandable attachment device, and wherein at least one of the first and second caudal branches includes a branch expandable attachment device extending circumferentially therearound and attached thereto.

**22**. The endovascular apparatus of claim **21**, wherein each branch expandable attachment device includes:

a plurality of tubular segments including first and second segment openings and a tubular segment body, the tubular segment body including an acute angle forming a caudally-pointing tubular segment apex, the first and second segment openings being mutually circumferentially spaced and being oriented substantially in the cranial direction, and

a plurality of received segments including first and second segment ends and a received segment body, the received segment body including an acute angle forming a cranially-pointing received segment apex longitudinally spaced cranially from the tubular segments, the first and second segment ends being mutually circumferentially spaced and being oriented substantially in the caudal direction;

wherein each first segment end is telescopically received into a second segment opening, and each second segment end is telescopically received into a first segment opening in an M configuration.

**23**. The endovascular apparatus of claim **19**, wherein the expandable attachment device is a first expandable attachment device, and wherein the caudal end opening includes a caudal end expandable attachment device extending circumferentially around the caudal end portion of the tubular sleeve.

24. The endovascular apparatus of claim 23, wherein the caudal end expandable attachment device includes:

a plurality of tubular segments including first and second segment openings and a tubular segment body, the tubular segment body including an acute angle forming a caudally-pointing tubular segment apex, the first and second segment openings being mutually circumferentially spaced and being oriented substantially in the cranial direction, and

a plurality of received segments including first and second segment ends and a received segment body, the received segment body including an acute angle forming a cranially-pointing received segment apex longitudinally spaced cranially from the tubular segments, the first and second segment ends being mutually circumferentially spaced and being oriented substantially in the caudal direction;

wherein each first segment end is telescopically received into a second segment opening, and each second segment end is telescopically received into a first segment opening in an M configuration.

25. The endovascular apparatus of claim 19, wherein the expandable attachment device is a first expandable attachment device, and the cranial end portion includes a second expandable attachment device located caudally of the first attachment device, the second expandable attachment device extending circumferentially around the tubular sleeve.

26. The endovascular apparatus of claim 25, wherein the second expandable attachment device includes:

a plurality of tubular segments including first and second segment openings and a tubular segment body, the tubular segment body including an acute angle forming a caudally-pointing tubular segment apex, the first and second segment openings being mutually circumferentially spaced and being oriented substantially in the cranial direction, and

a plurality of received segments including first and second segment ends and a received segment body, the received segment body including an acute angle forming a cranially-pointing received segment apex longitudinally spaced cranially from the tubular segments, the first and second segment ends being mutually circumferentially spaced and being oriented substantially in the caudal direction,

wherein each first segment end is telescopically received into a second segment opening, and each second segment end is telescopically received into a first segment opening in an M configuration; and

wherein at least a portion of the plurality of tubular segments and the plurality of received segments are attached to the tubular sleeve at a location longitudinally caudally spaced from the first expandable attachment device.

27. The endovascular apparatus of claim 19, wherein the plurality of tubular segments and the plurality of received segments are each selectively collapsible in the circumferential direction to selectively and reversibly reduce a total circumference of the expandable attachment device from an expanded apparatus condition to a collapsed apparatus condition.

28. The endovascular apparatus of claim 19, wherein the plurality of tubular segments and the plurality of received segments are collectively selectively collapsible in the longitudinal direction to selectively and reversibly telescope a total length of the endovascular apparatus from an extended apparatus condition to a retracted apparatus condition.

29. The endovascular apparatus of claim 22, wherein the plurality of tubular segments and the plurality of received segments are each selectively collapsible in the circumferential direction to selectively and reversibly reduce a total circumference of the expandable attachment device from an expanded apparatus condition to a collapsed apparatus condition.

30. The endovascular apparatus of claim 22, wherein the plurality of tubular segments and the plurality of received segments are collectively selectively collapsible in the longitudinal direction to selectively and reversibly telescope a total length of the endovascular apparatus from an extended apparatus condition to a retracted apparatus condition.

31. The endovascular apparatus of claim 24, wherein the plurality of tubular segments and the plurality of received segments are each selectively collapsible in the circumferential direction to selectively and reversibly reduce a total circumference of the expandable attachment device from an expanded apparatus condition to a collapsed apparatus condition.

32. The endovascular apparatus of claim 24, wherein the plurality of tubular segments and the plurality of received segments are collectively selectively collapsible in the longitudinal direction to selectively and reversibly telescope a total length of the endovascular apparatus from an extended apparatus condition to a retracted apparatus condition.

33. The endovascular apparatus of claim 26, wherein the plurality of tubular segments and the plurality of received segments are each selectively collapsible in the circumferential direction to selectively and reversibly reduce a total circumference of the expandable attachment device from an expanded apparatus condition to a collapsed apparatus condition.

34. The endovascular apparatus of claim 26, wherein the plurality of tubular segments and the plurality of received segments are collectively selectively collapsible in the longitudinal direction to selectively and reversibly telescope a total length of the endovascular apparatus from an extended apparatus condition to a retracted apparatus condition.

35. An endovascular apparatus comprising:

a tubular sleeve having a central lumen with a cranial end portion longitudinally separated from a caudal end portion, the cranial end portion including a cranial end opening and the caudal end portion including at least one caudal end opening; and

an expandable attachment device extending circumferentially around the cranial end portion of the tubular sleeve, the expandable attachment device including:

a plurality of fixation components positioned about the perimeter of the expandable attachment device,

a plurality of circumferentially extending arms, each arm being used to attach each fixation component to a circumferentially adjacent fixation component, and

at least one M spring including four angularly attached M segments, the M segments being arranged in a zig-zag configuration to form one inboard apex and two outboard apices, the M spring having two circumferentially spaced M free ends, each M spring being interposed between two selected adjacent fixation components with the M free ends each being attached to a different one of the two selected adjacent fixation components;

wherein the M springs are graft expanders operative to hold the tubular sleeve open.

**36**. The endovascular apparatus of claim **35**, wherein the caudal end portion of the tubular sleeve includes a first caudal branch laterally separated from a second caudal branch, the first and second caudal branches each including a branch opening oriented in a caudal direction.

**37**. The endovascular apparatus of claim **36**, wherein the expandable attachment device is a first expandable attachment device, and wherein at least one of the first and second caudal branches includes a branch expandable attachment device extending circumferentially therearound and attached thereto.

**38**. The endovascular apparatus of claim **37**, wherein each branch expandable attachment device includes:

a plurality of fixation components positioned about the perimeter of the expandable attachment device;

a plurality of circumferentially extending arms, each arm being used to attach each fixation component to a circumferentially adjacent fixation component; and

at least one M spring including four angularly attached M segments, the M segments being arranged in a zig-zag configuration to form one inboard apex and two outboard apices, the M spring having two circumferentially spaced M free ends, each M spring being interposed between two selected adjacent fixation components with the M free ends each being attached to a different one of the two selected adjacent fixation components;

wherein the M springs are graft expanders operative to hold the tubular sleeve open.

**39**. The endovascular apparatus of claim **35**, wherein the expandable attachment device is a first expandable attachment device, and wherein the caudal end opening includes a caudal end expandable attachment device extending circumferentially around the caudal end portion of the tubular sleeve.

**40**. The endovascular apparatus of claim **39**, wherein the caudal end expandable attachment device includes:

a plurality of fixation components positioned about the perimeter of the expandable attachment device;

a plurality of circumferentially extending arms, each arm being used to attach each fixation component to a circumferentially adjacent fixation component; and

at least one M spring including four angularly attached M segments, the M segments being arranged in a zig-zag configuration to form one inboard apex and two outboard apices, the M spring having two circumferentially spaced M free ends, each M spring being interposed between two selected adjacent fixation components with the M free ends each being attached to a different one of the two selected adjacent fixation components;

wherein the M springs are graft expanders operative to hold the tubular sleeve open.

**41**. The endovascular apparatus of claim **35**, wherein at least the arms and the M springs of the expandable attachment device are selectively collapsible in the circumferential direction to selectively and reversibly reduce a total circumference of the expandable attachment device from an expanded apparatus condition to a collapsed apparatus condition.

**42**. The endovascular apparatus of claim **38**, wherein at least the arms and the M springs of the expandable attachment device are selectively collapsible in the circumferential direction to selectively and reversibly reduce a total circumference of the expandable attachment device from an expanded apparatus condition to a collapsed apparatus condition.

**43**. The endovascular apparatus of claim **40**, wherein at least the arms and the M springs of the expandable attachment device are selectively collapsible in the circumferential direction to selectively and reversibly reduce a total circumference of the expandable attachment device from an expanded apparatus condition to a collapsed apparatus condition.

**44**. The endovascular apparatus of claim **35**, wherein at least one M spring is located directly adjacent to an exterior surface of the tubular sleeve.

**45**. The endovascular apparatus of claim **38**, wherein at least one M spring is located directly adjacent to an exterior surface of the tubular sleeve.

**46**. The endovascular apparatus of claim **40**, wherein at least one M spring is located directly adjacent to an exterior surface of the tubular sleeve.

**47**. The endovascular apparatus of claim **35**, wherein at least one M spring is located directly adjacent to an interior surface of the tubular sleeve.

**48**. The endovascular apparatus of claim **38**, wherein at least one M spring is located directly adjacent to an interior surface of the tubular sleeve.

**49**. The endovascular apparatus of claim **40**, wherein at least one M spring is located directly adjacent to an interior surface of the tubular sleeve.

**50**. The endovascular apparatus of claim **35**, wherein at least one circumferentially extending arm is a telescoping arm having a plurality of segments in slideable contact with one another.

**51**. The endovascular apparatus of claim **38**, wherein at least one circumferentially extending arm is a telescoping arm having a plurality of segments in slideable contact with one another.

**52**. The endovascular apparatus of claim **40**, wherein at least one circumferentially extending arm is a telescoping arm having a plurality of segments in slideable contact with one another.

**53**. The endovascular apparatus of claim **50**, wherein each of the M free ends of a selected M spring is attached to a different segment of a selected arm.

**54**. The endovascular apparatus of claim **51**, wherein each of the M free ends of a selected M spring is attached to a different segment of a selected arm.

**55**. The endovascular apparatus of claim **52**, wherein each of the M free ends of a selected M spring is attached to a different segment of a selected arm.

**56**. The endovascular apparatus of claim **35**, wherein a plurality of M segments of a single M spring are telescoping arms.

**57**. The endovascular apparatus of claim **38**, wherein a plurality of M segments of a single M spring are telescoping arms.

**58**. The endovascular apparatus of claim **40**, wherein a plurality of M segments of a single M spring are telescoping arms

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