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(54) **SURGICAL TUNNELER**

(71) Applicants: **Pieter W.C.J. le Blanc**, Rancho Cordova, CA (US); **John Nguyen**, San Ramon, CA (US); **Keith Kearsley**, Burlington, MA (US); **Julien Duhamel**, Billerica, MA (US)

(72) Inventors: **Pieter W.C.J. le Blanc**, Rancho Cordova, CA (US); **John Nguyen**, San Ramon, CA (US); **Keith Kearsley**, Burlington, MA (US); **Julien Duhamel**, Billerica, MA (US)

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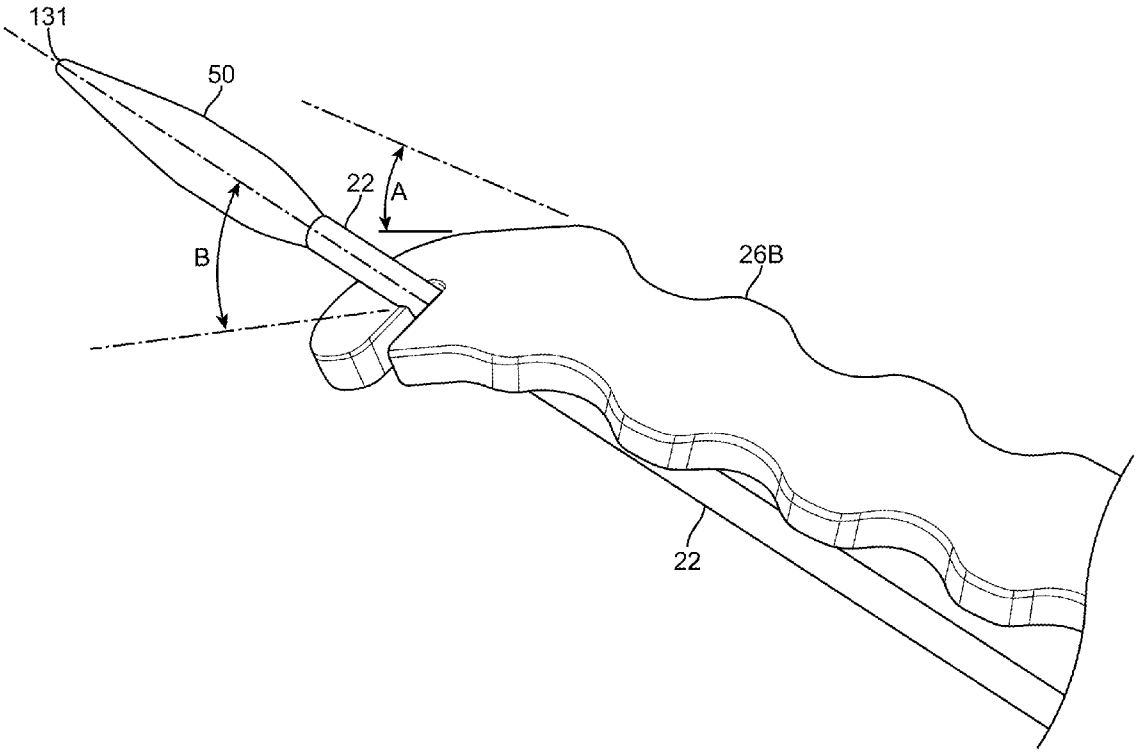
(57) **ABSTRACT**

A surgical tunneler assembly is used to pass a cable or other elongate member through the skin. A surgical tunneler may include a lance including a first segment, a second end segment, and a connector on each one of the first end segment and the second end segment. A cable adapter includes a lance connection portion and a cable connection portion. The lance connection portion engages and disengages the connectors. The cable connection portion engages and disengages a cable. A handle engages and disengages the lance.



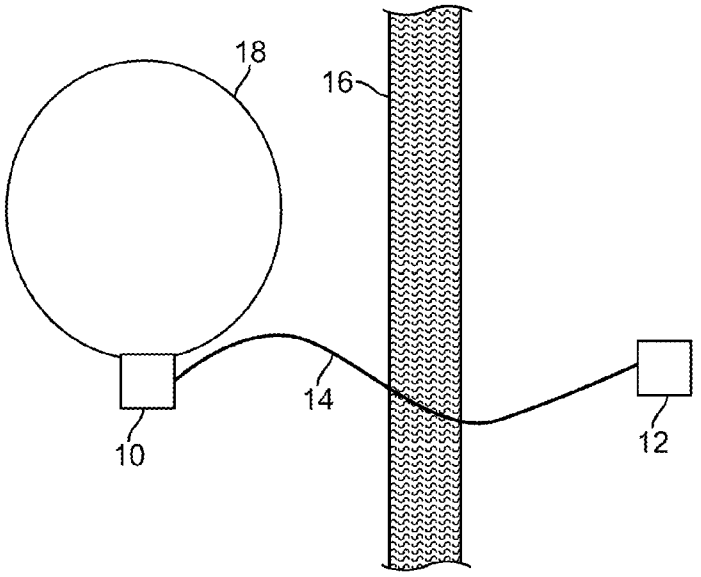


FIG. 1

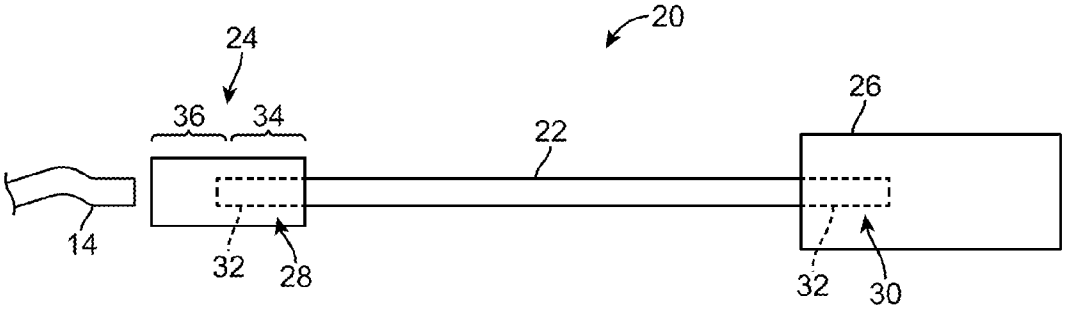


FIG. 2

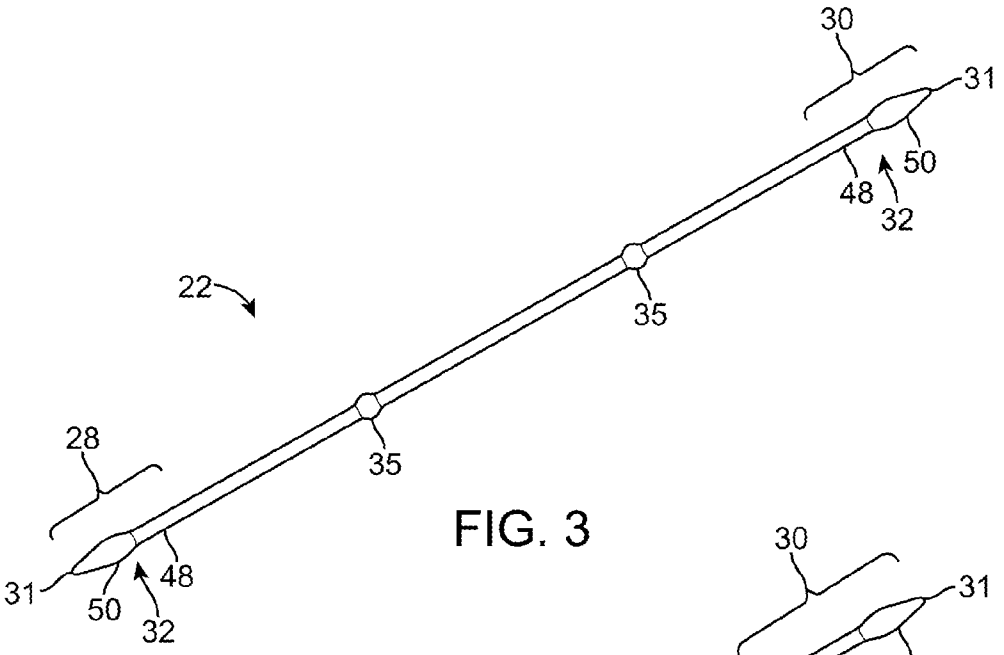


FIG. 3

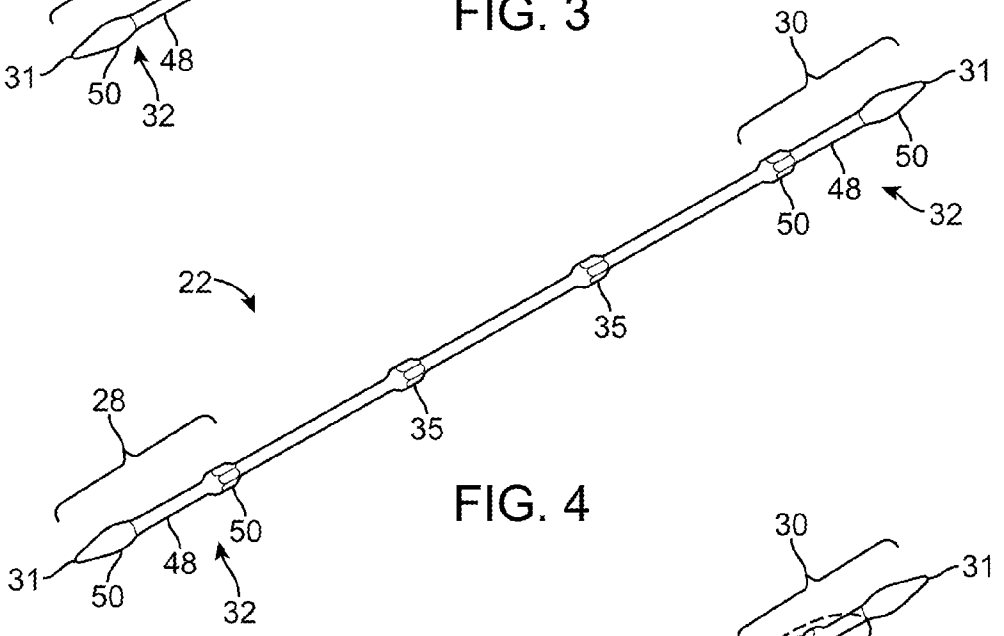


FIG. 4

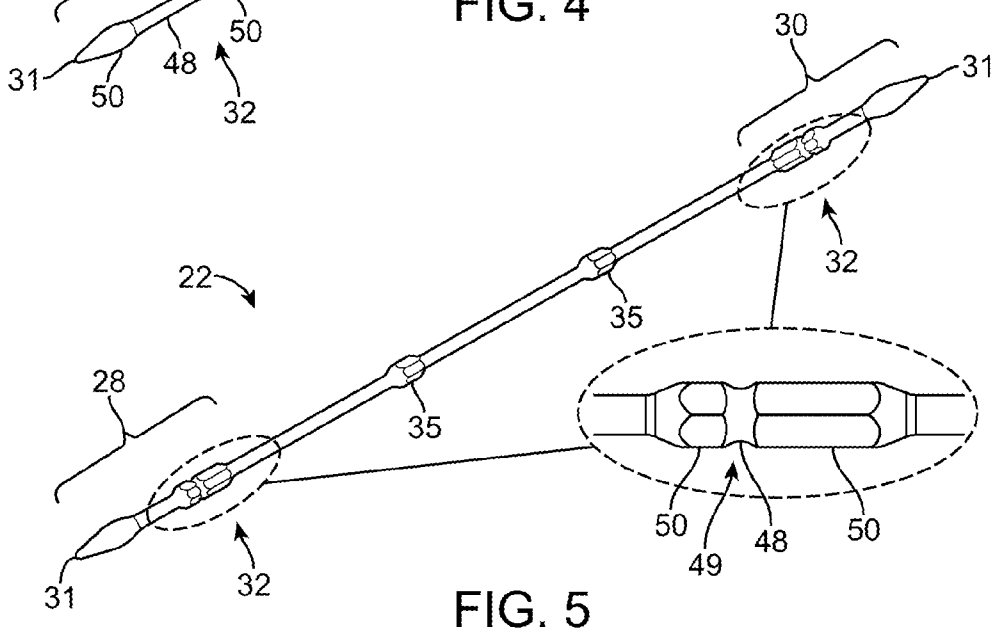


FIG. 5

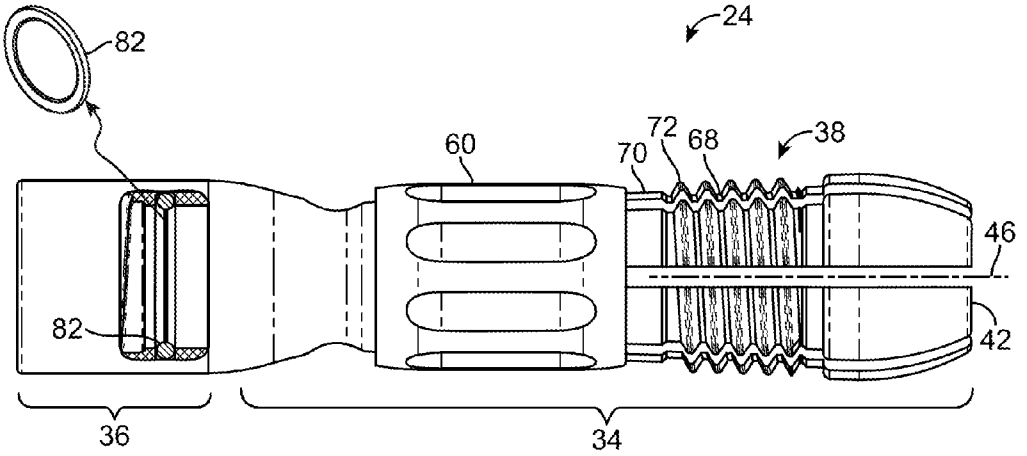

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FIG. 6A

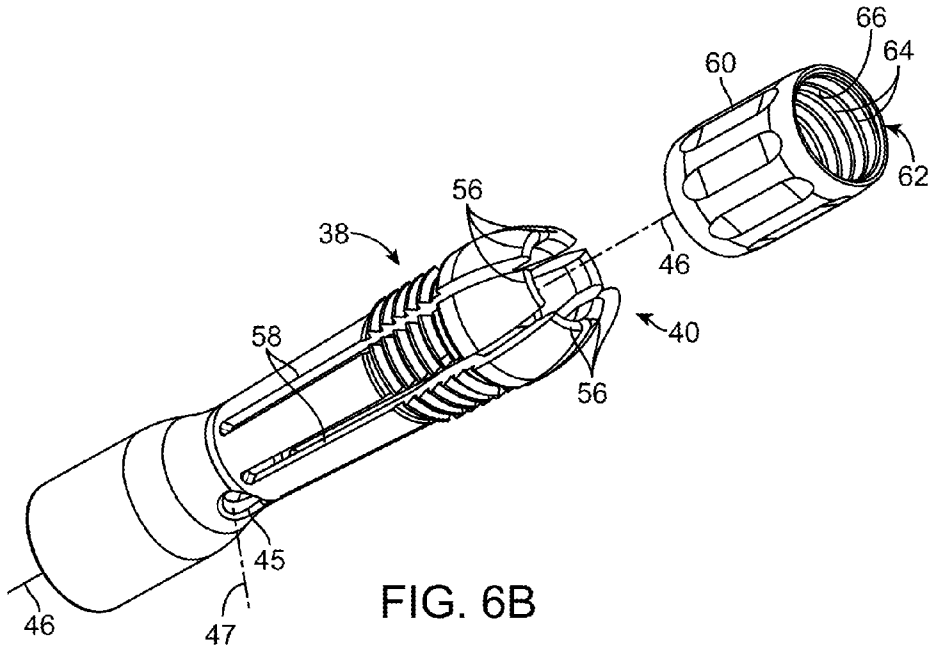
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FIG. 6B

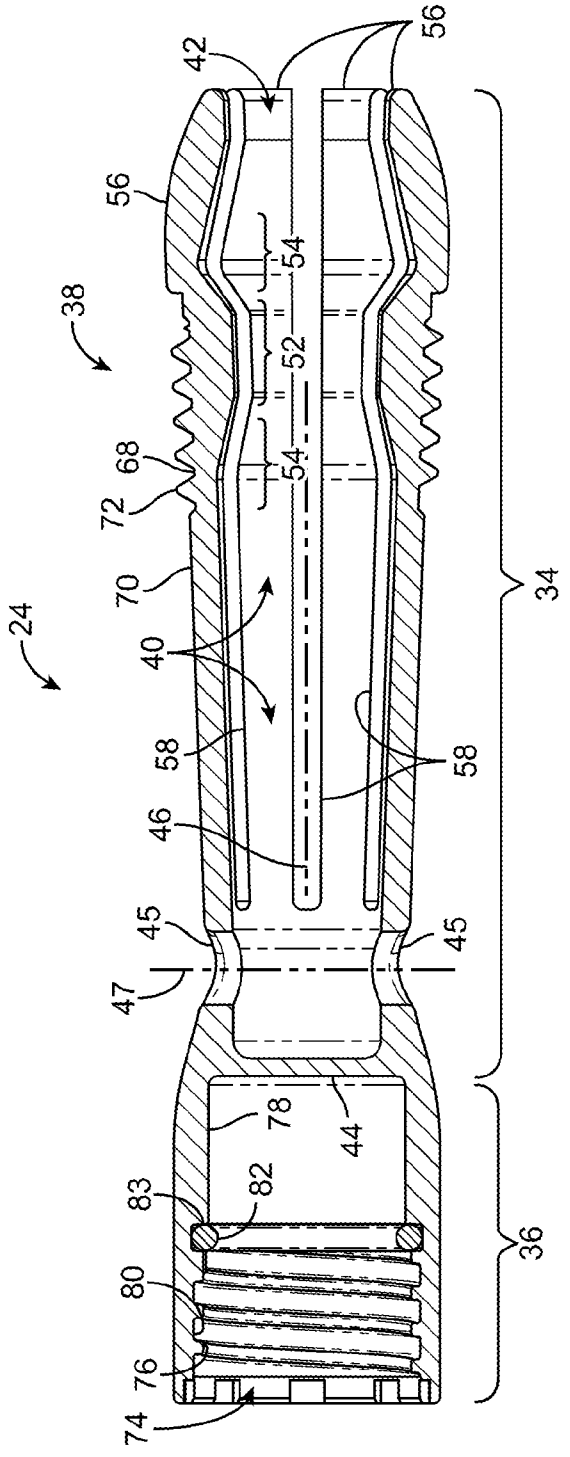
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FIG. 6C

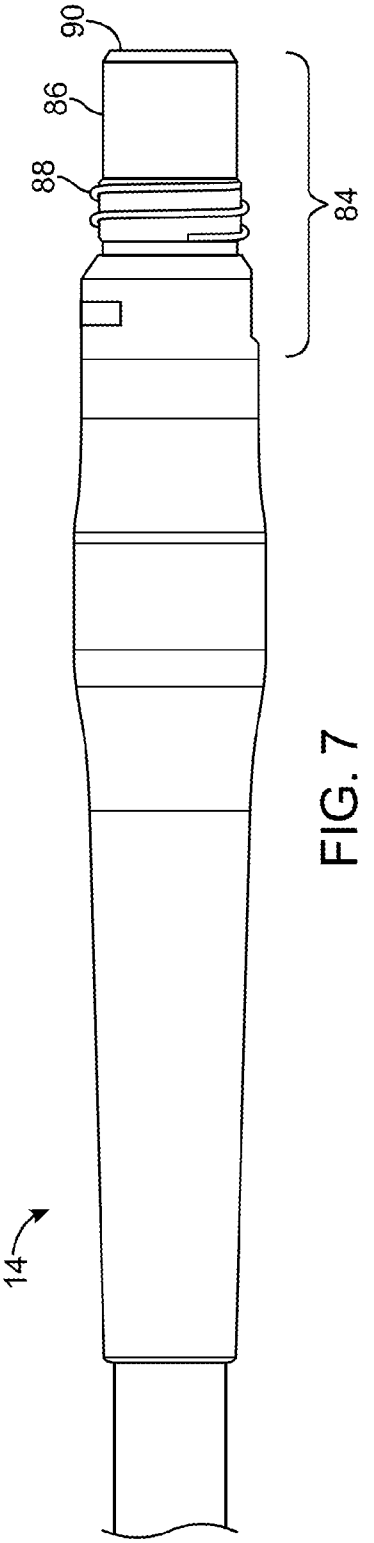
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FIG. 7

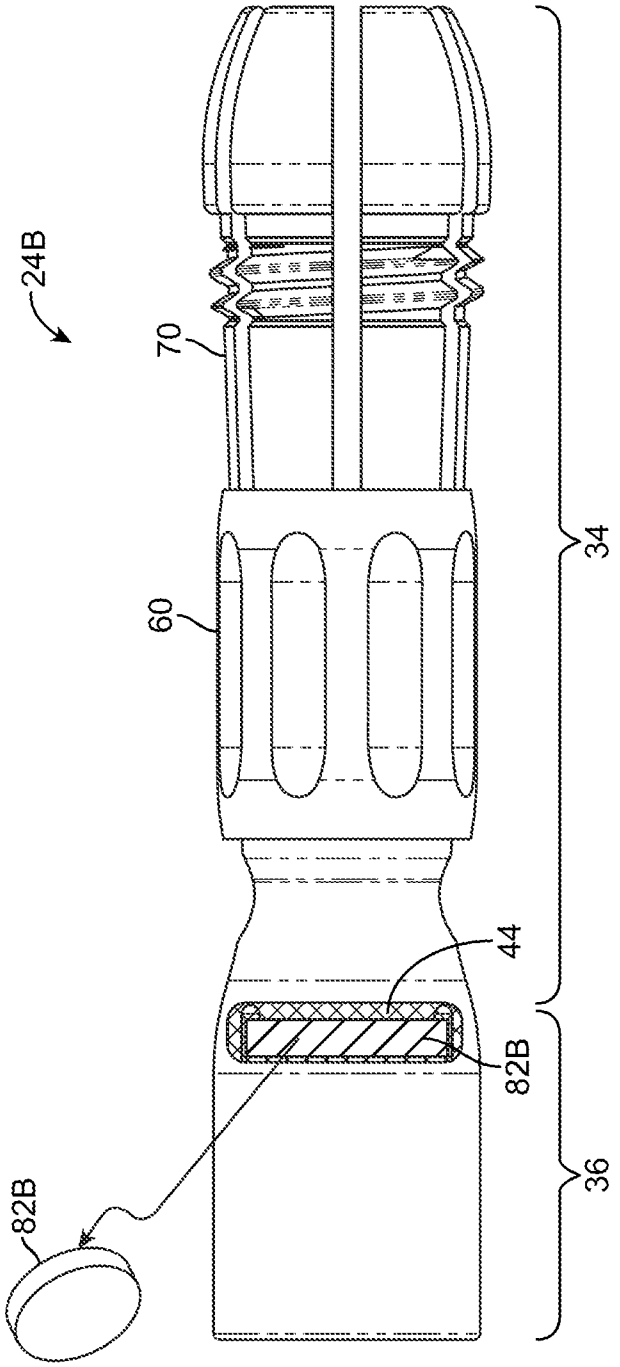

FIG. 8A

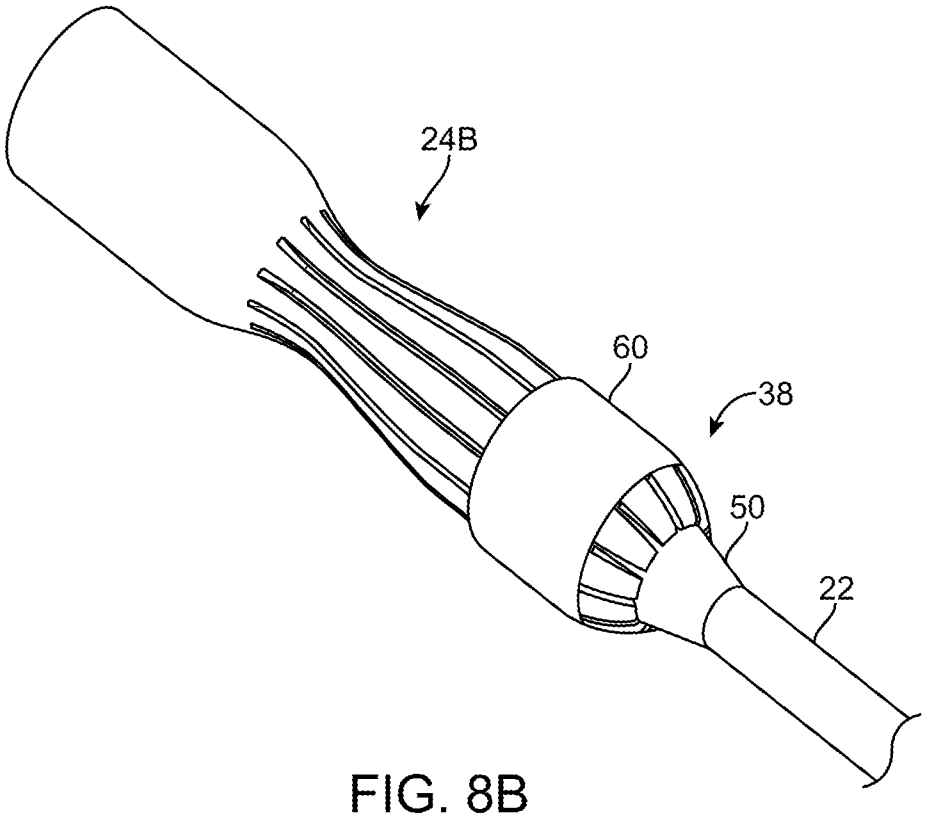

FIG. 8B

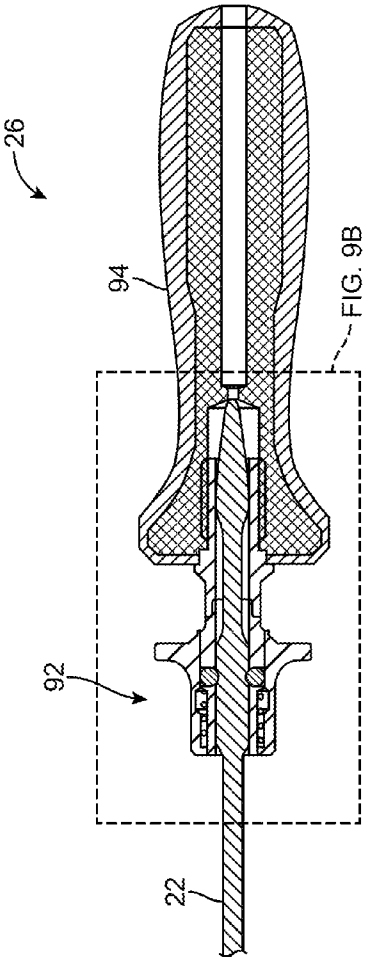
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FIG. 9B
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FIG. 9A

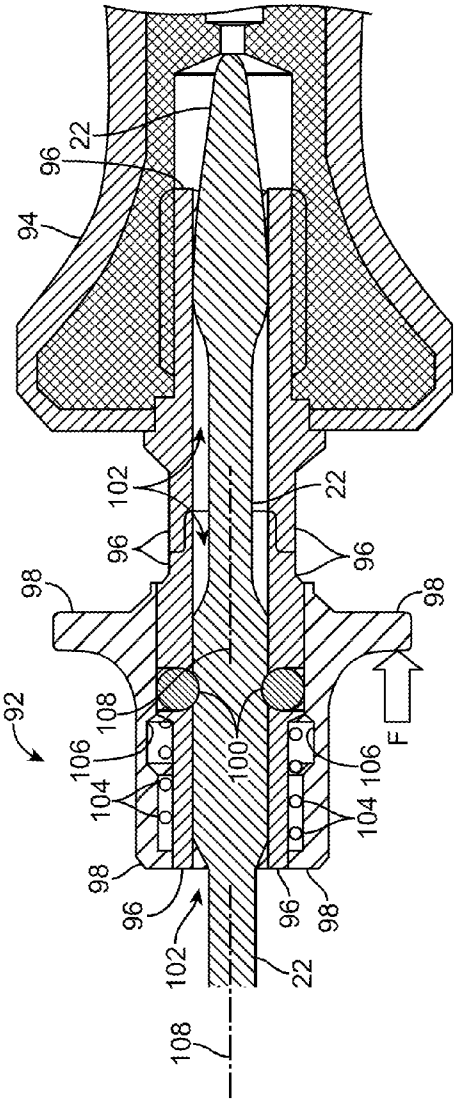
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FIG. 9B

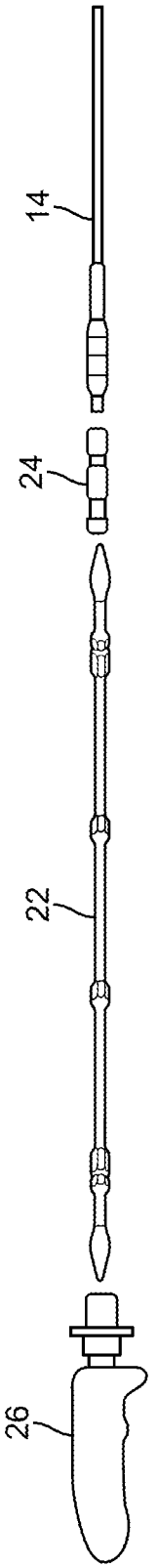


FIG. 10

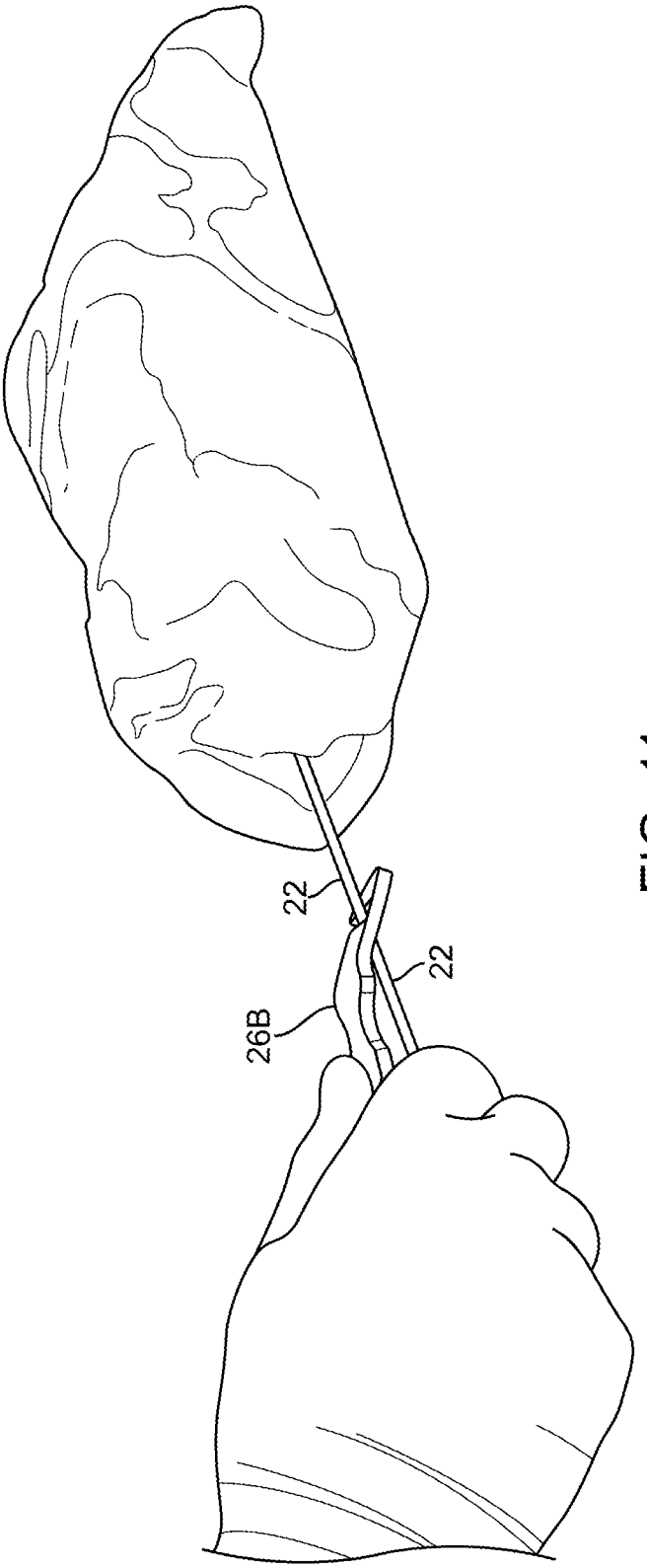
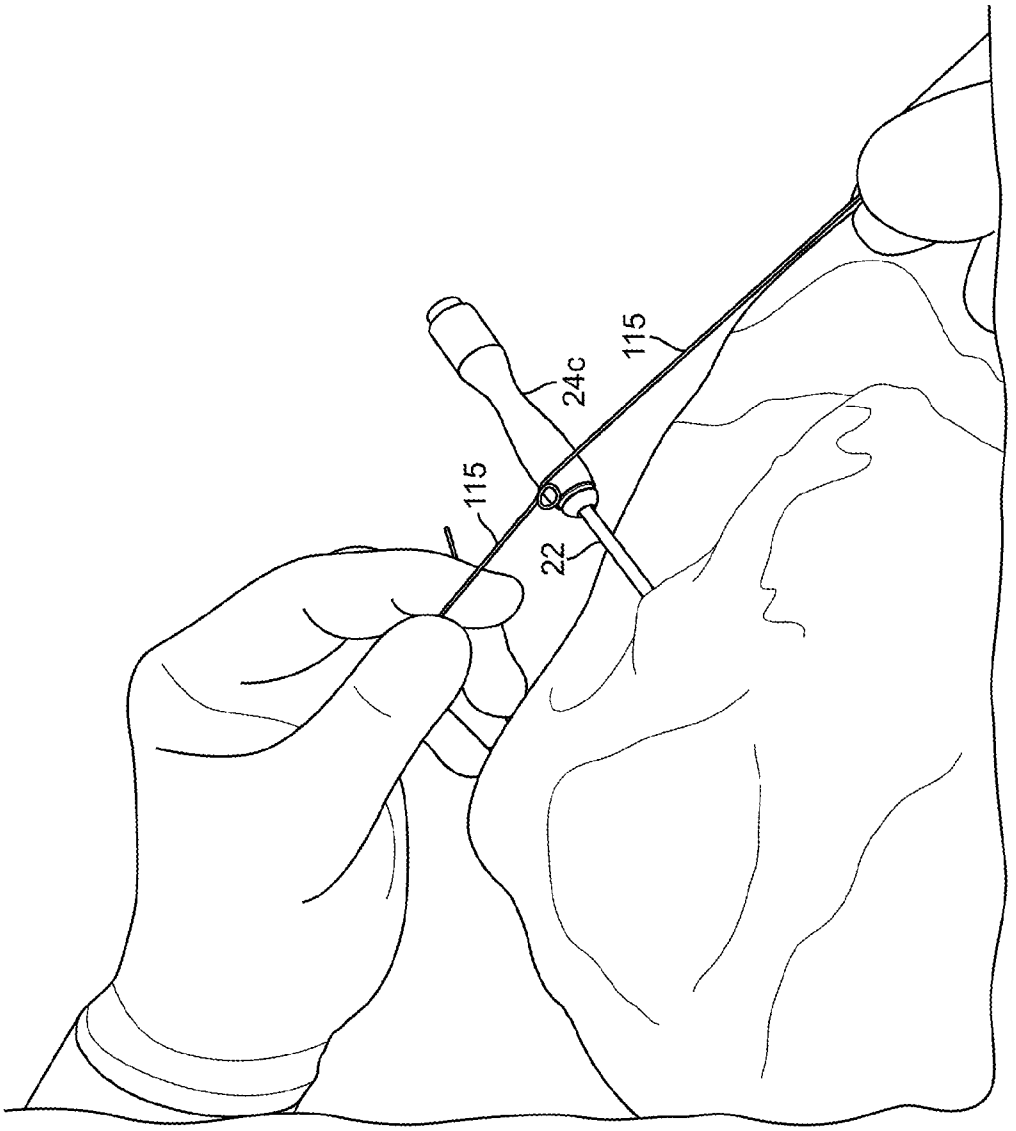


FIG. 11

FIG. 12



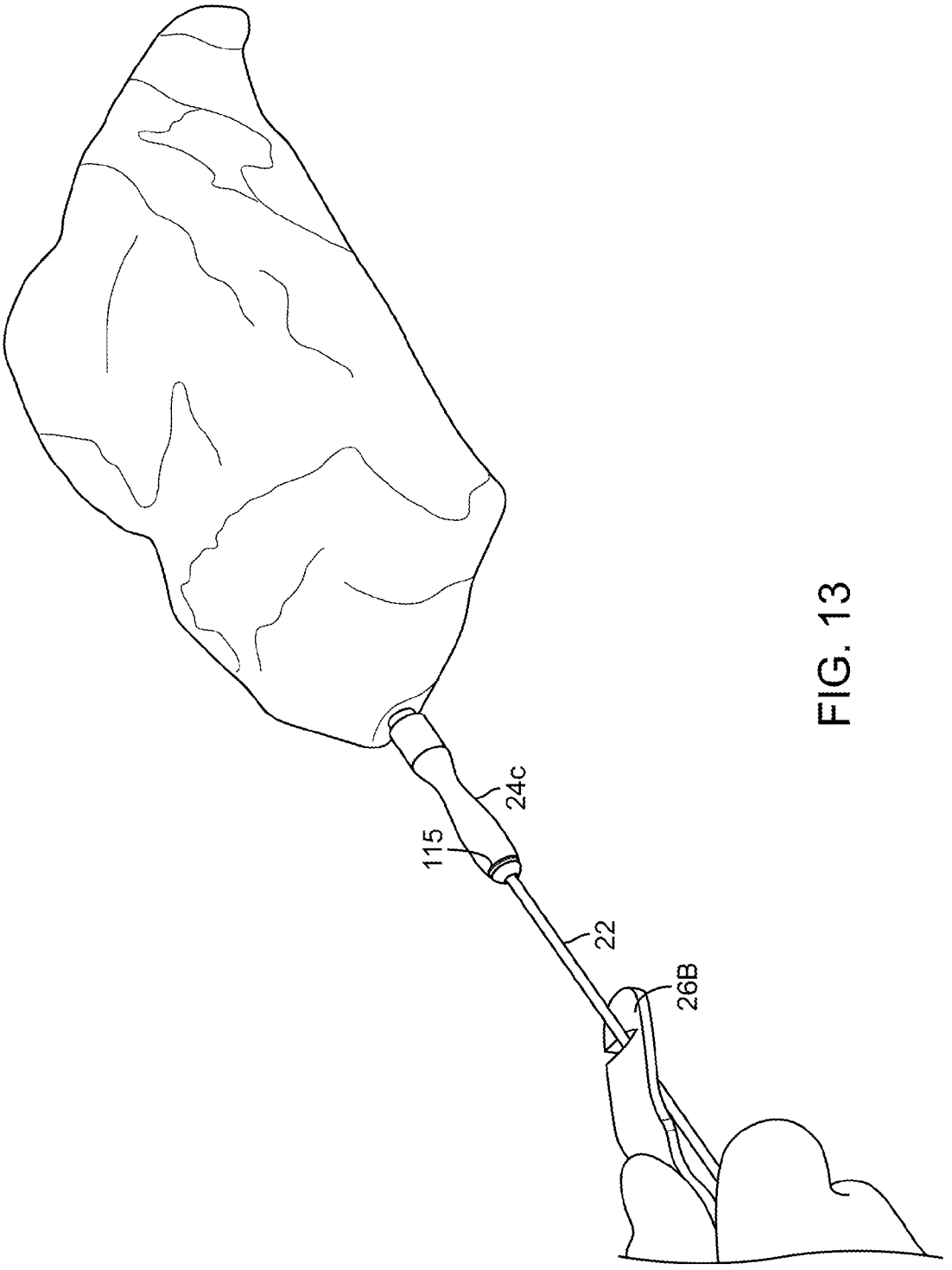


FIG. 13

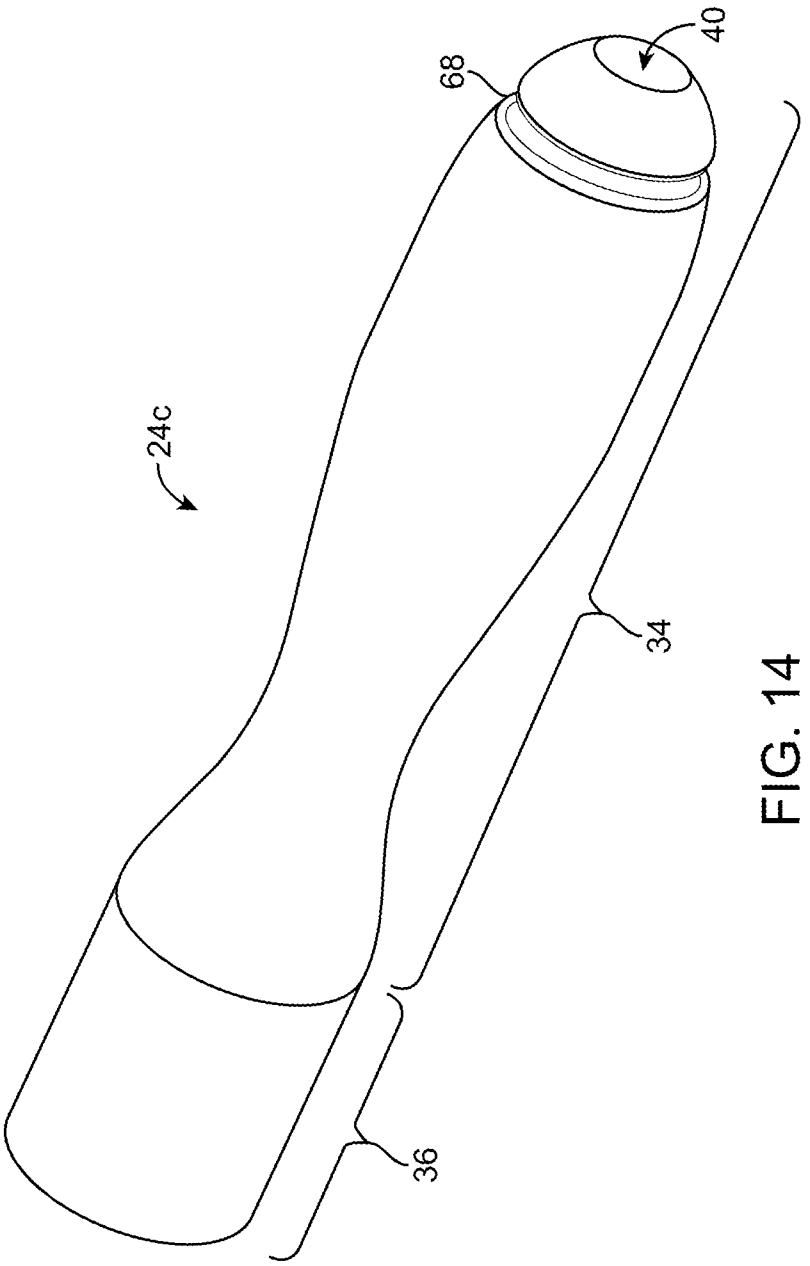


FIG. 14

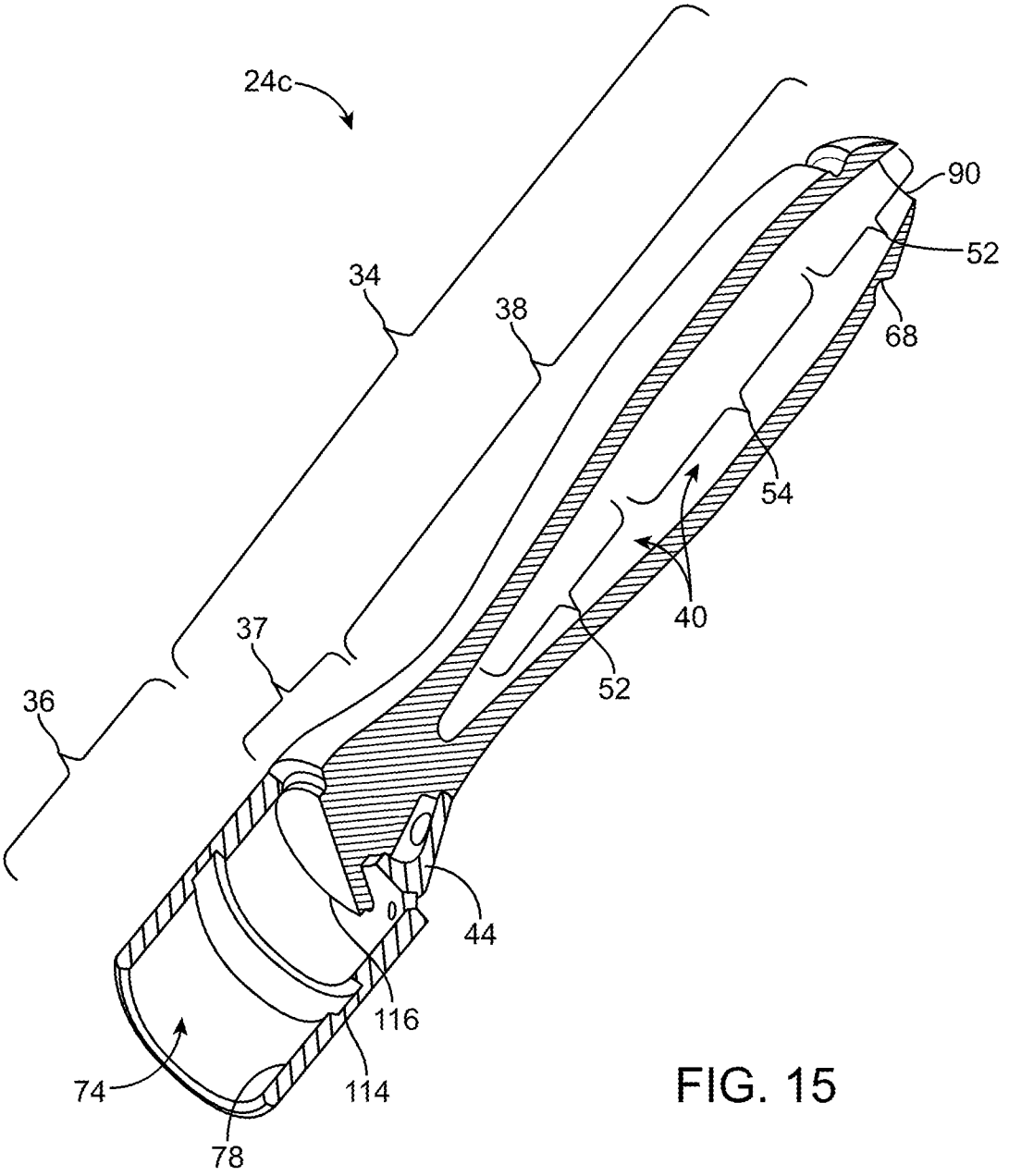


FIG. 15

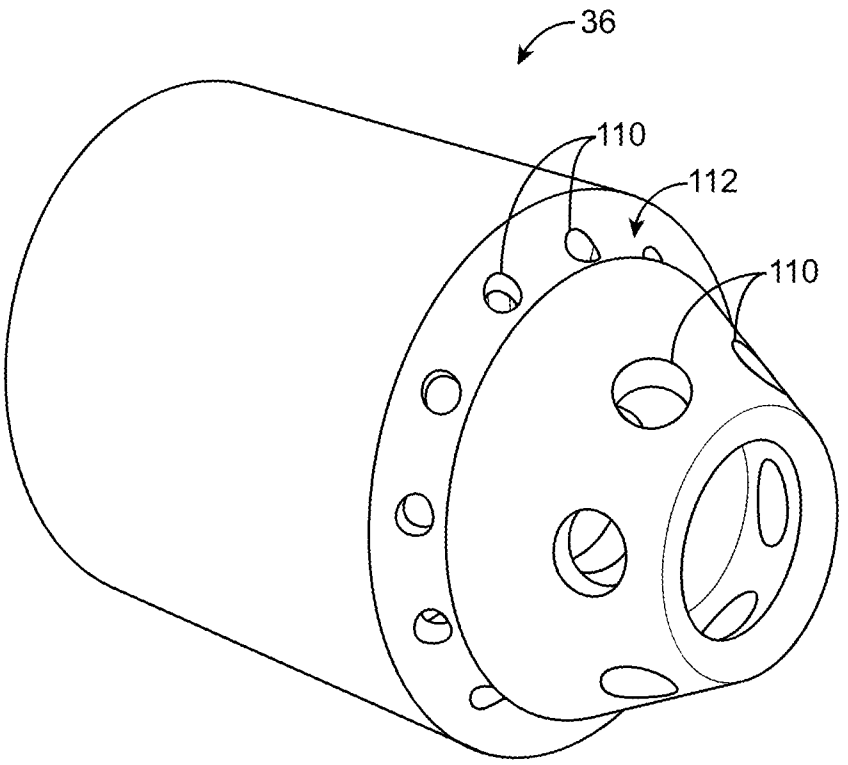


FIG. 16

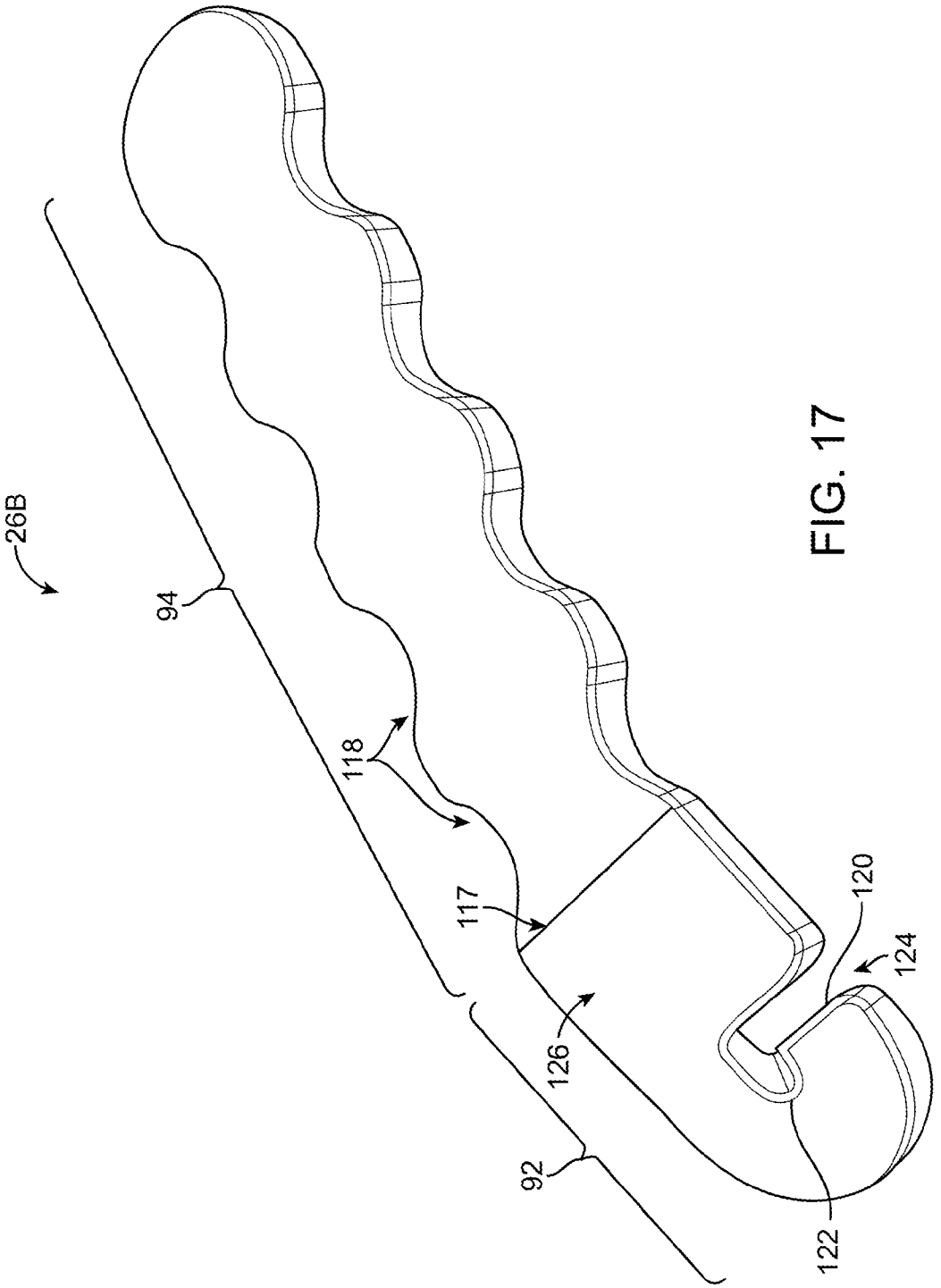


FIG. 17

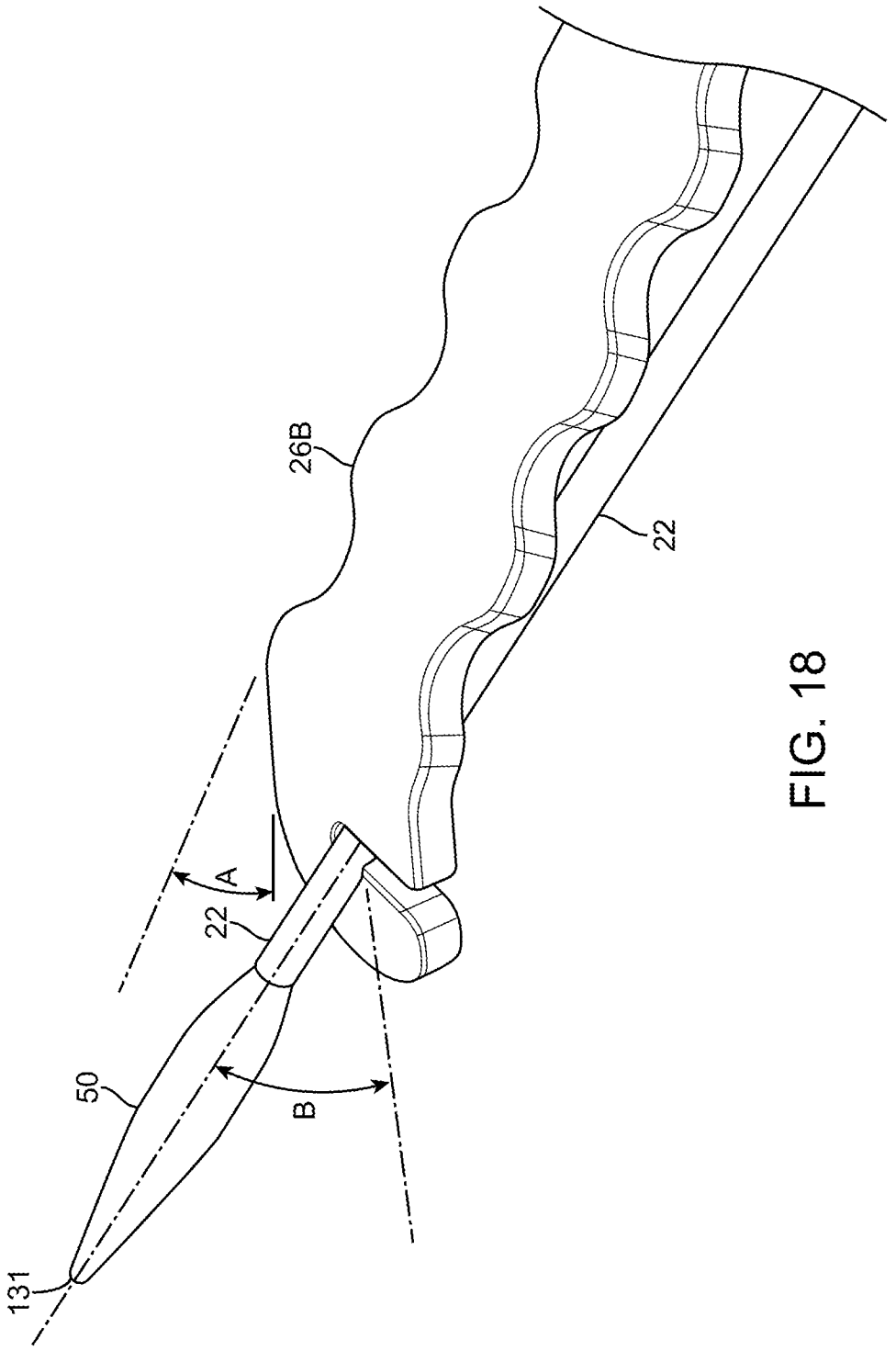


FIG. 18

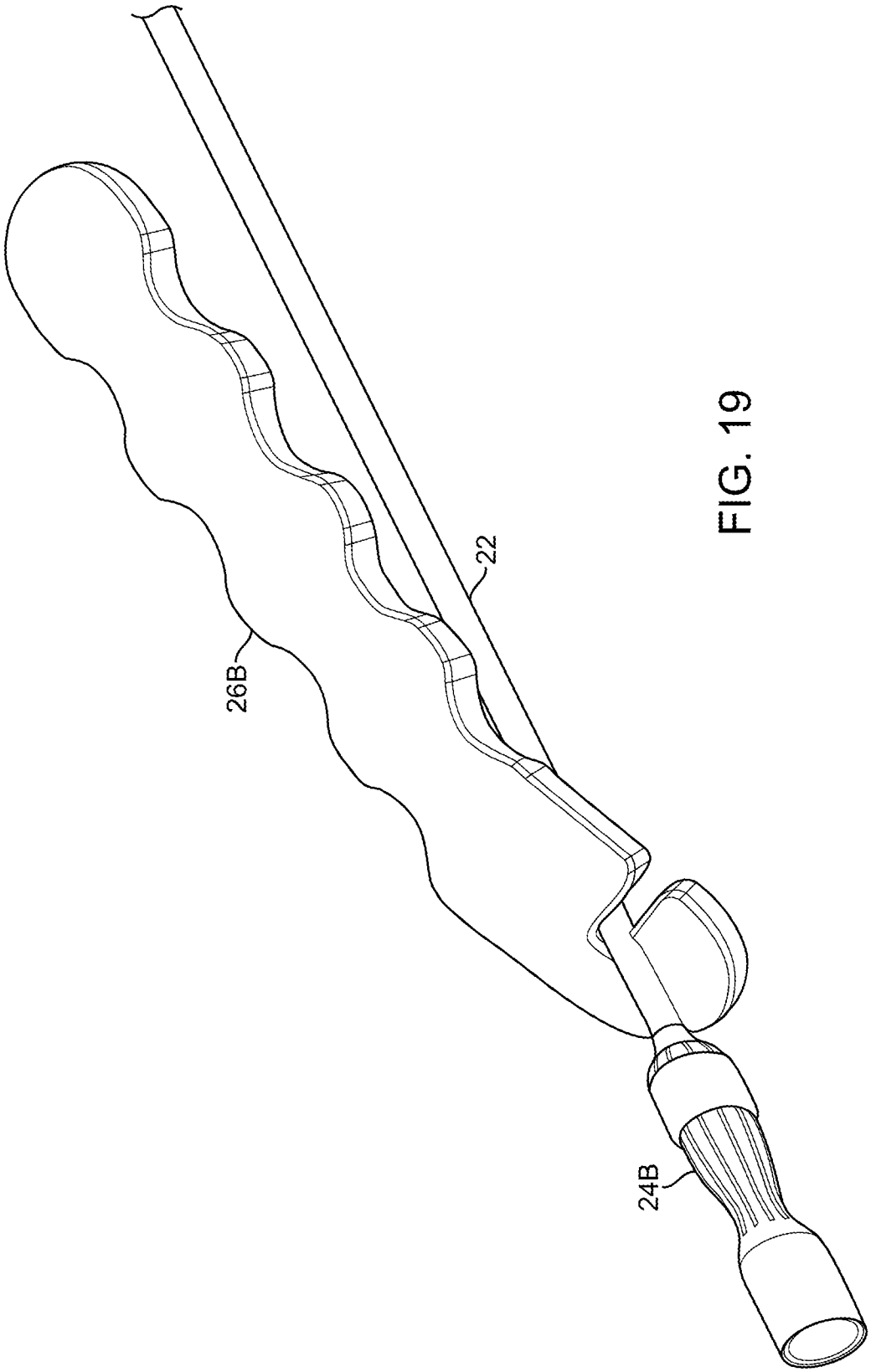


FIG. 19

SURGICAL TUNNELER

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application No. 61/746,441, filed Dec. 27, 2012, which is incorporated herein by reference in its entirety and for all purposes.

FIELD OF THE INVENTION

[0002] This invention relates generally to a surgical tool, more particularly, a surgical tool for placing a cable through the skin.

BACKGROUND OF THE INVENTION

[0003] Implantation of various medical devices requires forming a tunnel through the skin or body for placement of a catheter, cable, or other elongate member. For example, a cable must be passed through the skin to connect to many types of implantable devices. The cable may connect the implanted device to an external controller that provides electrical power, data, and/or control signals. Various systems may require tunneling a cable between two or more implanted structures. For example, it may be necessary to connect an implanted electronics housing in one anatomical location to an operative device in another location. In another example, certain medical procedures require placement of a catheter in a patient's body for an extended period of time.

[0004] A surgical tool used to pass the electrical cable through the skin is often referred to as a tunneler. Different types of tunnelers are available and suitable to particular methods of tunneling. Certain surgical procedures require a tunneler that can push through tissue in two directions. Such tunnelers are sometimes referred to as bi-directional tunnelers. Tunneler assemblies often are provided as part of a tool set including adaptors, plugs, and caps.

[0005] Existing surgical tools often suffer from several drawbacks. In the example of implantation of a left ventricular assist device (LVAD), a surgical team may be called on to tunnel a percutaneous cable between the LVAD and an external controller. Existing tools may require a lance to create a passageway through the skin and another tool to pull the cable through the passageway. Some tools may be designed to form the passageway and pull the cable, but these tools typically still require a cumbersome exchange of adaptors. Additionally, the elongate shape of the lance can make it difficult for a clinician to firmly grasp the tunneler and get sufficient leverage to push through tissue. Some tunnelers are designed with a handle removable from an elongate lance that performs the tunneling. The handle allows the clinician to manipulate the lance in the tissue. If the clinician needs to push the lance completely through the tissue, however, there must be a way to remove the handle. Existing designs lack an easy way to attach the handle to the lance in a robust manner and an easy way to remove the handle. For example, many tools require a user to screw a handle onto the lance, which adds significant time to the procedure. Moreover, when the handle is removed, the clinician lacks any finger holds for the last bit of pushing.

[0006] There is a continuing need for an improved tunneler, for example, one that is easy to use and allows for flexibility of use in a variety of tunneling methods. There is a continuing need for a tunneler that decreases the time for surgical procedures. There is a need for a tunneler with improved versatility, control, and ease of use to efficiently create a path through soft tissue. There is a continuing need for a lower cost tunneler useful in a variety of applications. There is a continuing need for a tunneler assembly that overcomes these and other problems.

SUMMARY OF THE INVENTION

[0007] Briefly and in general terms, the present invention is directed to a surgical tunneler assembly and surgical implantation kit.

[0008] Various aspects of the invention are directed to a tunneler assembly including an elongate lance, each end of the lance configured to pierce tissue, and a handle configured to receive one end of the lance, the handle including a lance coupling for securing the end of the lance therein. The ends of the lance may include a needle or point for piercing tissue. In various aspects, the lance coupling is a quick connector. The lance coupling may include a collet adaptor. The lance coupling may include an actuator and locking device. The locking device may comprise a spring-loaded ring lock. The lock may be actuated by a switch or other element controlled by the user, or the lock may be engaged automatically by inserting the lance into the handle. The handle may include a gripping feature.

[0009] Various aspects of the invention are directed to an elongate lance having two ends, each end configured to pierce tissue, and an intermediate gripping feature.

[0010] Various aspects of the invention are directed to an adaptor for a tunneling system, the adaptor configured to connect a tissue piercing end of an elongate lance to a cable or a catheter. The adaptor may include a passageway sized and dimensioned to fit over the piercing end of the lance. The adaptor may be substantially tubular. One end of the adaptor may be sized and dimensioned to correspond to the piercing end. One end of the adaptor may be configured to radially expand and compress to secure to the piercing end. The adaptor may include engagement members configured to grasp the piercing end and form a secure connection thereto. The adaptor may include one or more through holes in a connecting portion of the adaptor. One end of the adaptor may include a connector for connecting the adaptor to a cable, catheter, or the like. The connector may be a screw thread.

[0011] In aspects of the invention, a surgical tunneler assembly comprises a lance including a first segment, a second end segment, and a connector on each one of the first end segment and the second end segment, further comprises a cable adapter including a lance connection portion and a cable connection portion, the lance connection portion configured to engage and disengage the connectors, the cable connection portion configured to engage and disengage an electrical cable, and further comprises a handle configured to engage and disengage the lance.

[0012] In other assembly aspects in combination with any one of the above assembly aspects, the lance connection portion includes a flexible device configured to deform and to engage and disengage the connectors.

[0013] In other assembly aspects in combination with any one of the above assembly aspects, either the lance connection portion the flexible device includes a lance passageway configured to radially expand to allow disengagement of the cable adapter from the connectors and to radially contract to allow engagement of the cable adapter to the connectors.

[0014] In other assembly aspects in combination with any one of the above assembly aspects, each of the connectors

includes a narrow segment and a wide segment, and the lance passageway includes a constricted segment or an enlarged segment configured to engage the narrow segment or the wide segment respectively.

[0015] In other assembly aspects in combination with any one of the above assembly aspects, either the lance connection portion or the flexible device includes a plurality of engagement members configured to flex apart from each other and toward each other.

[0016] In other assembly aspects in combination with any one of the above assembly aspects, the cable adapter includes a ring configured to clamp around either one of the lance connection portion, the flexible device, the lance passageway, or the engagement members.

[0017] In other assembly aspects in combination with any one of the above assembly aspects, the ring includes an internal wall and a protrusion on or a depression into the internal wall configured to engage a depression into or protrusion on an outer surface of either one of the lance connection portion, the flexible device, the lance passageway, or the engagement members.

[0018] In other assembly aspects in combination with any one of the above assembly aspects, the cable connection portion includes a protrusion or a depression configured to engage the electrical cable.

[0019] In other assembly aspects in combination with any one of the above assembly aspects, the protrusion or the depression of the cable connection portion forms a helical thread.

[0020] In other assembly aspects in combination with any one of the above assembly aspects, the helical thread is disposed within the cable connection portion.

[0021] In other assembly aspects in combination with any one of the above assembly aspects, the cable connection portion includes a resilient device configured to form a liquid tight seal on the electrical cable when the cable connection portion is engaged to the electrical cable.

[0022] In other assembly aspects in combination with any one of the above assembly aspects, the resilient device is disposed within the cable connection portion.

[0023] In other assembly aspects in combination with any one of the above assembly aspects, the resilient device includes any one or a combination of an o-ring seal and a flat seal.

[0024] In other assembly aspects in combination with any one of the above assembly aspects, the handle is configured to engage and disengage the connectors.

[0025] In other assembly aspects in combination with any one of the above assembly aspects, the handle includes a tube having a passageway configured to receive the connectors, an actuator configured to move relative to the tube with application of an external force on the actuator, a lock member trapped within the tube, wherein the lock member is pushed into the passageway when the actuator is moved to a first position relative to the tube, and the lock member is capable of moving away from the passageway when the actuator is moved to a second position relative to the tube.

[0026] In other assembly aspects in combination with any one of the above assembly aspects, each of the connectors includes a depression configured to receive the lock member.

[0027] In aspects of the invention, a surgical implantation kit comprises an electrical device, an electrical cable including a first end connected to or configured for connection to the electrical device, and the surgical tunneler assembly of any one of the preceding assembly aspects.

[0028] In other kit aspects in combination with any one of the above kit aspects, the electrical device is a ventricular assist device or a controller for a ventricular assist device.

[0029] In other kit aspects in combination with any one of the above kit aspects, the kit further comprises a second electrical device connected to or configured for connection to a second end of the electrical cable.

[0030] In other kit aspects in combination with any one of the above kit aspects, the second electrical device is either a controller when the first electrical device is a ventricular assist device or a ventricular assist device when the first electrical device is a controller.

[0031] Various aspects of the invention are directed to a method of assembling an adaptor to a lance to form a tunneler assembly as described above. Various aspects of the invention are directed to a method of using a tunneler assembly, handle, lance, and/or adaptor as described above. The method can include attaching the handle to the lance; manipulating the handle to form a passageway through tissue in a patient requiring treatment; removing the handle from an end of the lance; attaching an adaptor over the end, the adaptor configured to carry a cable; securing a cable to the adaptor before or after the attaching; and pulling the lance carrying the cable through at least part of the passageway. In various embodiments, the manipulating includes pushing the lance through the tissue in one direction and the pulling includes pulling the lance in substantially the reverse direction.

[0032] The features and advantages of the invention will be more readily understood from the following detailed description which should be read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] FIG. **1** is a block diagram showing exemplary electrical devices connected to each other by an electrical cable passing through the skin.

[0034] FIG. **2** is a block diagram showing an exemplary electrical cable and an exemplary tunneler assembly for passing the electrical cable through the skin.

[0035] FIGS. **3** to **5** are perspective views of exemplary lances forming a part of a tunneler assembly.

[0036] FIGS. **6**A to **6**C are plan, perspective, and cross-section views of an exemplary cable adapter forming a part of a tunneler assembly.

[0037] FIG. **7** is a plan view showing an end segment of an exemplary electrical cable.

[0038] FIG. **8**A is a plan view of an exemplary cable adapter forming a part of a tunneler assembly.

[0039] FIG. **8**B is a perspective view of the cable adaptor connected to a lance, illustrating the adaptor in a locked position.

[0040] FIGS. **9**A and **9**B are cross-section and detailed cross-section views showing an exemplary end segment of a lance locked within an exemplary connection device of a handle.

[0041] FIG. **10** is an assembly view of an exemplary tunneler assembly in accordance with aspects of the invention, illustrating a lance, a handle, and a cable adaptor carrying a percutaneous cable.

[0042] FIGS. **11-13** show an exemplary method of using the tunneler assembly of FIG. **10**.

[0043] FIGS. **14-16** show a perspective view of a cable adapter, a perspective partial cross-sectional of the cable adapter, and a perspective view of a cable connection portion of the cable adaptor in accordance with aspects of the invention.

[0044] FIGS. **17-19** are perspective views showing a handle (FIG. **17**) in accordance with aspects of the invention, the handle attached to the lance (FIG. **18**), and the handle attached to the lance with cable adapter (FIG. **19**).

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0045] Referring now in more detail to the exemplary drawings for purposes of illustrating embodiments of the invention, wherein like reference numerals designate corresponding or like elements among the several views, there is shown in FIG. **1** internal electrical device **10** implanted within a human or animal body, and external electrical device **12** disposed outside the body. Internal electrical device **10** and external electrical device **12** are connected to each other by electrical cable **14** which passes through skin **16**. Electrical cable **14** transmits electrical power and control signals from external electrical device **12** to internal electrical device **10**. Internal electrical device **10** is attached to anatomical organ **18**.

[0046] In some embodiments, internal electrical device **10** is a ventricular assist device attached to heart **18**, and external electrical device **12** is an electronic controller configured to supply power, control, and monitor the ventricular assist device. The ventricular assist device includes a blood pump and is configured for attachment to the left ventricle of the heart. Suitable examples of a ventricular assist device include without limitation the pump devices described in connection with reference numeral 15 in U.S. Pat. No. 7,798,952 and reference numeral 1 in U.S. Pat. No. 7,850,594, both of which patents are incorporated herein for all purposes by reference. Other examples of ventricular assist devices include, but are not limited to, the devices described in U.S. Publication No. 2012/0046514 and U.S. Pat. No. 5,588,812, the entire contents of which are incorporated herein for all purposes by reference. Suitable examples of a controller include without limitation the devices described in connection with reference numeral 17 in U.S. Pat. No. 6,991,595 and reference numeral 10 in U.S. Pat. No. 7,850,594, both of which patents are incorporated herein for all purposes by reference.

[0047] In alternative embodiments, internal electrical device **10** is a cardiac pacemaker attached to heart **18**.

[0048] In alternative embodiments, internal electrical device **10** is a sensor disposed within the body, and external electrical device **12** is a device configured to store, measure, and/or analyze a parameter detected by the sensor.

[0049] Suitable examples of electrical cable **14** include without limitation the percutaneous cable described in connection with reference numeral 14 in U.S. Publication No. 2012/0046515, which is incorporated herein for all purposes by reference.

[0050] Turning now to FIG. **2**, a tunneler assembly in accordance with various aspects of the invention is shown. Aspects of the tunneler assembly may be similar to those described in U.S. Publication Nos. 2012/0083794 and 2012/0059321 and International Publication Nos. WO2003/008020 and WO2006/050191, the entire contents of which are incorporated herein for all purposes by reference.

[0051] In some embodiments, an implantation kit includes any one or both of electrical devices **10**, **12**, electrical cable **14**, and tunneler assembly **20** as shown in FIG. **2**.

[0052] In FIG. **2**, tunneler assembly **20** includes lance **22**, cable adapter **24**, and handle **26**. Cable adapter **24** and handle **26** are configured to engage on to and disengage from lance **22**. Cable adapter **24** and handle **26** are capable of exchanging places with each other on lance **22**.

[0053] Aspects of cable adaptor **24** may be similar to those described in U.S. Publication Nos. 2006/0030871 and 2005/0288762, the entire contents of which are incorporated herein for all purposes by reference.

[0054] In some embodiments, lance **22** is a rod of aluminum or stainless steel. Lance **22** can be made any metal, synthetic plastic, composite, or other material known in the art as being suitable for use in surgical instruments. Lance **22** can be about **16** inches in length, **24** inches in length, or another length depending on the patient, the region of the body on which the tunneling procedure is to be performed and/or the method of tunneling to be performed.

[0055] In some embodiments, lance **22** is as shown in any one of FIGS. **3** to **5**. Lance **22** includes first end segment **28**, second end segment **30**, connector **32** on each one of first end segment **28** and second end segment **30**, tapered tip **31** at the free end of each one of first end segment **28** and second end segment **30**, and intermediate gripping features **35** spaced apart from each other along the axial length of lance **22**. Tapered tip **31** facilitates passage of lance **22** through body tissue. The exemplary lance includes a pointed tip on each end to allow for bi-direction pushing through soft tissue. As will be described in further detail below, the lance and handle combination allow a clinician to comfortably and accurately create a path through soft tissue with fewer restrictions in terms of surgical technique compared to existing tunneler designs. For example, in the case of an open surgical procedure the tunneler system can be used to create a path from the inside out or from the outside in.

[0056] Connector **32** is configured to allow lance **22** to be selectively engaged onto and disengaged from cable adapter **24** and handle **26**. Cable adapter **24** can be disconnected from first end segment **28** of lance **22** and connected to second end segment **30**. Handle **26** can be disconnected from second end segment **30** of lance **22** and connected to first end segment **28**. Lance **22** can be rigid, semi-rigid, or resiliently flexible. In some embodiments, lance **22** is malleable to allow plastic deformation of lance **22**.

[0057] In alternative embodiments, lance **22** is identical or similar in shape to the malleable member described in connection with reference numeral 102 in U.S. Pat. No. 8,088,138, which is incorporated herein for all purposes by reference.

[0058] Referring again to FIG. **2**, cable adapter **24** includes lance connection portion **34** and cable connection portion **36**. Lance connection portion **34** is configured to engage and disengage connectors **32** on lance **22**. Cable connection portion **36** is configured to engage and disengage electrical cable **14**. When lance connection portion **34** is engaged on lance **22**, cable adapter **24** is capable of rotating freely about its central axis **46** to prevent cable **114** from developing twists or kinks during performance of a tunneling method.

[0059] In some embodiments, cable adapter **24** is as shown in FIGS. **6**A to **6**C. Lance connection portion **34** includes flexible device **38** configured to elastically deform and to engage and disengage connectors **32** of lance **22**. Flexible

device **38** defines lance passageway **40** extending into cable adapter **24**. Passageway **40** includes opening **42** and septum wall **44** (FIG. **6**C) located opposite and coaxially aligned with opening **42** along central axis **46** of cable adapter **24**. Passageway **40** is configured to radially expand to allow cable adapter **24** to disengage from connectors **32** of lance **22** and to radially contract to allow cable adapter **24** to engage connectors **32**. A pair of through holes **45** is formed through lance connection portion **34**. Through holes **45** can be used to tie cable adapter **24** to cable **14** when packaged in a sealed tray so that when the tray is opened in preparation for an implantation procedure, the cable adapter **24** does not inadvertently fall on the floor. Through holes **45** are aligned along transverse axis **47** perpendicular to central axis **46**.

[0060] Referring again to FIGS. **3** to **5**, each of connectors **32** of lance **22** includes narrow segment **48** and wide segment **50** that are immediately adjacent to each other. There may be multiple narrow segments **48** and multiple wide segments **50**. Narrow segment forms recess **49** located adjacent wide segment **50** or between pairs of wide segments **50**.

[0061] As shown in FIG. **6**C, lance passageway **40** includes constricted segment **52** and enlarged segments **54** surrounding constricted segment **52**. The diameter of lance passageway **40** is smaller at constricted segment **52** than at enlarged segments **54**. Constricted segment **52** is configured to engage narrow segment **48** of lance **22**. Enlarged segment is configured to receive and/or engage wide segment **50** of lance **22**.

[0062] As shown in FIGS. **6**A to **6**C, flexible device **38** of cable adapter **24** includes a plurality of engagement members **56** configured to flex apart from each other and toward each other. Engagement members **56** are arranged circumferentially around passageway **40**. Each engagement member **56** is spaced apart by axial slot **58** from adjacent engagement members **56**. Slots **58** provide spaces which allow engagement members **56** to collapse toward each other, which causes constriction of passageway **40** and causes constricted segment **52** and enlarged segments **54** of passageway **40** to engage narrow segment **48** and wide segment **50** of lance **22**.

[0063] As shown in FIGS. **6**A and **6**B, cable adapter **24** includes ring **60**. Ring **60** is omitted from FIG. **6**C. Ring **60** is configured to clamp around engagement members **56**. Ring **60** includes internal wall **62**, protrusion **64** on internal wall **62**, and grooves or depression **66** into internal wall **62**. Protrusion **64** is integrally formed on internal wall **62** and is configured to engage depression **68** formed into outer surface **70** of each engagement member **56**. Depression **66** of ring **60** is configured to receive and engage protrusion **72** integrally formed on outer surface **70** of each engagement member **56**. Protrusion **64** and depression **66** of ring **60** forms an internal helical thread on internal wall **62**. Protrusion **72** and depression **68** on engagement members **56** form an external helical thread interrupted by slots **58**. The external helical thread on engagement members **56** mates with the internal helical thread on ring **60**.

[0064] As shown in FIG. **6**C, cable connection portion **36** of cable adapter **24** includes blind hole **74** configured to receive an end segment of electrical cable **14**. Protrusion **76** is integrally formed on internal wall **78** of blind hole **74**. A groove or depression **80** is formed into internal wall **78**. Internal wall **78** is annular, and protrusion **76** and depression **80** form a helical thread within blind hole **74**.

[0065] As shown in FIGS. **6**A and **6**C, cable connection portion **36** includes a resilient device in the form of o-ring seal **82** made of synthetic rubber, silicone, or other resilient material. In FIG. **6**, a cutaway window is presented for illustration purposes to show o-ring seal **82**. The cutaway window does not actually exist on cable connection portion **36**. O-ring seal **82** is retained within annular groove **83** formed into internal wall **78**. O-ring seal **82** forms a liquid tight seal on electrical cable **14** when cable connection portion **36** is engaged to electrical cable **14**.

[0066] In some embodiments, electrical cable **14** is as shown in FIG. **7**. End segment **84** of electrical cable **14** includes cylindrical wall **86** and external helical thread **88**. O-ring seal **82** of cable adapter **24** encircles and presses against cylindrical wall **86**. O-ring seal **82** is compressed between cylindrical wall **86** of electrical cable **14** and internal wall **78** of cable adapter **24**.

[0067] In an exemplary adapter-to-cable connecting method, end segment **84** of electrical cable **14** is pushed into blind hole **74** of cable adapter **24** until external helical thread **88** of electrical cable **14** abuts the internal thread formed by protrusion **76** and depression **80** within blind hole **74**. Next, cable adapter **24** is twisted about its central axis **46**. Twisting can be accomplished by manually by grasping the body of cable adapter **24** and then rotating cable adapter **24** about central axis **46** so that the external and internal threads helically engage each other and force end segment **84** of electrical cable **14** further into blind hole **74**. As end segment **84** moves further into blind hole **74**, o-ring seal **82** encircles and presses against cylindrical wall **86** of end segment **84**. When end opening **90** is axially disposed between o-ring seal **82** and septum wall **44**, electrical contacts housed within end segment **84** and which are accessible through end opening **90** are protected from any liquid which may be present outside cable adapter **24** during a surgical procedure.

[0068] Next, in an exemplary adapter-to-lance connecting method, any one of first end segment **28** and second end segment **30** of lance **22** is inserted into passageway **40** in lance connection portion **34** of cable adapter **24** while ring **60** is at a retracted position shown in FIG. **6**A. As lance **22** is inserted into passageway **40**, engagement members **56** flex radially outward as constricted segment **52** of passageway **40** passes over wide segment **50** of connector **32** on lance **22**, and then move radially inward as constricted segment **52** becomes seated around narrow segment **48** of lance **22**. While constricted segment **52** is seated around narrow segment **48**, ring **60** is pushed by the user into contact with the external thread formed by depression **68** and protrusion **72** on outer surface **70** of engagement members **56**. Upon contact, ring **60** is rotated about central axis **46** which brings ring **60** to an extended position over constricted portion **52**. Ring **60** now prevents engagement members **56** from flexing radially outward, which keeps the inserted connector **32** of lance **22** locked within lance connection portion **34** of cable adapter **24**.

[0069] In the exemplary embodiment, no tools are necessary to attach cable adapter **24** to electrical cable **14** and to lance **22**. One of skill will appreciate from the description herein, however, that the adaptor can be modified for use with standard or customized tools. One will also appreciate that the adaptor can be modified to carry other components such as catheters and data cables.

[0070] In alternative embodiments, cable adapter **24**B is as shown in FIGS. **8**A-**8**B. Lance connection portion **34** is identical to that of FIGS. **6**A to **6**C, except a lesser number of turns of the external thread on outer surface **70** are present in FIGS. **8**A-**8**B. Cable connection portion **36** is identical to that of

FIGS. **6**A to **6**C, except the resilient device for sealing against electrical cable **14** is in the form of flat seal **82**B made of synthetic rubber, silicone, or other resilient material. Flat seal **82**B is disposed against septum wall **44** as shown through the cutaway window. The cutaway window does not actually exist on cable connection portion **36** and is presented for illustration purposes to show the location of flat seal **82**B.

[0071] Cable adapter **24**B is functionally identical to cable adapter **24** of FIGS. **6**A to **6**C, except sealing is achieved differently. In an exemplary adapter-to-cable connecting method, as end segment **84** of electrical cable **14** moves further into blind hole **74** with twisting of cable adapter **24**, forward edge of end opening **90** of electrical cable **14** presses against flat seal **82**B. When forward edge of end opening **90** is pressed against flat seal **82**B, electrical contacts housed within end segment **84** and which are accessible through end opening **90** are protected from any liquid which may be present outside cable adapter **24** during a surgical procedure.

[0072] FIG. **8**B shows cable adapter **24**B of FIG. **8**A after ring **60** is moved into the lock position. Pull action by the user places ring **60** in tension. Push action by the user maintains the lock position of ring **60** via tissue friction.

[0073] Referring to FIG. **8**B, in some embodiments, a protrusion and/or depression forms a snap feature on the outer surface of flexible device **38** of cable adapter **24**B, and the internal wall of ring **60** has a corresponding snap feature configured to mate with and/or engage the snap feature on flexible device **38**. The user advances ring **60** linearly toward and over the snap feature on flexible device **38** so that ring **60** is locked in position over flexible device **38** and prevents lance **22** from pulling out of flexible device **38**. The snap features on flexible device **38** and ring **60** can be configured so that ring **60** need not be twisted relative to flexible device **38** in order to lock ring **60** over flexible device **38**.

[0074] In alternative embodiments, the resilient device for sealing against electrical cable **14** includes o-ring seal **82** as described in connection with FIGS. **6**A to **6**C and flat seal **82**B as described in connection with FIG. **8**A.

[0075] In some embodiments, handle **26** is as shown in FIGS. **9**A and **9**B. Handle **26** includes lance coupling device **92** and grip **94**. Lance coupling device **92** includes tube **96**, actuator **98**, and lock member **100**. Tube **96** is fixedly mounted into grip **94**. Tube **96** has passageway **102** configured to receive any of the first end segment **28** and second end segment **30** of lance **22**. Actuator **98** is configured to move relative to tube **96** and grip **94** when external force F is axially applied on actuator **98**.

[0076] Lock member **100** is trapped within tube **96**. Lock member **100** can be a ring or a ball. Lock member **100** is pushed into the passageway when actuator **98** is moved to an extended or first position relative to tube **96**, as shown in FIG. **9**B. Coil spring **104** is trapped between tube **96** and actuator **98**. Coil spring **104** is under compression and continuously urges actuator **98** to move to the first position.

[0077] Depression **106** is formed into actuator **98**. When actuator **98** is in the first position, as shown in FIG. **9**B, depression **106** is axially spaced apart from lock member **100**, which prevents lock member from moving radially outward away from central axis **108** of passageway **102**. When the user pulls actuator **98** toward grip **94** with application of force F, coil spring **104** is compressed further and actuator **98** is moved to a retracted or second position relative to tube **96**. When actuator **98** is in the second position, depression **106** is aligned with and disposed over lock member **100**, which allows lock member **100** to move radially outward and away from central axis **108**.

[0078] In alternative embodiments, handle **26** is identical or similar in configuration to the handle described in connection with reference numeral 112 in U.S. Pat. No. 8,088,138, which is incorporated herein for all purposes by reference.

[0079] FIG. **10** shows an exemplary tunneler assembly having quick connect handle **26**, tunneler **22** with gripping features (such as shown in FIG. **5**), and collet cable adaptor **24** (such as shown in FIGS. **6**A and **8**A) for carrying driveline **14** (such as a percutaneous cable).

[0080] In an exemplary lance attachment method, a user moves actuator **98** to its second position and holds it while lance **22** is pushed into passageway **102**. As wide segment **50** of lance **22** passes across lock member **100**, lock member **100** moves into depression **106** of actuator **98**. When the tip of lance **22** abuts stop **108** within grip **94**, narrow segment **48** of lance **22** is axially aligned with lock member **100**. Upon contacting the tip of lance **22** with stop **108**, the user releases actuator **98**. Coil spring **104** causes actuator **98** to return to its first position (FIG. **9**B), which moves depression **106** away from lock member **100**. Lock member **100** is forced onto narrow segment **48** of lance **22**. Because depression **106** is no longer aligned with lock member **100**, lock member **100** cannot disengage narrow segment **48**, which prevents wide segment **50** of lance **22** from pulling out of tube **96**. To release lance **22** from tube **96**, the user moves actuator **98** to its second position and holds it there while lance **22** is pulled out, during which time lock member **100** moves in a radially outward direction as wide segment **50** of lance **22** slides past lock member **100** and out of tube **96**.

[0081] It will be appreciated that tunneler assembly **20** provides the user with the ability to selectively attach and remove handle **96** and cable adapter **24** to any end segment **28**, **30** of lance **22**. This allows for flexibility in surgical method.

[0082] With reference to FIGS. **11** to **13**, in an exemplary surgical tunneling method, end segment **84** of electrical cable **14** is pulled out from within the body of the patient using tunneler assembly **20**, which may be accomplished as follows. Lance **22** is placed outside the body of the patient with handle **26** attached to one of the end segments **28**, **30** of lance **22** according to the exemplary lance attachment method described above or other method. The opposite end segment of lance **22** is pushed through the skin and into the body of the patient. At any prior time during the surgical tunneling method, cable adapter **24** and electrical cable **14** are connected together according to the exemplary adapter-to-cable connecting method described above or other method. For example, the adapter-to-cable connecting method may include twisting cable adapter **24** relative to electrical cable **14** to attach and seal end segment **84** of electrical cable **14** within cable adapter **24**. Thereafter, cable adapter **24** is connected to lance **22** according the exemplary adapter-to-lance connecting method described above or other method. For example, the adapter-to-lance connecting method may include twisting or sliding ring **60** relative to flexible device **38** in order to tighten ring **60** over flexible device **38**. It will be appreciated that adapter-to-lance connecting method may be performed before or after the adapter-to-cable connecting method. Next, the user pulls electrical cable **14** from inside the patient's body, through the skin, and out of the patient's body by pulling handle **26** which remains attached to the same end segment of lance **22**. Cable adapter **24** is released from

lance **22** by unscrewing and loosening ring **60** from flexible device **38**. Next, cable adapter **24** is twisted relative to electrical cable **14** to disconnect it from electrical cable **14**.

[0083] In another exemplary surgical tunneling method, end segment **84** of electrical cable **14** is pulled into the body of the patient using tunneler assembly **20**, which may be accomplished as follows. Lance **22** is placed outside the body of the patient with handle **26** attached to one of the end segments **28**, **30** of lance **22** according the exemplary lance attachment method described above or other method. The opposite end segment of lance **22** is pushed through the skin and into the body of the patient. With electrical cable **14** located outside the patient's body, cable adapter **24** is connected to electrical cable **14** either before or after cable adapter **24** is connected to lance **24**. Handle **26** is removed from lance **22** and is replaced by cable adapter **24** on the same end segment of lance **22**. Handle **26** is attached to the opposite end segment of lance **22**. The user then pulls electrical cable **14** from outside the patient's body, through the skin, and into the body by pulling handle **26**. Cable adapter **24** is released from lance **22** by unscrewing and loosening ring **60** from flexible device **38**. Next, cable adapter **24** is twisted relative to electrical cable **14** to disconnect it from electrical cable **14**.

[0084] In yet another exemplary surgical tunneling method, end segment **84** of electrical cable **14** is pulled out from inside the body of the patient using tunneler assembly **20**, which may be accomplished as follows. One of the end segments **28** of lance **22** is positioned inside the body of the patient with handle **26** attached to the opposite end segment **30** of lance **22** according the exemplary lance attachment method described above or other method. Tip **31** of end segment **28** is pushed from inside the body, through the skin, and to the exterior of the body. Handle **26** is removed from lance **22** and is replaced by cable adapter **24** on end segment **30** of lance **22**. Cable adapter **24** is connected to electrical cable **14** either before or after cable adapter **24** is connected to lance **24**. Handle **26** is attached to end segment **28** of lance **22** which was previously pushed through the skin and is now outside the patient's body. The user then pulls handle **26** away from the body which causes electrical cable **14** to be pulled from inside the patient's body, through the skin, and out of the body. Cable adapter **24** is released from lance **22** by unscrewing and loosening ring **60** from flexible device **38**. Next, cable adapter **24** is twisted relative to electrical cable **14** to disconnect it from electrical cable **14**.

[0085] One of skill in the art will appreciate from the description herein that the tunneler assembly may be modified to suit different procedures and other design needs.

[0086] In some embodiments, the cable adapter is as shown in FIGS. **14-16**. Cable adapter **24**C includes cable connection portion **36** made of a substantially rigid material, such as aluminum, stainless steel, or other material. Cable adapter **24**C includes lance connection portion **34** made of an elastomeric material that is flexible and capable elastic deformation. Connection portion **34** includes interface segment **37** and flexible device **38**.

[0087] Interface segment **37** of lance connection portion **34** is fixedly attached to cable connection portion **36**. For example, cable connection portion **36** can be inserted in a mold in the shape of lance connection portion **34** and molten material for the lance connection portion **34** can be introduced into the mold. The molten material flows through a hole formed through septum wall **44** and into through holes **110** and grooves **102** (FIG. **16**) formed through lance connection portion **34**. Upon solidification of the molten material, lance connection portion **34** is fully formed and permanently attached to cable connection portion **36**.

[0088] Flexible device **38** includes lance passageway **40** that includes constricted segments **52** and enlarged segment **54**. The diameter of passageway **40** is smaller in constricted segments **52** than in enlarged segment **54**. The inner surface of constricted segment **52** and enlarged segments **54** combined has a shape that matches and mates with the shape of the outer surface of connector **32** of lance **22** Annular groove or depression **68** is formed in outer surface **70** of flexible device **38**. Depression **68** is located around constricted segment **52** adjacent to end opening **90** of lance passageway **40**.

[0089] In alternative embodiments, flexible device **38** includes a plurality of axially extending engagement members similar to engagement members **56** in FIG. **6**B.

[0090] In alternative embodiments, flexible device **38** includes one or more axially extending slots similar to slots **58** in FIG. **6**B.

[0091] Referring to FIG. **15**, blind hole **74** extends into cable connection portion **36** and is configured to receive an end segment of cable **14**. Annular groove or depression **114** is formed into inner surface **78** of cable connection portion **36**. Depression **114** may be configured to engage and retain the end segment of cable **14** or may be configured to receive and retain an o-ring seal similar to o-ring seal **82** in FIG. **6**C for providing a water-tight seal around the end segment of cable **14**. End segment **116** of lance connection portion **34** extends through the hole in septum wall **44** and into blind hole **78**. End segment **116** has a flat surface and may serve the same function as flat seal **82**B in FIG. **8** for providing a water-tight seal on end opening **90** of cable **14**.

[0092] In alternative embodiments, inner surface **78** of cable connection portion **36** includes an internal helical thread for engaging and retaining end segment **84** of cable **14**.

[0093] In an exemplary adapter-to-lance connecting method, any one of first end segment **28** and second end segment **30** of lance **22** is inserted into passageway **40** in lance connection portion **34** of cable adapter **24**C. As lance **22** is inserted into passageway **40**, flexible device **38** expands radially outward as wide segment **50** of connector **32** of lance **22** passes through constricted segment **54** of passageway **40** adjacent to end opening **90**, and then autonomously contracts as wide segment **50** of lance **22** is received within enlarged segment **54** of passageway **40**. Next, a piece of string or lacing **115** (FIG. **12**) is wrapped around and into depression **68**, and then tightened and tied to prevent loosening. Lacing **115** prevents constricted segment **54** adjacent to end opening **90** from expanding, which keeps connector **32** of lance **22** locked within lance connection portion **34** of cable adapter **24**C until the lacing is cut or untied.

[0094] FIGS. **17-19** show handle **26**B configured to engage onto and disengage from lance **22** at any number of locations along the axial length of lance **22**. Handle **26**B is in the shape of a flat bar and includes lance coupling device **92** and grip **94**. There is a bend **117** between coupling device **92** and grip **94** such that coupling device **92** is oriented in a downward angle A (FIG. **18**) between about 5 degrees and about 90 degrees, or more narrowly between about 10 degrees and about 45 degrees. Other angles are possible. Grip **94** includes a plurality of arc-shaped depressions **118** to prevent the hand of the user from slipping off of grip **94**. Slot **120** is formed into coupling device **92** and is sized to receive lance **22**. The width of slot **120** is the same as or slightly larger than the cross-

sectional diameter of the rod body of lance **22**. Depression or groove **122** is formed at the end of slot **120** and is configured to allow lance **22** to pivot within the end of slot **120**. For example, lance **22** can be inserted into opening **124** while lance **22** is perpendicular to surface plane **126** of lance coupling device **92**. When lance **22** reaches groove **122**, lance **22** can be pivoted from its perpendicular orientation to angle B less than 90 degrees relative to surface plane **126**. Groove **122** is configured such that pivoting is stopped when angle B reaches an angle between about 10 degrees to 80 degrees, or more narrowly between about 10 degrees and about 45 degrees. Other angles are possible.

[0095] After pivoting lance **22** within slot **120** to angle B, the rod body of lance **22** is separated from the bottom surface of grip **94**. The space between lance **22** and grip **94** is due to bend angle A, the distance of groove **122** from bend **117**, and pivot angle B. When a user squeezes grip **94** and lance **22** together, surfaces of groove **122** and/or slot **120** press against lance **22**, which engages handle **26**B and lance **22** together. Friction between lance coupling device **92** and lance **22** prevents lance **22** from slipping relative to handle **26**B when the user squeezes grip **94** and lance **22** together. In some embodiments, gripping features **35** of lance **22** prevents lance **22** from slipping relative to handle **26**B.

[0096] In some embodiments angle B is greater than or equal to angle A to help ensure that the rod body of lance **22** remains separated from the bottom surface of grip **94**.

[0097] Handle **26**B (FIG. **17-19**) can be used in place of handle **26** (FIGS. **9**A and **9**B) or used in conjunction with handle **26** in the exemplary surgical tunneling methods described above. In some embodiments, the method includes the user manually holding gripping features **35** of the rod body of lance **22** to help maneuver, pull, and/or push lance **22**.

[0098] The outer surface of gripping features **35** forms a hexagonal cross-section which prevents lance **22** from rotating about axis **108** relative to handle **26** and **26**B, which allows the user to steer lance **22** through a desired tunnel path. The inner surface of tube **96** (FIG. **9**B) of handle **26** forms a corresponding hexagonal cross-section and is configured to receive, engage, and prevent axial rotation of gripping feature **35** within tube **96**. The bottom surface of engagement end **92** (FIG. **17**) of handle **26**B is configured to engage a flat surface of gripping feature **35** and prevent axial rotation of gripping feature **35**. Other shapes, such has square and triangular, for the cross-section of gripping feature **35** can be implemented to prevent axial rotation relative to handle **26** and **26**B.

[0099] In some embodiments, a surgical implantation kit includes cable adapter **24**, cable **14**, and optionally an operative device which, for example, can be a ventricular assist device, a controller for a ventricular assist device, or other medical device. In other embodiments, the surgical implantation kit further includes lance **22** and handle **26** or **26**B, both of which lance and handle can be re-sterilized and reused to perform a tunneling procedure on another patient.

[0100] While several particular forms of the invention have been illustrated and described, it will also be apparent that various modifications can be made without departing from the scope of the invention. It is also contemplated that various combinations or subcombinations of the specific features and aspects of the disclosed embodiments can be combined with or substituted for one another in order to form varying modes of the invention. Accordingly, it is not intended that the invention be limited, except as by the appended claims.

1. A surgical tunneler assembly comprising:
- a lance including a first segment, a second end segment, and a connector on each one of the first end segment and the second end segment;
- a cable adapter including a lance connection portion and a cable connection portion, the lance connection portion configured to engage and disengage the connectors, the cable connection portion configured to engage and disengage a cable; and
- a handle configured to engage and disengage the lance.

2. The assembly of claim **1**, wherein the lance connection portion includes a flexible device configured to deform and to engage and disengage the connectors.

3. The assembly of claim **1**, wherein the lance connection portion includes a lance passageway configured to radially expand to allow disengagement of the cable adapter from the connectors and to radially contract to allow engagement of the cable adapter to the connectors.

4. The assembly of claim **3**, wherein each of the connectors includes a narrow segment and a wide segment, and the lance passageway includes a constricted segment or an enlarged segment configured to engage the narrow segment or the wide segment respectively.

5. The assembly of claim **1**, wherein the lance connection portion includes a plurality of engagement members configured to flex apart from each other and toward each other.

6. The assembly of claim **1**, wherein the cable adapter includes a ring configured to clamp around of the lance connection portion.

7. The assembly of claim **6**, wherein the ring includes an internal wall and a protrusion on or a depression into the internal wall configured to engage a depression into or protrusion on an outer surface of the lance connection portion.

8. The assembly of claim **1**, wherein the cable connection portion includes a protrusion or a depression configured to engage the cable.

9. The assembly of claim **8**, wherein the protrusion or the depression of the cable connection portion forms a helical thread.

10. The assembly of claim **9**, wherein the helical thread is disposed within the cable connection portion.

11. The assembly of claim **1**, wherein the cable connection portion includes a resilient device configured to form a liquid tight seal on the cable when the cable connection portion is engaged to the cable.

12. The assembly of claim **11**, wherein the resilient device is disposed within the cable connection portion.

13. The assembly of claim **11**, wherein the resilient device includes any one or a combination of an o-ring seal and a flat seal.

14. The assembly of claim **1**, wherein the handle is configured to engage and disengage the connectors.

15. The assembly of claim **1**, wherein the handle includes:
- a tube having a passageway configured to receive the connectors;
- an actuator configured to move relative to the tube with application of an external force on the actuator; and
- a lock member trapped within the tube,
- wherein the lock member is pushed into the passageway when the actuator is moved to a first position relative to the tube, and the lock member is capable of moving away from the passageway when the actuator is moved to a second position relative to the tube.

16. The assembly of claim **15**, wherein each of the connectors includes a depression configured to receive the lock member.

17. A surgical implantation kit comprising:

an operative device;

a cable including a first end connected to or configured for connection to the operative device; and

the surgical tunneler assembly of claim **1**.

18. The kit of claim **17**, wherein the operative device is a ventricular assist device or a controller for a ventricular assist device.

19. The kit of claim **17**, further comprising a second operative device connected to or configured for connection to a second end of the cable.

20. The kit of claim **19**, wherein the second operative device is either:

a controller when the first operative device is a ventricular assist device, or

a ventricular assist device when the first operative device is a controller.

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