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(54) **Title**: METHOD AND APPARATUS FOR PERFORMING RETRO PERITONEAL DISSECTION

(57) **Abstract**: The foregoing application describes a system and method of performing a minimally invasive surgical operation. More specifically, the invention involves the use of disposable cannula and slender dilators of variable lengths, which incorporate a source of illumination to carry light to a surgical site and video capabilities for capturing and displaying images from a CMOS or CCD camera device. According to one embodiment, fiber optics run semi-circumferentially or along walls of the cannula/dilator and terminate at about a centimeter from the distal end of the cannula/dilator, thereby preventing illumination from "bottoming out" at the floor of the incision. According to one alternate embodiment, the light fibers may be fashioned in an annulus around one or more camera chips to provide illumination and video of the surgical site.

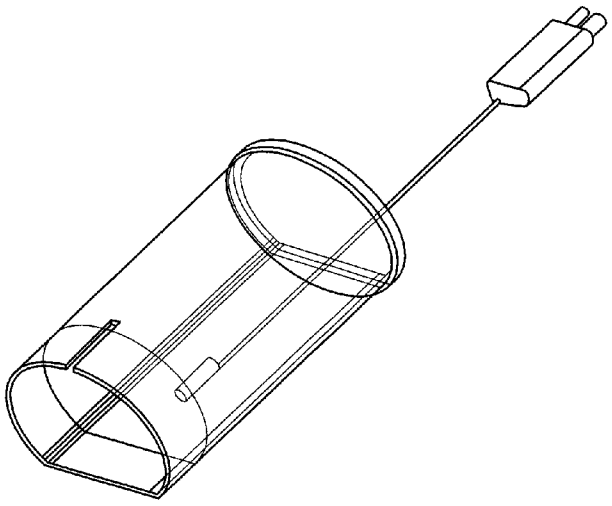


FIG.16

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METHOD AND APPARATUS FOR PERFORMING RETRO PERITONEAL DISSECTION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Patent Application Serial No. 61/326,138, filed April 20, 2010, and U.S. Provisional Patent Application Serial No. 61/355,250 filed June 16, 2010, the entire disclosures of which are hereby incorporated herein by reference.

FIELD OF THE INVENTION

This disclosure relates to human surgical procedures performed percutaneously, and more specifically to a progressive cannula system that can be disposable and contains methods to enhance illumination and visibility. The disclosure also relates to a system and method for providing one or more disposable or reusable camera/video devices, including camera/video devices incorporating CCD and/or CMOS technology.

BACKGROUND OF THE INVENTION

Surgical procedures to address illness, disease or injury vary depending on a number of factors, including the ability of the surgeon(s) to access and perform the necessary procedures at the affected site. As one example, individuals who suffer degenerative disc disease, natural spine deformations, a herniated disc, spine injuries or other spine disorders often require surgery on the affected region to relieve pain or prevent further injury to the spine and nerves. Spinal surgery may involve removal of damaged joint tissue, insertion of a tissue implant and/or fixation of two or more adjacent vertebral bodies. These procedures are often difficult due to the location of the spine and adjacent nerves, sensitive anatomy, etc. The surgical procedure will vary in approach and duration depending on the nature and extent of the injury.

One particular type of spinal surgery is referred to as "fusion." Fusion of vertebral bodies involves fixation of two or more adjacent vertebrae. This procedure may be performed through introduction of rods or plates, and screws or other devices into a vertebral joint to join various portions of a vertebra to a corresponding portion on an adjacent vertebra. Fusion may occur in the lumbar, interbody or cervical spine region of a patient. A fusion is designed to stop and/or eliminate all motion in the spinal segment by destruction of some or all of the joints in that segment and further utilizing bone graft material and/or rigid implantable fixation devices for securing the adjacent vertebrae. By eliminating movement, back pain and further degenerative disc disease may be reduced or

avoided. Fusion requires tools for accessing the vertebrae, such as surgical cannulae for "minimally-invasive" surgical procedures, and other tools for implanting the desired implant, bioactive material, etc. Such procedures often require introduction of additional tools to prepare a site for implantation. These tools may include drills, drill guides, debridement tools, irrigation devices, vises, clamps, cannula, and other insertion/retraction tools.

Spinal surgeries may be performed by a number of different "minimally-invasive" procedures, as opposed to conventional surgical procedures and methods, which typically require cutting of muscles, removal of bone, and retraction of other natural elements. With minimally invasive spinal surgery, a less destructive approach to the spine is carried out by using portals, which take advantage of anatomy and current technology to limit the damage to intervening structures.

Typically, skeletal landmarks are established fluoroscopically and a small incision is made over the landmark(s). According to methods known in the prior art, a series of dilators are applied until one or more cannula is placed over the anatomic structure. A microscope is then placed over the operative site. The microscope provides illumination and magnification with a three dimensional view of the anatomical site. While this process provides substantial advantages relative to open surgery, it requires the use of an operating microscope. This particular piece of equipment is extremely expensive (most quality brands are in the $250,000 range). The microscope is an unwieldy device requiring uncomfortable gyrations of the surgeon's back and neck in order to gain the necessary view and is a nuisance to drape (a large, sterile plastic bag has to be placed over the eight foot tall structure). The illumination is also difficult to direct due to the size of the microscope.

A significant danger of performing intervertebral operations or accessing an intervertebral space during spine surgery is that of inadvertently contacting or damaging the para-spinal nerves, including the exiting nerve roots, traversing nerves and the nerves of the cauda equina. The exact location of these para-spinal nerves cannot be determined prior to the commencement of surgery, and therefore are dependent on a surgeon's ability to visually locate the same after the initial incision is made. Moreover, intervertebral spaces in the spine have other sensitive nerves disposed at locations which are not entirely predictable prior to insertion of the surgical tool into the intervertebral area. Accordingly, the danger of pinching or damaging spinal nerves when accessing an intervertebral space has proven to be quite limiting to the methods and devices used during minimally invasive

spinal surgery. In addition, as cannula are received through the patient's back, such as when performing minimally invasive spinal surgery, minor blood vessels are ruptured, thereby blocking the surgeon's vision inside the intervertebral region after the cannula has been inserted. Other anatomical features at a particular patient may also destruct the surgeon's view or make it difficult to provide illumination within the cannula.

Lateral based spinal surgery is a known alternative to conventional surgical procedures, and is generally referred to as a "minimally-invasive" procedure. Lateral based procedures offer the advantages of shorter recovery times, reduced blood loss, reduced post-operative complications, and shorter operating times than conventional procedures and methods. For example, one surgical approach for spinal fusion using a minimally invasive technique is known as "lumbar interbody fusion" or LIF for short. Other known examples of lateral based approaches include the Nuvasive XLIF procedure and Medtronic D-LIF System. However, these systems and methods have problems and shortcomings, including, but not limited to, limited visualization and lighting in the surgical area, increased risk of impinging upon the nerves of the lumbosacral plexus, and the ilioinguinal and genitofemoral nerves and the risk of devices and/or instruments becoming dislodged during the various procedures, among others. These problems, alone or in combination, may result in post-operative pain and discomfort experienced by patients of lateral based spinal surgery. In some instances, these problems require or otherwise lead to additional surgeries, further complicating the likelihood of recovery and successful fusion.

Various devices and surgical access systems are known in the art to facilitate minimally invasive surgical procedures while allowing for a sufficiently large surgical area. These devices may include a series of tools which, when consecutively inserted, serve to gradually expand an area, including cannula. Retractors are useful for gradually dilating the area of an incision or surgical opening in order to form a desired amount of space within which various procedures may be conducted. Retractors may take the form of a single device that may be inserted into a work area and expanded at the direction of a user, thus allowing for the creation and maintaining of a surgical work space. Many retractors fail to provide independent illumination sources or allow the surgeon to visualize the path of access to the surgical site. As these refractors are often the first (or one of the first) tools used in the procedure, providing adequate illumination and enhancing visualization are important to the success of the operation.

Other problems experienced in minimally invasive surgical procedures include the risk of injury caused during the initial probing and dissecting of tissue between the incision and the surgical site. Typically, such probing is done using a finger or a slender dilator or other tool, which is used to navigate through the soft tissue, anatomy, and ultimately reach the desired point of access to the surgical site. During this probing, there is increased risk to injury to the lumbar plexus, particularly when the surgeon is attempting to access the lumbar spine. In addition, there is also an increased risk to the patient's anatomy, and to undesired dissection of various anatomical features between the incision and the surgical site. This risk of injury typically increases as the probe is inserted deeper into the body of a patient, and continues after the probe has been fully inserted and continuing through dilation, such as by inserting one or more progressive surgical cannula around the dilator proceeds. Damage to the peritoneal membrane, colon perforation, ureteral or great vessel injury can be the result of the "blind" dissection and is major reason why the lateral, transpoas approach is not a more commonly performed surgical procedure. Thus, there is a deep felt need in the art to mitigate these potentially catastrophic complications, and to address the other problems associated with performing these procedures in a "blind" manner.

Typically, as these processes for accessing the surgical site are done blind (i.e., without vision of where the probe is directed), it is not uncommon that the probe intersects and/or dissects the patient's anatomy, intercepts nerves, sensitive tissue, etc. Thus, there is also a need for an improved tool for initially dilating and accessing the tissue between the incision and the surgical site. There is a further need for an improved system and method for providing a surgeon with visibility of this area, to assist with the navigation through the tissue, anatomy, etc. and to provide enhanced illumination for a minimally invasive surgical procedure.

The disclosure of the invention herein addresses these and other problems by providing a system and method for achieving an endoscopic approach to a surgical site, coupled with the use of a unique illumination and video capability. The system of the invention is preferably achieved by incorporating a camera chip in the apparatus of the system, thereby obviating the need and disadvantages of the operating microscope and other expensive and cumbersome instrumentation. These and other considerations are addressed by the present disclosure in more detail in the Summary and Detailed Description.

SUMMARY OF THE INVENTION

Incorporated by reference in their entireties are the following U.S. patents and patent applications directed generally to methods and apparatus related to spinal procedures, thus providing written description support for various aspects of the present disclosure. The U.S. patents and pending applications incorporated by reference are as follows: U.S. Pat. Nos. 7,406,775 to Funk, et al.; 7,387,643 to Michelson; 7,341,590 to Ferree; 7,288,093 to Michelson; 7,207,992 to Ritland; 7,077,864 Byrd III, et al.; 7,025,769 to Ferree; 6,719,795 to Cornwall, et al.; 6,364,880 to Michelson; 6,328,738 to Suddaby; 6,290,724 to Marino; 6,113,602 to Sand; 6,030,401 to Marino; 5,865,846 to Bryan, et al.; 5,569,246 to Ojima, et al.; 5,527,312 to Ray; and 2008/0255564 to Michelson.

According to one particular embodiment of the present disclosure, the invention involves the use of a disposable cannula of variable lengths, which are applied over the dilator tools. These cannulas can have a variety of shapes depending upon the surgical requirement. Ovoid, egg-shaped or round cannulas are contemplated and may further comprise an angled working edge as described in greater detail herein. The devices described herein are unique in that they have incorporated a source of illumination, preferably attached to the walls of the cannula, which emit light to the base of the portal and enhance illumination within the cannula.

According to one embodiment of the disclosure, the illumination is provided by way of fiber optic strands or bundles. The fiber optics can run circumferentially or along one or more walls of the cannula, and preferably terminate at least a centimeter from the bottom of the device. This prevents the illumination from "bottoming out" at the floor of the incision. Additionally, the light fibers may be fashioned in an annulus around a camera chip device to provide illumination to the surgical site where images are being captured by the camera chip device. In still another embodiment, the light fibers may be replaced by one or more LEDs in a remote light source or at the distal-tip of the camera chip device. The light source may come from an external device such as a headlight lamp, or a standard-type light source commonly found in operating rooms which plugs into an adaptor on the disposable cannula.

According to embodiments described herein, the system comprises a disposable cannula that has at least one slot through which the camera chip device(s) can be passed and inserted on a composite insert, which preferably fits in a tongue and groove fashion down the slot of the cannula. The camera chip device may have associated wide-angle

optics and its composite insert can be easily removed/adjusted during the course of the operation for cleaning or when the cannula needs to be re-directed or reoriented during the course of the surgery.

The camera chip device, which according to a preferred embodiment is based on either CCD or CMOS technology, may have the necessary video-processing circuitry onboard the camera chip device housing, or the video-processing circuitry may be housed separately, several meters away from the camera chip device, and connected by a cable or alternatively via wireless transmission. For further details on the type of camera chip device according to a preferred embodiment of the present disclosure, applicant hereby incorporates by reference in its entirety the disclosure of U.S. Patent No. 6,310,642.

According to one embodiment, an apparatus and method and provided whereby, instead of the surgeon viewing the operative site through the oculars of the microscope, the anatomy is presented on a screen in front of him (or her) and in front of the assistant(s). Due to the camera chip device and associated optics housing being placed directly at the operative site, the image collected is free from the distortions and the "field-flattening" effects found when using complex optical stacks commonly found in operating microscopes and endoscopes. This results in a significant increase in "depth-cues" and color-reproduction and in turn improves visibility. The camera technology provides a three dimensional-type picture to the surgeon with enhanced illumination, and without the extra costs of adding a second camera device and expensive intra-ocular optical orientations. The costs of the microscope and its maintenance, plastic draping, sterility/contamination issues and surgeon fatigue are either eliminated or at least substantially reduced.

According to yet another embodiment of the present disclosure, a tool is provided that comprises at least one CMOS or CCD video imaging device, which permits a user to view images captured by the CMOS or CCD imaging device of the disc space or other surgical area to be operated on. For example, one or more angled tools may incorporate a video insert (described in greater detail below), for capturing and viewing images of the intervertebral disc space during or after dissection has occurred. This may be accomplished by providing a CMOS or CCD camera device at the distal end of the one or more angled tools, and either wirelessly or hardwire transmitting the images captured by that CMOS or CCD camera to a display. As one other example, one or more disc debridement tools may incorporate the video insert described in greater detail below, for capturing and viewing images of the intervertebral disc space after and during dissection.

This capacity allows for a more complete and safe disc space preparation. A more precise carpentry of the disc space allows for an increased potential for fusion and a reduction of vertebral endplate or soft tissue injury. This may be accomplished by providing a CMOS or CCD camera at the distal end of the one or debridement tools, and either wirelessly or hardwire transmitting the images captured by that CMOS or CCD camera to a display.

One having skill in the art will appreciate that the apparatus described herein, according to various embodiments of the present disclosure, may have various sizes. The sizes of the various elements of embodiments of the present disclosure may be sized based on factors including, for example, the anatomy of the patient, the person operating the apparatus, the surgical site location, physical features of any implanted device required with the surgical procedure, including, for example, width, length and thickness, and the size of the drill or other surgical tool being used with the apparatus, and other factors.

According to one embodiment, the illumination and camera/video capabilities described herein may be provided with one or more cannula having a shape other than round (e.g., oval, pointed, square cornered, egg-shaped etc.) and having an end (e.g., the end inserted into the patient, distal from the user) that is angled and/or tapered and/or shaped to be ideally seated in a particular surgical site. Asymmetrical cannulas may allow visualization of the facet joint of the spine, for example. An "egg-shaped" cross section may allow for the best view of the facet joint and further minimizes the medial-lateral dissection that a round cannula would require. Such shapes are specifically contemplated for incorporating the illumination and camera/video apparatus described herein.

Still other aspects of the invention are directed to cannula instruments that have a patient contacting end that is adjustable to assume a predetermined conformation. Thus, in one embodiment, material forms the end that comes into contact with bone, tissue, and especially as it nears nerve tissue, with such cannula end material being malleable to an extent necessary for the surgeon to mold the end such that it achieves the desired contours or avoids particular structures encountered in any particular surgery. By way of example but not limitation, if a bony outcropping, a nerve fiber, etc. is perceived by the surgeon, the cannula tip end can be adjusted to avoid undesired contact or interference with such tissues or structures.

In particular embodiments, the ability to adjust the geometric parameters of the cannula end may be achieved by manipulation of the other end of the instrument. For example, providing a turnable component at the opposite end of the instrument, the shape of the other end of the instrument (i.e. the end inserted into the patient) can be adjusted to

either expand circumference, reduce circumference, render the opening more or less oblong, etc. In such a manner, it is possible to avoid having to remove the instrument or cannula from the patient's site to adjust the morphology of the instrument, thus saving time, avoiding undesired reinsertion procedures, etc.

According to another embodiment of the present disclosure, a system is provided wherein the cannula further include one or more electrical probes at the exit portal, which are adapted to assist the surgeon in identifying the presence and location of nerves as the probe is advanced during minimally-invasive surgery, thereby providing further assistance and feedback for guiding the path of the cannula and other surgical instruments to be inserted into the surgical site.

An expandable tip cannula may be provided, which functions both as an access portal for surgery and as a system for nerve surveillance, such that the presence and relative position of para-spinal nerves, for example, can be detected as the expandable tip cannula is inserted through the patient's facia and musculature. One particular advantage of determining the position of the lumbosacral plexus with respect to the distal tip of the cannula is that the lumbosacral plexus can be avoided or gently moved out of the surgeon's way while inserting the cannula.

According to one embodiment, the present disclosure provides a system of cannulas adapted to assist the surgeon in guiding the path of surgical instruments received into the intervertebral space, while identifying the presence and location of para-spinal nerves as the cannula is advanced to a patient's intervertebral space during minimally invasive surgery. In various aspects of the present disclosure, the probes may be comprised of one or more electrodes powered at a low level to sense the position of a para-spinal nerve through continuous real time electromyographic monitoring. Alternatively, these electrodes can be powered at a higher level such that they operate to cauterize blood vessels. Safety systems ensure that power levels sufficient to cause cauterization are not activated if a nerve is sensed to be near the electrodes at the distal end of the cannula.

According to yet another embodiment of the present disclosure, a system is provided where the cannula further include one or more electrical probes at the exit portal, which are adapted to assist the surgeon in identifying the presence and location of nerves as the probe is advanced during minimally-invasive surgery, thereby providing a device for guiding the path of other surgical instruments to be inserted into the intervertebral space. An expandable tip cannula may be provided, which functions both as an access portal for spinal surgery and as a system for nerve surveillance, such that the presence and

relative position of the nerves of the lumbo-sacral plexus can be detected as the expandable tip cannula is inserted through the patient's fascia and musculature. One particular advantage of determining the position of the nerves with respect to the distal tip of the cannula is that the nerves can be avoided or gently moved out of the surgeon's way while inserting the cannula.

According to one embodiment, the present disclosure provides a system of cannulas adapted to assist the surgeon in guiding the path of surgical instruments received into the intervertebral space, while identifying the presence and location of para-spinal nerves as the cannula is advanced to a patient's intervertebral space during minimally invasive surgery. In various aspects of the present disclosure, the probes may be comprised of one or more electrodes powered at a low level to sense the position of the nerves of the lumbo-sacral plexus through continuous real time electromyographic monitoring. Alternatively, these electrodes can be powered at a higher level such that they operate to cauterize blood vessels. Safety systems ensure that power levels sufficient to cause cauterization are not activated if a nerve is sensed to be near the electrodes at the distal end of the cannula.

One having skill in the art will appreciate that embodiments of the present disclosure may be constructed of materials known to provide, or predictably manufactured to provide the various aspects of the present disclosure. These materials may include, for example, stainless steel, titanium alloy, aluminum alloy, chromium alloy, and other metals or metal alloys. These materials may also include, for example, PEEK, carbon fiber, ABS plastic, polyurethane, rubber, latex, synthetic rubber, and other fiber-encased resinous materials, synthetic materials, polymers, and natural materials.

One having skill in the art will appreciate that embodiments of the present disclosure may be controlled by means other than manual manipulation. Embodiments of the present disclosure may be designed and shaped such that the apparatus may be controlled, for example, remotely by an operator, remotely by an operator through a computer controller, by an operator using proportioning devices, programmatically by a computer controller, by servo-controlled mechanisms, by hydraulically-driven mechanisms, by pneumatically-driven mechanisms or by piezoelectric actuators.

The Summary of the Invention is neither intended nor should it be construed as being representative of the full extent and scope of the present disclosure. The present disclosure is set forth in various levels of detail in the Summary of the Invention as well as in the attached drawings and the Detailed Description of the Invention and no limitation as

to the scope of the present disclosure is intended by either the inclusion or non-inclusion of elements, components, etc. in this Summary of the Invention. Additional aspects of the present disclosure will become more readily apparent from the Detailed Description, particularly when taken together with the drawings.

The above-described benefits, embodiments, and/or characterizations are not necessarily complete or exhaustive, and in particular, as to the patentable subject matter disclosed herein. Other benefits, embodiments, and/or characterizations of the present disclosure are possible utilizing, alone or in combination, as set forth above and/or described in the accompanying figures and/or in the description herein below. Further details and description of embodiments of the present disclosure are provided in the Appendix A to this application.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure relates to systems and methods for accessing intervertebral space and facilitating the use of surgical tools and inserting spine implants between vertebral bodies. Those of skill in the art will recognize that the following description is merely illustrative of the principles of the disclosure, which may be applied in various ways to provide many different alternative embodiments. This description is made for illustrating the general principles of the teachings of this disclosure invention and is not meant to limit the inventive concepts disclosed herein.

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the disclosure and together with the general description of the disclosure given above and the detailed description of the drawings given below, serve to explain the principles of the disclosures.

Figure 1 is a perspective view of a cannula according to a preferred embodiment of the present disclosure;

Figure 2 is a perspective view of an interlocking cannula with the cannula of Figure 1;

Figure 3 is a cross-sectional view of the cannula shown in Figure 2;

Figure 4 is a view of the cannula of Figure 3 in a docked view;

Figure 5 is a perspective view of a cannula with at least one channel or slot for meeting with an illumination and/or video insert according to one embodiment of the present disclosure;

Figure 6 is a perspective view of the cannula of Figure 5 and the cannula of Figure 1;

Figure 7 is a perspective view of the cannula of Figure 6 in a docked view;

Figure 8 is a perspective view of the cannula of Figure 7 with an insert for providing illumination and/or video capabilities;

Figure 9 is a perspective view of an angled tool with illumination and/or video capabilities;

Figure 10 is an elevation view of the angled tool of Figure 9;

Figure 11 includes a cross-sectional view of the cannula, according to one alternative embodiment, with LED illumination devices and a CMOS/CCD camera slot, and a top plan view of the cannula according to this embodiment;

Figure 12 is a detailed cross-sectional view of the cannula shown in Figure 11;

Figure 13 is a perspective view of the cannula of Figure 11 shown with a hardwired CMOS/CCD camera insert;

Figure 14 is a detailed perspective view of the CMOS/CCD camera insert according to Figure 13 with a fiber optic array;

Figure 15 includes perspective views of a cannula, according to another alternative embodiment, with and without the CMOS/CCD camera insert;

Figure 16 includes various views of a slender dilator and pilot cannula according to one embodiment of the present disclosure;

Figure 17 is a perspective view of a dilator having CMOS/CCD video capabilities and illumination capabilities, according to one embodiment of the present disclosure;

Figure 18 is another perspective view of the dilator shown in Figure 17;

Figure 19 is a perspective view of a modified retractor according to one embodiment of the present disclosure; and

Figure 20 is another perspective view of the modified retractor of Figure 19.

It should be understood that the above-referenced drawing figures are not necessarily to scale. In certain instances, details that are not necessary for an understanding of the disclosure or that render other details difficult to perceive may have been omitted. It should be understood, of course, that the disclosure is not necessarily limited to the particular embodiments illustrated herein.

DETAILED DESCRIPTION

Various embodiments of the apparatus and methods of the present disclosure are described in detail below. According to one particular embodiment of the present disclosure, the invention involves the use of one or more cannula of variable lengths, which according to a preferred embodiment are applied over one or more dilators. These

cannulas can have a variety of shapes depending upon the surgical requirement. Ovoid, egg-shaped or round have been described, and an angled working edge is further contemplated. The apparatus of this system are unique in that they have incorporated a source of illumination built into the walls of the cannula, which carry the light to the base of the portal of the cannula, and further incorporate camera/video capabilities.

Attention is drawn to the appended drawing figures, which are expressly made part of the written description and are provided for purposes of describing certain embodiments of the present disclosure. The cannula in a preferred embodiment is generally tubular in form, with a support wall which has an open distal end and an open proximal end. The distal end may be rounded so that tissues are pushed aside gently as the cannula is inserted through the patient. A bore runs the length of the cannula from the open distal end to the open proximal end, and provides access to the targeted spinal area for instrument insertion, and insertion and removal of implant devices, arthroscopic devices, graft materials, bone cement, and other materials and devices.

A cross-sectional shape of the support wall of the bore may be round, oval, elliptical, crescent-shaped, a half-sphere or half-oval or another suitable shape. The cross-sectional shape has a width, which may have a measurement in the range of about 10-50 millimeters. Preferably the width is in the range of about 15-35 millimeters. The open proximal end may further comprise a plurality of grip features which allow the surgeon to grip the cannula. The cannula may be formed of substantially sterile material, and may further comprise biocompatible polymers, elastomers, ceramics, or aluminum or other metals. According to one embodiment, the cannula is disposable. In another embodiment, the cannula is reusable.

One aspect of the present disclosure is providing a cannula with an incorporated illumination source that provides enhanced illumination to the surgical site sufficient to incorporate camera/video capabilities with the apparatus and system. According to one particular embodiment, the illumination is provided by incorporating one or more fiber optic strands in the tubular body of the cannula. The fiber optics can run circumferentially or along opposite walls of the cannula and preferably terminate at least a centimeter from the bottom of the device (see appended drawing figures). The light fibers may be fashioned in an annulus around a camera chip device to provide illumination to the surgical site where images are being captured by the camera chip device. In still another embodiment, the light fibers may be replaced by one or more LEDs in a remote light source or at the distal-tip of the camera chip device. The light source may come from an

external device such as a headlight lamp, or a standard-type light source commonly found in operating rooms which plugs into an adaptor on the disposable cannula.

Referring now in detail to Figures 1-8, various cannula according to one embodiment of the system of the present disclosure are shown. In Figure 1, a perspective view of a cannula 2 is shown having a generally circular first surface 4 and a generally elliptical second surface 6. About one intersection of the first surface 4 and second surface 6 is a channel or lumen 8 for inserting one or more fastening devices, such as a screw, for securing the cannula 2 to the surgical site. The cannula 2 shown in Figure 1 may vary in lengths and widths according to the anatomy of the patient, the surgical site to be accessed, and other factors relating to the surgery, including the tools or implants that are required to be inserted into the cannula 2.

Referring now to Figure 2, the cannula 2 shown in Figure 1 may be coupled to one or more additional cannula 12, for example, by way of a compression fit between the two or more cannula 2, 12. As shown in Figure 2, the second cannula 12 may be inserted by a compression relief 14 formed about one distal end of the second cannula 12 that is dimensioned to fit in compression with the tubular body 10 of the first cannula 2. According to alternate embodiments, an interlocking fit may be further accomplished by way of a snap fitting, a tongue and groove fitting, or other means of securing the first cannula 2 to the second cannula 12 that are known in the art. In an alternative embodiment, the cannula (2, 12) may be interlocked in a predetermined configuration that permits the cannula (2, 12) to expand in telescoping fashion.

Referring now to Figure 3, the first and second cannula 2, 12 are shown in a cross-sectional view. This assembly includes at least one channel or lumen 8 for inserting at least one fastening device, such as a screw, as well as two smaller lumens or channels 14, 16 which may be used for inserting one or more fiber optic strands/bundles for providing enhanced illumination. These channels 14, 16 may run substantially the entire length of the second cannula 12, and may be greater or fewer in number than shown in Figure 3. The objective of providing these channels 14, 16 on the interior of the cannula assembly is to provide sufficient lighting to allow the surgeon to view the surgical site and complete the surgery without visual impairment.

Referring now in detail to Figure 4, the first and second cannula 2, 12 are shown in a docked or assembled state. The second cannula 12 may vary in length to accommodate surgery taking place in various portions of the patient's body, and according to alternate embodiments may be asymmetrical about its length, thereby providing a larger opening at

one end than the distal end which mates with the first cannula 2. Thus, in operation, the first cannula 2 is secured by way of a fastening member such as a screw, and then the second cannula 12 is inserted into the first cannula 2. According to a preferred embodiment, one or more of the cannula 2, 12 shown in Figure 4 may be disposable. According to alternate embodiments, the cannula 2, 12 shown in Figure 4 may be reusable.

Figure 5 shows a perspective view of a cannula 22 with at least one slot 24 for accommodating compression or expansion of the tubular body of the cannula 22. Similar to the second cannula 12 discussed above, this cannula may be inserted into the base cannula 2 which is secured to the surgical site. This cannula 22 also includes channels 26, 28 for inserting one or more fiberoptic bundles for providing illumination.

Referring now to Figure 6, the cannula 22 of Figure 5 is shown with the cannula 2 of Figure 1, and is oriented in a manner to permit interlocking between the first cannula 2 and this slotted cannula 22. Figure 7 shows the cannula 22 of Figure 5 and the cannula 2 of Figure 1 in a docked or assembled position. This docking occurs similar to that described in relation to Figure 2 above, such that there is a compression fit between the two cannula 2, 22. In certain embodiments, the placement of the slotted cannula 22 on the base cannula 2 does not interfere with the surgeon's ability to remove or replace the fastening member. This assembly therefore provides an extended cannula which includes channels 26, 28 for inserting one ore more fiberoptic bundles to provide adequate lighting. These channels 26, 28 may also provide a location for securing an insert which may provide video capabilities within the tubular body of the cannula assembly, either hardwired or wirelessly. In another embodiment, multiple slotted cannula, similar to cannula 22, may be joined such that the slot(s) in a first slotted cannula aligns with the slot(s) in a second slotted cannula.

Referring now in detail to Figure 8, a camera insert 40 which may be inserted into a slot of the cannula 12 shown in Figure 5 is displayed in an assembled state. Accordingly, the base cannula 2 which has been secured to the operating site is then coupled to the slotted cannula 12. Once the slotted cannula 12 is in place, a tool 45 may be used to insert the camera insert 40 into the slot 30 as shown in Figure 8. Subsequently, the tool 45 may be removed, or alternatively the tool 45 may incorporate electrical leads to the insert and remain in the slot 30 during the surgery. Additional illumination, including by one or more fiber optic strands/bundles (not shown in Figure 8) may also be provided to accommodate lighting insert. According to one embodiment, the camera insert 40 provides both video capabilities and illumination to the surgical site. Further description

of the various camera technologies which may be incorporated in this design shown in Figure 8 are described in greater detail below, but expressly include CCD and CMOS technology.

Figure 9 shows an angled tool for use in performing spinal surgery procedures where an implant is introduced to the surgical site that includes illumination and/or video capabilities. According to a preferred embodiment, the angled tool is comprised of a longitudinal shaft, and has a first or operating end and a second or working end. The shaft is preferably tubular and has a bore running through the length of the angular tool suitable for receiving an insert. The insert further comprises CMOS or CCD video imaging device(s), which permit a user to view images captured by the at least one CMOS or CCD imaging device. According to one embodiment the insert and CMOS/CCD video imaging device(s) are disposable. In another embodiment they are reusable. In yet another embodiment, the angled tool further comprises one or more illumination devices arranged in an annulus around the one or more CMOS or CCD video imaging devices to enhance illumination at the surgical site.

In use, by providing one or more CMOS or CCD video imaging devices (which according to one embodiment further comprise at least one wireless transmitter for transmitting data wirelessly to at least one display) and illumination surrounding the video imaging devices, the surgeon has the ability to view and illuminate the patient operating site and/or the interior of the surgical cannula with the angled tool, in addition to any illumination that is provided by the cannula. Figure 10 provides an elevation view of the angled tool of Figure 9 for further illustration of the tool and the features described herein.

According to yet another embodiment of the present disclosure, a tool (other than the angled tool described above) is provided that comprises at least one CMOS or CCD video imaging device, which permits a user to view images captured by the CMOS or CCD imaging device of the disc space or other surgical area to be operated on. For example, one or more specula, curettes, awls, blades, scrapers, or other surgical tools may incorporate the video insert described in greater detail below, for capturing and viewing images of the surgical site after dissection has occurred. This may be accomplished by providing a CMOS or CCD camera at the distal end of the one or more tools, and either wirelessly or hardwire transmitting the images captured by that CMOS or CCD camera to a display.

According to another embodiment of the present disclosure, a tool is provided that comprises at least one CMOS or CCD video imaging device, which permits a user to view

images captured by the CMOS or CCD imaging device of the disc space or other surgical area to be operated on. For example, one or more disc debridement tools may incorporate the video insert described in greater detail below, for capturing and viewing images of the intervertebral disc space after and during dissection. This capacity allows for a more complete and safe disc space preparation. A more precise carpentry of the disc space allows for an increased potential for fusion and a reduction of vertebral endplate or soft tissue injury. This may be accomplished by providing a CMOS or CCD camera at the distal end of the one or debridement tools, and either wirelessly or hardwire transmitting the images captured by that CMOS or CCD camera to a display.

According to an alternative embodiment, one or more light fibers/bundles may be fashioned in an annulus around the camera insert 40 to provide illumination to the surgical site. In still another embodiment, the light fibers may be replaced by LEDs in a remote light source or at the distal-tip of the cannula 12 or the camera insert 40. The light source may come from an external device such as a headlight lamp, or a standard-type light source commonly found in operating rooms which plugs into an adaptor on the cannula 12.

According to a preferred embodiment, the cannula described herein comprise at least one slot through which one or more camera chip(s) can be inserted on a complimentary thin plastic composite stem-shaped insert, which preferably fits in a tongue and groove fashion along the tubular body of the cannula. The camera chip(s) with associated wide-angle optics and its composite holder can be removed during the course of the operation for cleaning or when the cannula needs to be re-directed during the course of the surgery. The camera chip, which according to a preferred embodiment is based on either CCD or CMOS technology, may have the necessary video-processing circuitry onboard the camera chip housing or the video-processing circuitry may be housed several meters away from the camera chip and connected by a cable or via wireless transmission.

The following patents are hereby incorporated by reference for the express purpose of describing the technology related to the use of illumination and video capabilities described here, including the use of camera chips and CCD or CMOS technology: U.S. Patent No. 6,310,642; U.S. Patent No. 6,275,255; U.S. Patent No. 6,043,839; U.S. Patent No. 5,929,901; U.S. Patent No. 6,211,904; U.S. Patent No. 5,986,693; and U.S. Patent No. 7,030,904.

Referring again the drawing figures, Figure 11 shows two views of a cannula which incorporates light emitting diode or "LED" illumination devices and at least one slot

for incorporating a CMOS or CCD camera insert into the cannula wall. As shown in Figure 11, the cannula is generally ovoid in shape (as viewed in cross-section or in a top plan view), and has at least one inwardly facing shoulder, through which one or more LED's may be inserted or secured for providing illumination about the interior of the cannula. According to a preferred embodiment, the cannula further comprises at least one planar wall, which breaks the generally ovoid shape of the cannula, and it is about this planar surface that the CMOS or CCD camera insert is preferably secured.

According to a preferred embodiment, the CMOS or CCD camera insert is inserted into a slot or groove or channel which is formed about one interior wall of the planar surface of cannula as shown in Figure 11. Alternatively, the CMOS or CCD camera insert can be attached by other means, such as by using fastening devices known in the art, or by attaching magnetically, for example, by way of one or more neodymium magnets.

According to the embodiment shown in Figure 11, the inwardly facing shoulder creates an interior plane (as viewed in cross-section) which accommodates the coupling of a progressive cannula, thereby extending the overall length of the cannula. Thus, one or more of the progressive cannula, which may be coupled together in a telescoping arrangement, may be disposable, reusable, etc.

Figure 12 shows a more detailed view of the location of the LED devices, which according to a preferred embodiment are at least three in number. The LED devices are preferably spaced equidistance from one another and at opposite poles of the generally ovoid cross-sectional shape of the cannula. According to alternate embodiments, fewer or greater number of LEDs may be provided for providing sufficient illumination within the cannula, and it is expressly understood that locations other than those shown in Figure 10 are understood to be compatible with the nature of the invention disclosed herein.

Referring now to Figure 13, a CMOS or CCD camera insert which is hardwired to a connector is shown in a perspective view in relation to a progressive cannula according to one embodiment. As shown in Figure 13, the CMOS or CCD camera insert may be inserted along the interior portion of the generally planar surface of cannula, to a certain depth of the cannula, such that it is positioned to capture images at the distal end of cannula (i.e., the end of the cannula closest to the surgical site).

As shown in Figure 13, the distal end of the cannula may also comprise a exterior slot for securing to an anchor or guide wire, which may be affixed to one or more anatomical features located at or adjacent the surgical site. Alternatively, this slot may also facilitate connection of this cannula to one or more progressive cannula. The

connector shown in Figure 13 may be hardwired to the CMOS or CCD camera device, and is of a nature to connect to one or more display means, such as an LCD or LED or other video display. Thus, images captured by the CMOS or CCD camera device are transmitted via the connector to the display for viewing either still or live video images captured during the surgery.

Referring now to Figure 14, a detailed perspective view of the CMOS or CCD camera device and fiber optic array of illumination members are shown. According to this embodiment, the CMOS or CCD camera device is protected by a housing, which is generally cylindrical and surrounds a portion of the CMOS or CCD camera device. At one end of the camera housing is an opening for the lens of the CMOS or CCD camera device, and also for the fiber optic array of illumination members. In this embodiment, the fiber optic array of illumination members substantially surrounds the lens of the CMOS or CCD camera device. These illumination members according to a preferred embodiment are fiber optic strands, which are arranged in one or more layers about the circumference of the lens of the CMOS or CCD camera device. The overall size of the CMOS or CCD camera device, fiber optic array of illumination members and camera housing are sufficiently small such that they do not interfere with the insertion of tools, implants, etc. in the body of the cannula and used by the surgeon during the surgical procedure. Other details regarding the CMOS or CCD camera insert are provided above in connection with Figures 1-8.

Additional views of the CMOS or CCD camera insert and the cannula according to a preferred embodiment are shown in Figure 15. As shown in Figure 15, the CMOS or CCD camera insert is attached to an insert which operates like a stem and slides longitudinally down one planar surface of the cannula where it engages a slot. This engagement between the insert and the slot secures the CMOS or CCD camera device to the interior of the cannula. The connector shown in Figure 15 provides both power and the illumination necessary to operate the CMOS or CCD camera device, including the fiber optic array of illumination members.

Referring now to Figure 16, a pilot cannula and dilator assembly are shown in both cross-sectional and elevation views. During the surgical procedure, it may be necessary for a initial probe, such as a slender dilator or also known as a pilot cannula to be inserted into a small incision and used to probe the tissue between the incision and the surgical site. The pilot cannula or dilator may be used for this purpose, and may incorporate the video and/or illumination capabilities as described in more detail above. As shown in Figure 16,

the pilot cannula is approximately 2.5 millimeters to 5 millimeters in diameter, after the pilot cannula is inserted and located on the surgical site, a first dilator may be inserted on top of or around the pilot cannula, which first dilator is generally in the range of 5 millimeters to 10 millimeters in diameter.

Additional dilators may be inserted over the first dilator in a progressive fashion until a sufficient pathway through the patient's tissue and anatomy has been formed for inserting one or more of the progressive cannula described above over these progressive dilators. By way of example but not limitation, a second dilator ranging in diameter from 7.5 millimeters to 12.5 millimeters may be placed over and around the first dilator, then a third dilator ranging in diameter from 10 millimeters to 15 millimeters may be placed over the second dilator, and a fourth dilator ranging in diameter from 12.5 millimeters may be placed over the third dilator. This step may be repeated several times by the surgeon, as necessary, until an adequate sized pathway is formed for inserting the cannula over the dilator assembly without causing trauma to the incision, the patient's anatomy, the surgical site, etc. It is expressly understood, although not depicted in Figure 16, the video capabilities and illumination capabilities described herein may be incorporated with the pilot cannula and each of the first, second, third and fourth dilators shown in Figure 4 (and any additional progressive dilators) for facilitating insertion, placement, and for achieving the other benefits described in the present disclosure.

According to one particular embodiment of the present disclosure, a system is provided where the cannula/dilator tools further include one or more electrical probes at the exit portal, which are adapted to assist the surgeon in identifying the presence and location of nerves as the probe is advanced during minimally-invasive surgery, thereby providing a device for guiding the path of other surgical instruments to be inserted into the intervertebral space. For example, an expandable tip cannula may be provided, which functions both as an access portal for spinal surgery and as a system for nerve surveillance, such that the presence and relative position of the nerves of the lumbo-sacral plexus can be detected as the expandable tip cannula is inserted through the patient's fascia and musculature. One particular advantage of determining the position of the nerves with respect to the distal tip of the cannula is that the nerves can be avoided or gently moved out of the surgeon's way while inserting the cannula. This concept may also be incorporated in the one or more slender dilator tools described in detail herein.

According to another embodiment, the present disclosure provides a system of cannulas/dilators adapted to assist the surgeon in guiding the path of surgical instruments

received into the intervertebral space, while identifying the presence and location of para-spinal nerves as the cannula/dilator is advanced to a patient's intervertebral space during minimally invasive surgery. In various aspects of the present disclosure, the probes may be comprised of one or more electrodes powered at a low level to sense the position of the nerves of the lumbo-sacral plexus through continuous real time electromyographic monitoring. Alternatively, these electrodes can be powered at a higher level such that they operate to cauterize blood vessels. Safety systems ensure that power levels sufficient to cause cauterization are not activated if a nerve is sensed to be near the electrodes at the distal end of the cannula/dilator.

Figures 17-18 show a specific dilator or "wand" according to one preferred embodiment, which may be used for achieving the objectives described above in connection with Figure 16. In this embodiment, the dilator or wand has a generally ovoid cross-sectional shape and is sufficient in size to accommodate a plurality of lumens, through which a CMOS or CCD camera insert and/or illumination means may be incorporated. According to a preferred embodiment, the dilator or wand comprises at least one lumen which extends beyond the length of the generally ovoid section of the dilator or wand, which may be used in a tapering configuration (and according to one alternative embodiment, a telescoping configuration) for gently probing through tissue, achieving vision (via CMOS or CCD video technology) of the anatomy through which the surgeon must navigate prior to securing the cannula to the surgical site, etc. In this embodiment, the dilator or wand also comprises a second lumen through which one or more conductive materials may be inserted for stimulation of the various nerves of the psoas. This second lumen may also house illumination means, such as fiber optic strands and/or LED devices, for allowing a light source at the useable end of the dilator or wand.

In use, this enhanced dilator allows the surgeon to have direct visualization and illumination of the retroperitoneal space, and allows simultaneous stimulation of the psoas or other spinal nerves, via one or more electrical probes which are incorporated into one of the plurality of lumens of the dilator. This dilator therefore serves as a guide, which allows the surgeon to safely and securely reach the surgical site without causing damage to any of the patient's anatomy, and continue with application of progressively larger dilators and working cannula (including those described herein) without causing injury to the patient.

The dilator may vary in length, according to the patient and the unique anatomy presented for the surgical operation. According to a preferred embodiment, the length

dilator is in the range of 50-500 millimeters in length, and the diameters is approximately 2-10 millimeters. The material of the dilator is preferably selected from the group consisting of aluminum, iron, titanium, steel, stainless steel, surgical stainless steel of the general alloy type of iron, carbon, chromium (12-20%) molybdenum (0.2-3%) and nickel (8-12%), martensitic steel, grade 316L austenitic steel, grade 316LVM austenitic steel, grade 316 stainless steel, medical grade plastic and PEEK.

According to one embodiment of the present disclosure, the same distal end of the dilator that comprises a CCD or CMOS video device further comprises a conductive material, which is capable of transmitting signals, such as neurological signals to a measuring device for detecting one or more nerves in-between the incision and the surgical site. This distal tip may be made of a variety of different conductive materials, including but not limited to copper, brass, aluminum, metal alloy, inherently conductive polymers or any of the known polymers having a conductive filler, such as metal fillers, metal-cooled glass and/or carbon fiber fillers. Alternatively, the CCD or CMOS video device located at the distal end of the dilator may be surrounded by a lens, and the lens made of a conductive glass, wherein the conductivity of the device and the lens of the device are accomplished in a single integrated apparatus. According to a preferred embodiment, the distal end of the dilator is generally ovoid in shape and provides for a compound radii, which further assists in moving soft and often sensitive tissue away from the tip of the dilator as it is inserted into the patient. Similarly, the conductive material at the distal tip of the dilator is preferably ovoid, and permits material to be moved gently away from the device at is progressed deeper into the incision.

According to various embodiments, the dilator further comprises one or more fiber optic fibers which extend longitudinally down the shaft of the dilator for providing illumination. According to one embodiment, the one or more strands are positioned proximate to the CCD or CMOS video device, such that the CCD or CMOS video device has adequate illumination for capturing images at the distal end of the dilator. This illumination also allows a surgeon to achieve adequate visualization, both with the naked eye and through images captured by the CCD or CMOS video device. In an alternate embodiment, the illumination is proved by one or more LED devices.

Referring again to the drawing figures, according to one embodiment, the dilator is comprised of a generally cylindrical body, having a generally ovoid cross-section, and may incorporate multiple lumens extending therethrough. One or more internal lumens may incorporate the fiber optic illumination strands and/or the CCD or CMOS video

device, while the second lumen may provide a channel for receiving signals via the conductive material at the distal end of the dilator. This second lumen may alternately serve as a guide for wire anchors to be positioned from the end opposite the CCD or CMOS video device, which allow the surgeon to insert, for example, .0625 inch K-wire or other suitable wire or fastening device to secure to the disc space. According to the embodiment shown in the drawing figures (Figs. 17, 18), the illumination and CCD or CMOS video device may extend a distance beyond the generally cylindrical body of the dilator, such that the illumination and video device precede the navigation of the generally cylindrical body of the dilator, thereby permitting the surgeon to see and illuminate tissue, sensitive anatomy, etc. prior to impact by the dilator.

Referring now to Figure 19, a perspective view of a modified retractor according to one embodiment of the present disclosure is shown, which incorporates illumination and/or video capabilities of the nature described above. This "Sherrill" retractor comprises a longitudinal shaft, which extends longitudinally a length sufficient for inserting into a patient to assist in retracting tissue between the incision and the surgical site, and may incorporate one more lumens internal to the shaft for providing illumination means and/or CMOS or CCD video capabilities. This "Sherrill" retractor may alternatively be used, or used in connection with the dilator or wand described above in connection with Figures 17-18. Further details of this modified retractor are provided below.

Figure 20 depicts another perspective view of the modified retractor of Figure 19. In a preferred embodiment, the blade of the modified retractor (such as the one shown in Figure 20) comprises two thin edges formed by the thickness of the blade, which are convenient for use in attaching a semi-circular or semi-oval shaped cannula by sliding the cannula over the two this edges. Thus, according to one embodiment, a cannula is provided with two corresponding grooves or tracks along an external surface of the cannula body, and oriented to couple with the two thin edges of the modified retractor.

In this manner, a surgeon using the modified retractor may first insert the retractor, retract any tissue and other anatomical features between the incision and the surgical site, and then attach the cannula by sliding the cannula along the two thin edges in a longitudinal direction relative to the blade of the retractor. In another embodiment, the two thin edges may have slightly raised surfaces or lips for facilitating this attachment via a tongue and groove connection. In one embodiment the handle of the modified retractor extends in generally the same direction as the blade of the modified retractor, or is offset

from the plane of the blade by an angle less than 90 degrees (such as the handle depicted in Figures 19-20) to facilitate this interconnectivity between the modified retractor and the cannula described above.

According to one embodiment of the present disclosure, a method is disclosed whereby the dissecting finger is followed by a deep retractor or "Sherrill" retractor, which preferably incorporates one or more LED lights at its distal end, and a handle containing the LED power source. According to this method, as the surgeon advances his blunt finger dissection of the retroperitoneal space, the Sherrill retractor follows the finger with a visible path preventing inadvertent damage to intra- and retroperitoneal structures. The Sherrill retractor is preferably modified to incorporate one or more camera chips (such as CMOS chips) at its contacting end and secured within a housing for allowing safe, visual placement through the dissected retroperitoneal space onto the psoas muscle while avoiding the ilioinguinal and genitofemoral nerves on the surface of the muscle.

According to one embodiment, a flexible sleeve may be fabricated to fit over the body of an existing retractor or distractor device and incorporate the lumens or channels for inserting one or more fiber optic strands or bundles, and may also include a slot for inserting a camera insert such as the type described above. Therefore, existing retractors manufactured by various parties may incorporate the concepts of the present disclosure despite having no prefabricated lumens or slots for accommodating the necessary illumination and/or video capabilities discussed herein.

According to varying embodiments, this dilator and cannula system allows simultaneous illumination and video imaging of the path through which the surgeon must navigate to reach the surgical site. This in turn reduces the risk of unwanted dissection, unwanted exposure and damage to surrounding nerves, soft or sensitive tissue, etc. In use, the dilator may be further manipulated in conjunction with the Sherrill retractor (see Fig. 19), wherein this Sherrill retractor provides a narrow yet deep retracting blade, which may or may not incorporate a illuminated end, such as by an LED, which allows the surgeon to initially probe using the blade and remove the initial tissue immediately below the incision. The Sherrill retractor blade therefore provides an initial depth of illumination and navigation, and clears a passage for further insertion of the dilator. Multiple views of the Sherrill retractor used in combination with the dilator are shown in the appended drawing figures.

In use, a method of retro peritoneal dissection involves using one or more slender video dilators to gently probe through the incision and to view the images captured by the

CCD or CMOS video device located on or near the distal end of the one or more slender dilators. As the surgeon encounters sensitive anatomical features, such as the patient's intestine, images of those anatomical features will become apparent to the surgeon via the display. The images of other anatomical features are also captured by the CCD or CMOS video device during dissection and insertion of the one or more slender dilators.

If certain anatomical features cannot be moved from the path of the dilator, the approach of the surgeon may be adjusted accordingly, and the dilator inserted around these features to avoid undesired dissection. This in turn allows the surgeon to view the path to the disc space, achieve the desired approach and insure that any further instrumentation or apparatus that are inserted through the incision do not encounter the sensitive anatomical features of the patient, and further insure that the cannula are properly seated adjacent the disc space.

Once the slender dilator has been inserted through the sensitive anatomy of the patient and approaches the desired surgical cite, the surgeon can further use the images captured from the CCD or CMOS video device to find the desired location of the disc space where the operation will proceed, dissection of the disc space will occur, etc. According to one embodiment, this method involves incorporating one or more cannula, which may be inserted over the video dilator, and seated on the disc space using the same path achieved by insertion of the video dilator. Additional cannula may then be placed over this initial cannula, until the desired access has been achieved. Once the cannula are in position over the slender dilator, the surgeon may remove the dilator and use direct vision through the cannula, or use the slender dilator to continue to view the disc space, or both.

This approach and apparatus is further advantageous in that it alleviates a common problem experienced by surgeons performing minimally invasive surgical procedures, which is fatigue. Using this dilator apparatus and method the surgeon is not required to position himself or herself over the cannula, or over a cumbersome or bulky microscope, which are frequently required in other surgical methods. By avoiding the positioning of the surgeon over the patient's body, the cannula, the microscope, etc., the surgeon is able to avoid significant discomfort and fatigue, which occurs naturally over time, particularly due to the surgery exceeding two hours to complete, or in some cases, 8 to 10 hours to complete. Using this method, the surgeon further avoids the necessary precautions required for exposure to radiographic imaging using this method. For example, the surgeon, by eliminating the use of x-rays and other radiographic equipment, is not required

to wear a lead vest, a neck shield, a leaded glass face shield, etc. This further reduces the weight that the surgeon must bear during the operation, further reducing the stress and fatigue on the surgeon during the procedure.

Although not shown in the enclosed drawing figures, the slender dilator may further comprise one more mechanisms for cleaning or clearing the lens of the CMOS video camera at the distal end of the dilator. According to one embodiment, the clearing of the lens may occur mechanically, such as by a wiping mechanism, applied to a dilator such as the one shown in Figures 16-18. This wiping mechanism may be mechanically operated from the opposite distal end of the slender dilator as the one incorporating the CCD or CMOS video device, such as by a trigger mechanism. In operation, by moving the trigger longitudinally along the axis of the dilator, the surgeon can move the wiping device across the lens of the CCD or CMOS video device, thereby clearing the lens of loose tissue, mucus, or other fluids.

Accordingly, the method of this invention provides a surgeon viewing the operative site, instead of through the oculars of the microscope, but rather with the ability to view the patient's anatomy by presenting the images of the surgical site on a video screen or other display in front of him (or her) and in front of any assistant(s), consulting surgeons, hospital staff, etc. Due to the camera chip device and associated optics being placed directly at or immediately adjacent the operative site, the image collected is free from the distortions and the "field-flattening" effect commonly associated with complex optical stacks commonly used in operating microscopes and endoscopes. The results in a significant increase in "depth-cues" and color-reproduction. The camera technology (preferably CCD or CMOS technology) available provides a three dimensional-type picture to the surgeon with all necessary illumination and without the extra costs of adding a second camera and expensive intra-ocular optical orientations. The costs of the microscope and its maintenance, plastic draping, sterility/contamination issues and surgeon fatigue are either eliminated or substantially reduced.

The system according to one embodiment of the present disclosure includes providing illumination and video capability with a cannula having a shape other than round (e.g., oval, pointed, square cornered, etc.) and having an end (e.g., the end inserted into the patient, distal from the user) that is angled and/or shaped to be ideally seated in a surgical site. Asymmetrical cannulas may allow visualization of the facet joint, and an "egg-shaped" cross section may allow for the best view of the facet joint and minimizes the medial-lateral dissection that a round cannula would require.

Still other aspects of the invention are directed to cannula instruments that have a patient contacting end that is adjustable to assume a predetermined conformation. Thus, in one embodiment, material forms the tip end that comes into contact with bone, tissue, and especially as it nears nerve tissue, with such cannula end material being malleable to an extent necessary for the surgeon to mold the end conformation such that it achieves desired avoidance of particular structures encountered in any particular surgery. Thus, if a bony outcropping, a nerve fiber, etc. is perceived by the surgeon, the cannula tip end can be adjusted to avoid undesired contact or interference with such tissues or structures. In particular embodiments, the ability to adjust the geometric parameters of the tip end is achieved by manipulation of the other end of the instrument. For example, providing a turnable component at the opposite end of the instrument, the shape of the other end of the instrument (i.e. the end inserted into the patient) can be adjusted to expand circumference, reduce circumference, render the opening more or less oblong, etc. In such a manner, it is possible to avoid having to remove the instrument or cannula from the patient's site to adjust the morphology of the instrument or cannula operating end, thus saving time, avoiding undesired reinsertion procedures, etc.

Certain embodiments of the surgical cannula, which may be used in conjunction with certain aspects of the present disclosure, include cannula having a bottom opening that is angled oblique to the top opening. These cannuale may be in correspondingly larger or smaller form factors so that they may become nested within one another for facilitating insertion in the patient. The cannula may have an elliptical cross-section. In one embodiment, the ellipse has a width of about 20 millimeters in its major axis, and a width of about 16 millimeters in its minor axis. It will be appreciated that the cannula cross-section may be of a different size and have a different shape including, for example, an oval, a rectangle, a square, a rhombus, a trapezoid, a parallelogram, a polygon and a generally oblong shape such as an egg or football shape. As will be appreciated by one having skill in the art, the cross-sectional shape of the cannula permits the user to employ instruments in the cannula that require movement or manipulation in one direction, preferably along the major axis, but to a lesser extent in the other direction. The oblong shape of the cannula would permit, for example, rasps and curettes to be manipulated and used in a joint in a minimally invasive fashion. Similarly, other tools can be manipulated and used in a joint at any angle relative to the shaft of the tool. One having skill in the art will appreciate that the specific dimensional requirements of the cannula will vary based on the length of the cannula, and the items or tools being inserted therein.

As will be appreciated, the cannula provides access to adjacent facets of two adjacent vertebrae. The oval or elliptical shape of the cannula, however, allows the procedure to be performed in a minimally invasive fashion by reducing the incision required to gain access to the surgical site and the reducing the tissue exposed during the procedure. Another advantage provided by certain embodiments of the cannula of the present disclosure is that it provides optimal access to a surgical site that may have anatomy or bone features that make it desirable to have, for example, an angled and/or curved end to the cannula. One having skill in the art will further appreciate that an ideally shaped cannula will allow the user to more safely and reliably access the surgical site and will reduce the risk of injury to the surrounding tissue.

Various dilators may be used (in connection with the cannula of the system described above) having various sizes, various lengths and cross-sectional areas. The dilators, like the cannula described above, may have an oval or elliptical shape. According to a preferred embodiment, one or more dilators may be used to dilate the muscle or other tissue of the patient to access the surgical site. According to a preferred embodiment, a first slender dilator is used to probe through the muscle or other tissue and to locate the desired vertebrae. Once that first slender dilator is seated, additional dilators may be inserted around the previously seated dilator until the desired circumference through the muscle or other tissue is achieved. In this fashion, the first slender dilator serves as a radiographic marker, and establishes the path for subsequent dilators of greater circumference than the first slender dilator. This serves to reduce ischemic injury to the patient and reduces the time necessary to locate and access the desired vertebrae. The first slender dilator has a sufficient circumference to be easily viewed by x-ray or other imaging technology when seating the dilator on the desired vertebrae. The dilators are variable in length, preferably ranging from 3-14cm.

Once the dilators have been used to dilate the muscle tissue surrounding the path to the desired vertebrae, a cannula may be inserted into the interior circumference of the dilators. The cannula according to a preferred embodiment is ovoid in shape to permit dissection from caudad to cephalad (as opposed to from medial to lateral) and further accommodate dissection about the facet joint. As with the dilators, the cannula may be variable in length, ranging preferably from 3-10cm, to accommodate varying depths from skin to bone. As mentioned above, the cross-sectional geometry of the cannula is preferably ovoid in shape, and in a preferred embodiment the major diametrical axis of the cannula is about 20mm, and the minor diametrical axis of the cannula is about 16mm.

Varying embodiments of the cannula described herein may further comprise an angled or sloped surface at one distal end of the cannula for accommodating access and viewing of an implant site that is not directly below the incision. By way of example but not limitation, a surgeon may use one or more of the cannula described herein in conjunction with the dilators described herein to probe through the muscle or other tissue using an angled approach, thereby allowing access to a specific vertebrae either above or below the vertebrae directly below the incision. Once the dilators have been used to clear a path through the muscle or other tissue at an angled approach, the angled cannula may be inserted with the angled or sloped surface oriented so that the angled or sloped surface rests near horizontally against the vertebrae. These cannula assist the access and visibility of additional vertebrae without requiring additional incisions, and further permits securing fastening devices such as screws using an angled approach.

As with the other cannula described above, the cross-sectional shape of the angled cannula is preferably ovoid in shape, and the entire longitudinal length of the angled cannula may be slightly greater than the other cannula described herein. According to another embodiment of the present disclosure, a system is provided where the cannula further include one or more electrical probes at the exit portal, which are adapted to assist the surgeon in identifying the presence and location of nerves as the probe is advanced during minimally-invasive surgery, thereby providing a device for guiding the path of other surgical instruments to be inserted into the intervertebral space.

An expandable tip cannula may be provided, which functions both as an access portal for spinal surgery and as a system for nerve surveillance, such that the presence and relative position of para-spinal nerves can be detected as the expandable tip cannula is inserted through the patient's facia and musculature. An advantage of determining the position of the para-spinal nerve with respect to the distal tip of the cannula in particular is that the para-spinal nerve can be avoided or gently moved out of the surgeon's way while inserting the cannula.

Accordingly, the present disclosure provides a system of cannulas adapted to assist the surgeon in guiding the path of surgical instruments received into the intervertebral space, while identifying the presence and location of para-spinal nerves as the cannula is advanced to a patient's intervertebral space during minimally invasive surgery. In various aspects of the present disclosure, the probes may be comprised of one or more electrodes powered at a low level to sense the position of a para-spinal nerve through continuous real time electromyographic monitoring. Alternatively, these electrodes can be powered at a

higher level such that they operate to cauterize blood vessels. Safety systems ensure that power levels sufficient to cause cauterization are not activated if a nerve is sensed to be near the electrodes at the distal end of the cannula.

A variety of other apparatus and methods may be employed in conjunction with the various aspects described herein to achieve fusion without departing from the spirit of the invention, such as the following apparatus and methods hereby incorporated by reference in their entireties: U.S. Patent Publication Nos. 2010/0137690 to Miles, et al.; 2009/0299411 to Laskowitz, et al.; 2009/0299412 to Marino; 2009/0299477 to Clayton, et al.; 2009/0275995 to Truckai, et al.; 2009/0287262 to Bertagnoli; and U.S. Patent No. 7,621,955 to Goble, et al. Accordingly, additional apparatus, such as a retractor or distractor may incorporate the use of fiberoptic bundles and/or camera inserts described in relation to Figures 6-8 above. In particular, according to one embodiment of the present disclosure, a retractor device may incorporate one or more camera inserts along the shaft of the retractor similar to the camera insert described in relation to Figure 8 above. Also, one or more fiberoptic bundles may be integrated with the insert, or alternatively run along independent lumens or channels along the arms of the retractor or distractor device.

While various embodiment of the present disclosure have been described in detail, it is apparent that modifications and alterations of those embodiments will occur to those skilled in the art. However, it is to be expressly understood that such modifications and alterations are within the scope and spirit of the present disclosure, as set forth in the following claims.

The foregoing discussion of the disclosure has been presented for purposes of illustration and description. The foregoing is not intended to limit the disclosure to the form or forms disclosed herein. In the foregoing Detailed Description for example, various features of the disclosure are grouped together in one or more embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed disclosure requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the following claims are hereby incorporated into this Detailed Description, with each claim standing on its own as a separate preferred embodiment of the disclosure.

Moreover, though the present disclosure has included description of one or more embodiments and certain variations and modifications, other variations and modifications are within the scope of the disclosure, e.g. the use of disposable components comprising

some or all of the apparatus described herein, as may be within the skill and knowledge of those in the art, after understanding the present disclosure. It is intended to obtain rights which include alternative embodiments to the extent permitted, including alternate, interchangeable and/or equivalent structures, functions, ranges or steps to those claimed, whether or not such alternate, interchangeable and/or equivalent structures, functions, ranges or steps are disclosed herein, and without intending to publicly dedicate any patentable subject matter.

What is claimed is:

1. A cannula comprising:

A first or proximal end and a second or distal end and a generally tubular body therebetween;

a bore through the generally tubular body of the cannula extending from the first end to the second end;

a camera insert comprising one or more CMOS or CCD camera devices;

wherein the cannula further comprises at least one slot about a surface of the bore of the cannula for receiving the camera insert within the at least one slot of the cannula; and

wherein the cannula includes at least one first channel for inserting one or more fastening devices and at least one second channel for inserting one or more illumination devices.

2. The cannula according to Claim 1 wherein the cannula may be coupled to a second cannula to extend the effective length of the coupled cannula.

3. The cannula according to Claim 2 wherein the second cannula is attached to the first cannula by a compression relief formed about the first end of the second cannula which is dimensioned to fit in compression with the second end of the first cannula.

4. The cannula according to Claim 2 wherein the second cannula varies in length to accommodate surgery in various portions of a patient's body.

5. The cannula according to Claim 2 wherein the second cannula is asymmetrical about its length.

6. The cannula according to Claim 1 wherein the one or more CMOS or CCD camera devices further comprise wide-angle optics suitable for providing a three dimensional image on an associated display.

7. The cannula according to Claim 1 wherein the camera insert is comprised of a thin, generally stem-shaped plastic composite insert that is received within the at least one slot in a tongue and groove fashion.

8. The cannula according to Claim 1 wherein the camera insert is attached to a surface of the bore of the cannula magnetically.

9. The cannula according to Claim 1 wherein the cannula has a asymmetrical, ovoid, egg-shaped, crescent-shaped, half-sphere, half-oval round cross-sectional shape.

10. The cannula according to Claim 1 wherein the one or more CMOS or CCD devices further comprises at least one wireless transmitter for transmitting images captured by the one or more CMOS or CCD devices to a display.

11. The cannula according to Claim 1 wherein the cannula has a width in the range of about 15-35 millimeters.

12. The cannula according to Claim 1 wherein the cannula is formed of substantially sterile material, and may further comprise biocompatible polymers, elastomers, ceramics, aluminum or other metals

13. The cannula according to Claim 1 wherein the second end of the cannula is adjustable to a desired conformation.

14. The cannula according to Claim 1 wherein the second end of the cannula further comprises at least one exterior slot for securing to an anchor or guide wire for affixing the cannula to one or more anatomical features of a patient.

15. The cannula according to Claim 1 further comprising one or more electrical probes at or adjacent the second end of the cannula for identifying the presence and location of nerves in the patient.

16. The cannula of Claim 15 wherein the probes may be comprised of one or more electrodes powered at a low level to sense the position of a para-spinal nerve through electromyographic monitoring.

17. The cannula according to Claim 1 further comprising an expandable tip at the second end of the cannula for detecting the presence and relative position of para-spinal nerves.

18. The cannula according to Claim 1 wherein the one or more illumination devices are comprised of fiber optic strands or bundles.

19. The cannula according to Claim 1 wherein the one or more illumination devices are arranged circumferentially along one or more walls of the cannula.

20. The cannula according to Claim 1 wherein the one or more illumination devices terminate at least a centimeter from the second end of the cannula.

21. The cannula according to Claim 1 wherein the one or more illumination devices are arranged in an annulus around the one or more CMOS or CCD camera devices to enhance illumination at the surgical site.

22. The cannula according to Claim 1 wherein the one or more illumination devices are comprised of one or more light emitting diodes.

23. The cannula according to Claim 1 wherein the at least one second channel for inserting one or more illumination devices exists substantially the entire length of the cannula.

24. The cannula according to Claim 1 wherein the one or more illumination devices are comprised of fiber optic strands or bundles for transmitting light.

25. a surgical tool comprising:

a shaft connecting a operating end of the tool with a working end of the tool;

a disposable insert that is attachable to the shaft of the tool;

the disposable insert further comprising at least one CMOS or CCD video imaging device, which permits a user to view images captured by the at least one CMOS or CCD imaging device;

wherein the at least one CMOS or CCD video imaging device further comprises at least one wireless transmitter for transmitting data wirelessly to at least one display for displaying images captured by the at least one CMOS or CCD camera device.

26. The surgical tool according to Claim 25 further comprising one or more illumination devices arranged in an annulus around the one or more CMOS or CCD video imaging devices to enhance illumination at the surgical site.

27. A dilator comprising:

at least one lumen extending further than the length of the dilator;

a plurality of fiber optic strands and/or light emitting diode devices coupled to the dilator;

one or more electrical probes at the distal end of the dilator which are connected to electrical leads at the opposite end of the dilator;

wherein the one or more electrical probes are provided to assist the surgeon in identifying the presence and location of nerves as the dilator is advanced within a patient's body and for establishing a path for subsequent surgical instruments;

wherein the plurality of fiber optic strands and/or light emitting diode devices illuminate the area immediately surrounding the distal end of the dilator for enhancing vision of the anatomy through which the dilator is inserted.

28. The dilator according to Claim 27 further comprising at least one CMOS or CCD video imaging device at or near the distal end of the dilator for capturing photographic images of the patient's anatomy and the surgical site.

29. The dilator according to Claim 27 having a diameter in the range of approximately 2.5 millimeters to 10 millimeters.

30. The dilator according to Claim 27 wherein the material of the dilator is preferably selected from the group consisting of aluminum, iron, titanium, steel, stainless steel, surgical stainless steel of the general alloy type of iron, carbon, chromium (12-20%) molybdenum (0.2-3%) and nickel (8-12%), martensitic steel, grade 316L austenitic steel, grade 316LVM austenitic steel, grade 316 stainless steel, medical grade plastic and PEEK.

31. The dilator according to Claim 27 having a length in the range of 50-500 millimeters.

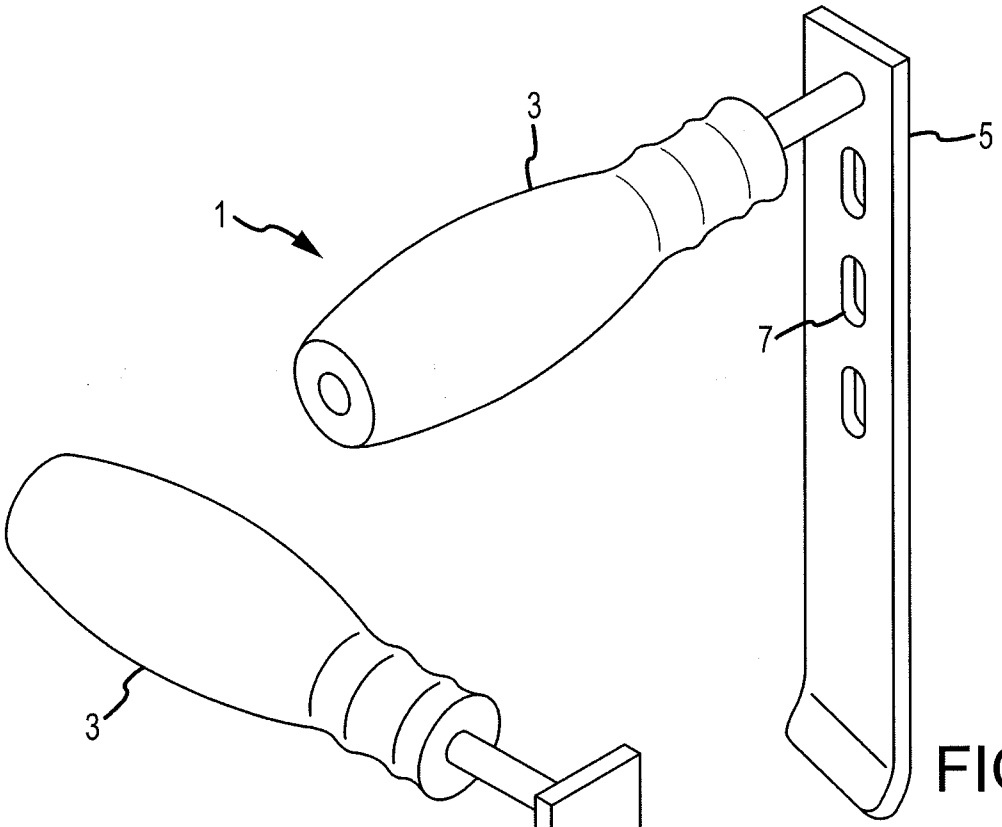


FIG.1

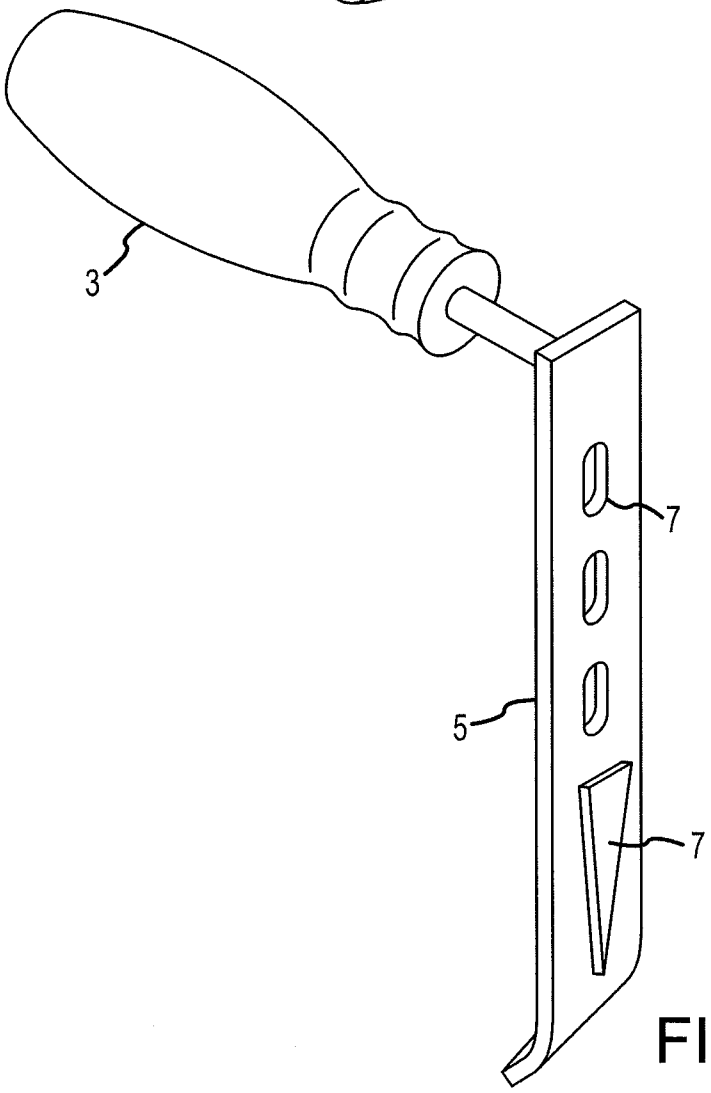


FIG.2

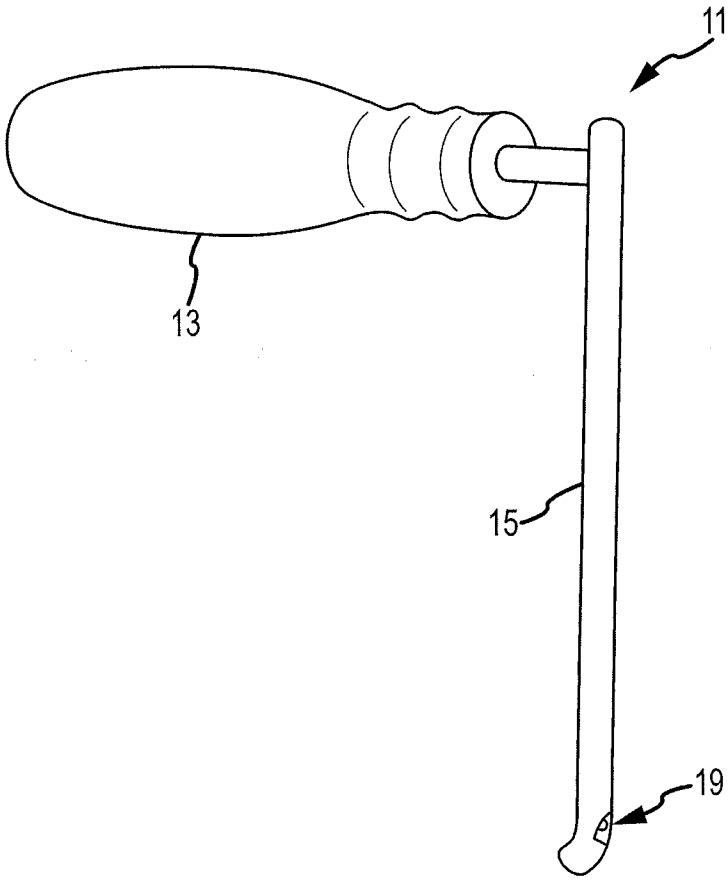


FIG.3

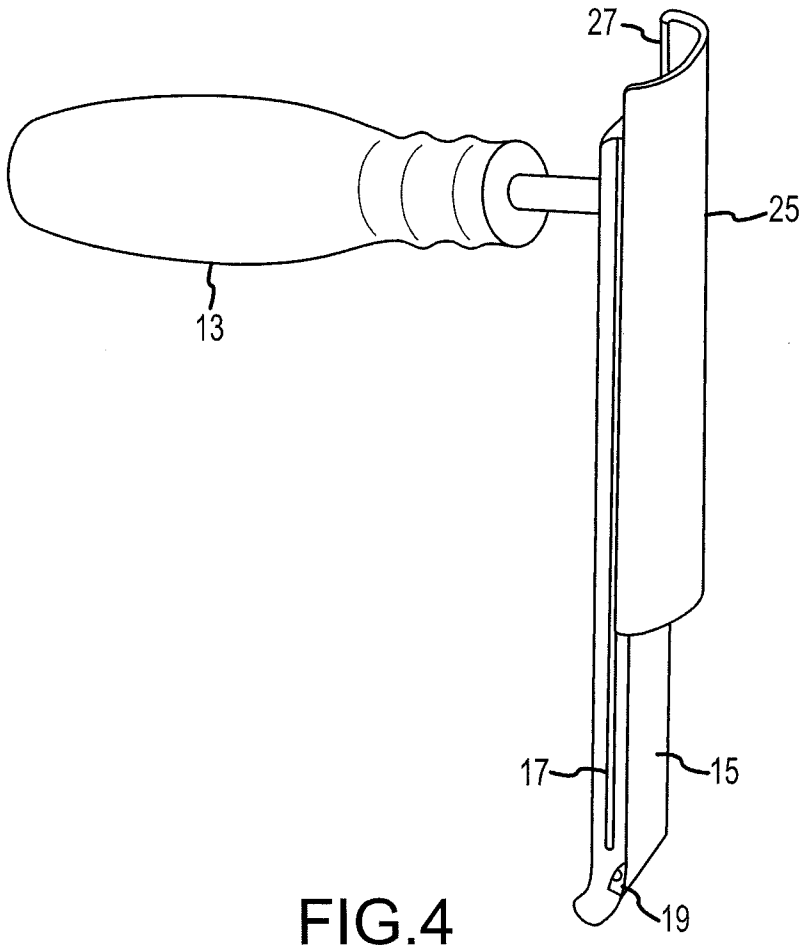


FIG.4

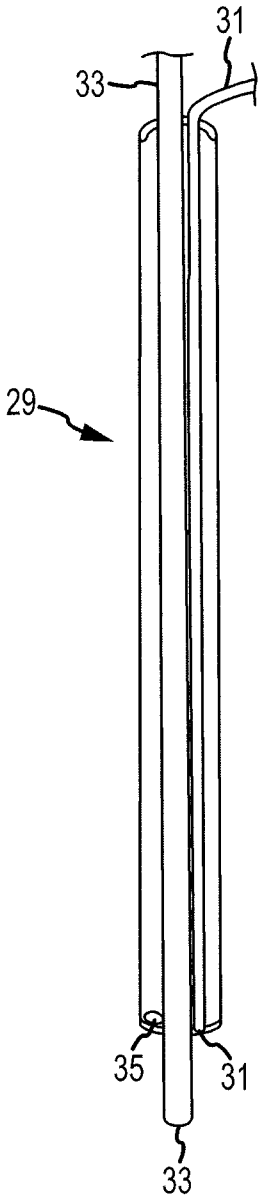


FIG.5

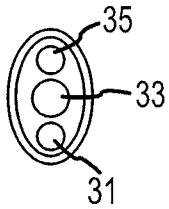


FIG.6

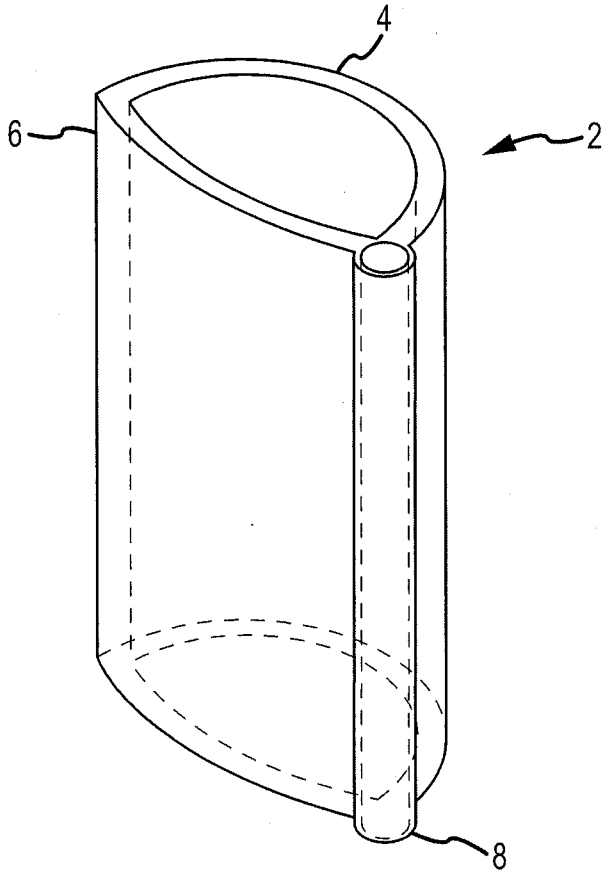


FIG.7

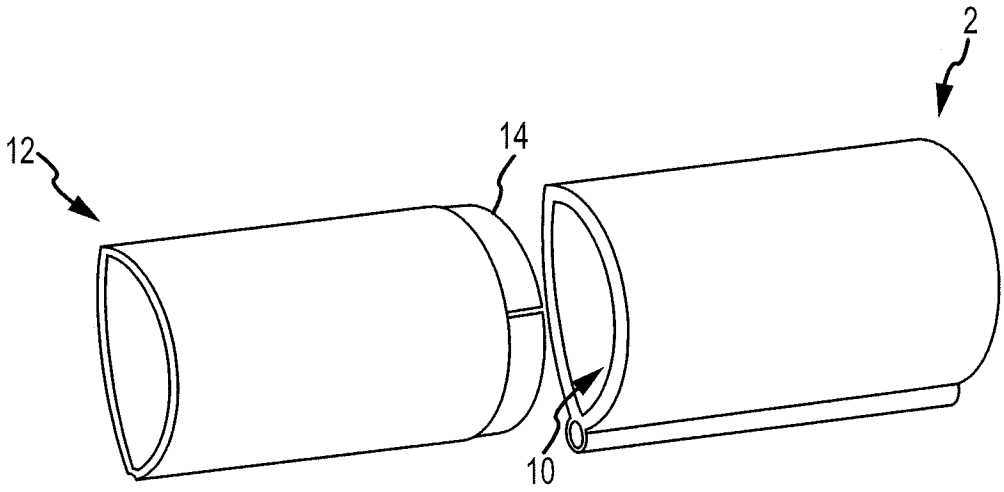


FIG.8

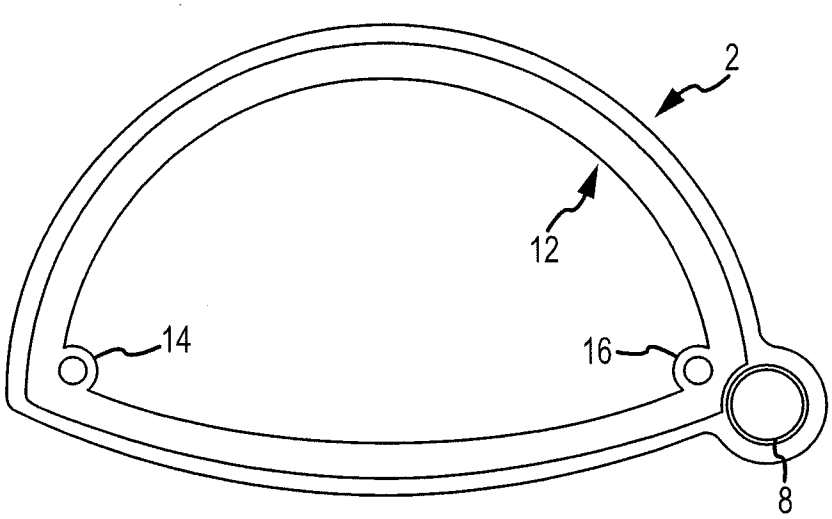


FIG.9

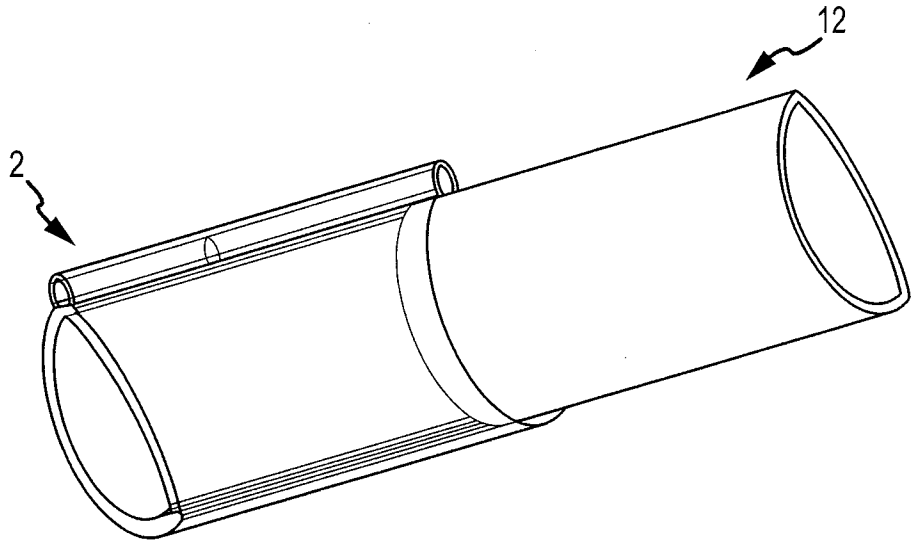


FIG.10

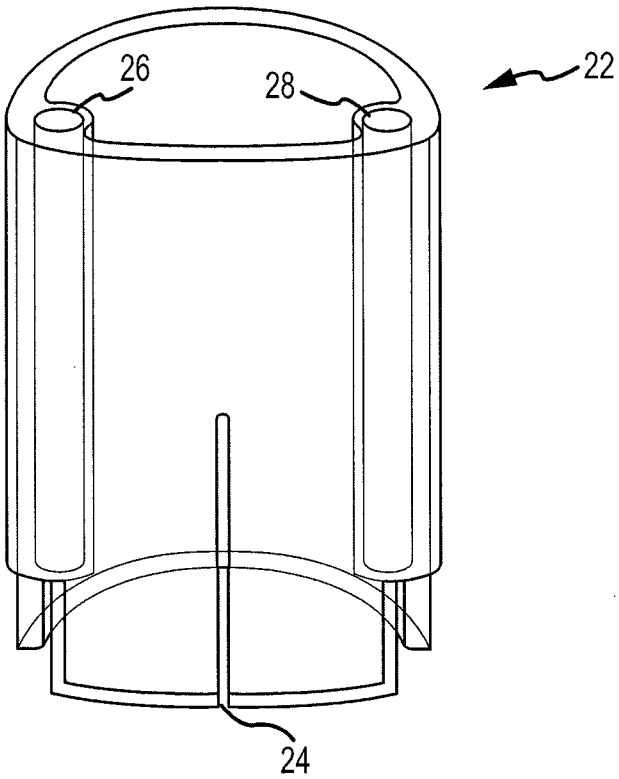


FIG.11

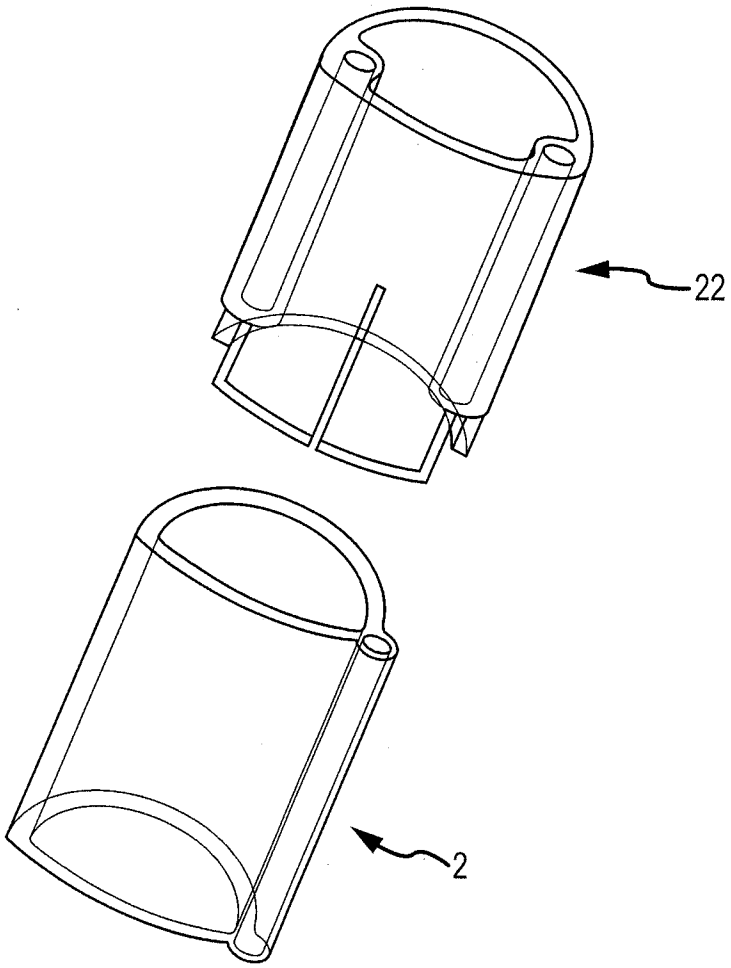


FIG.12

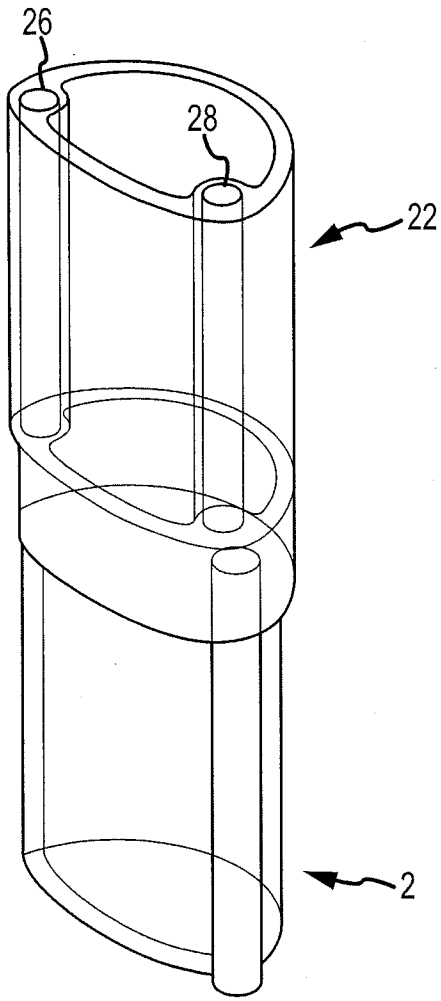


FIG.13

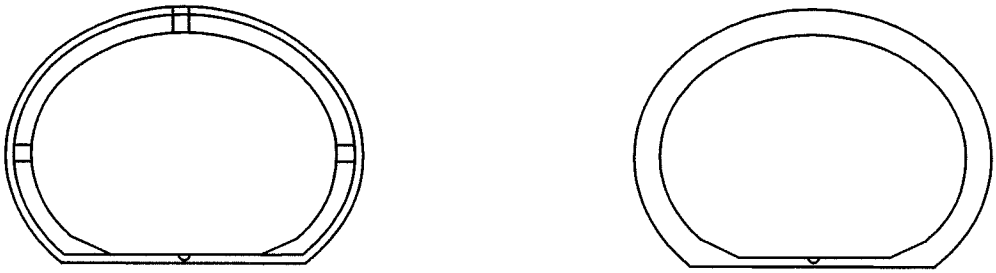


FIG.14

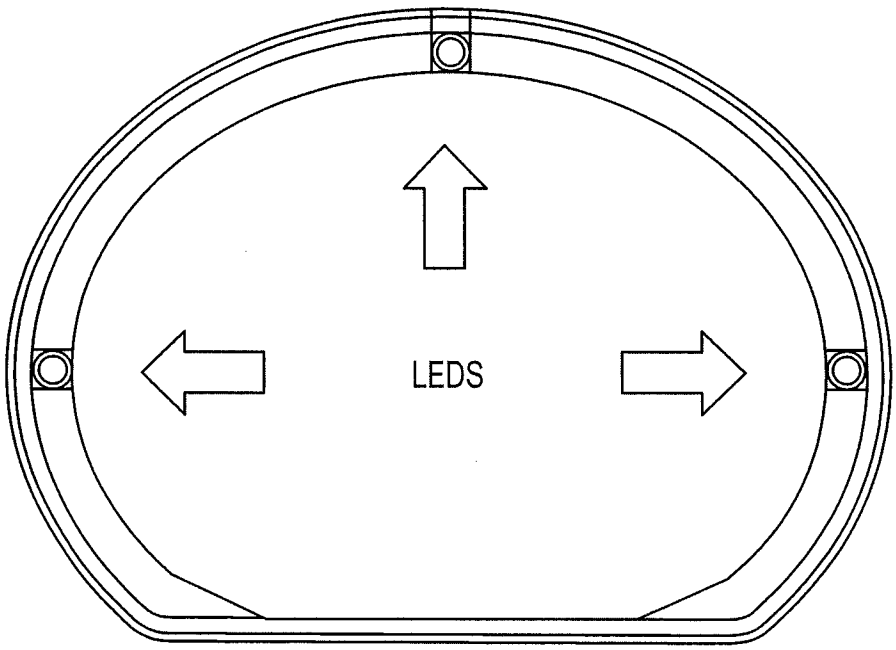


FIG.15

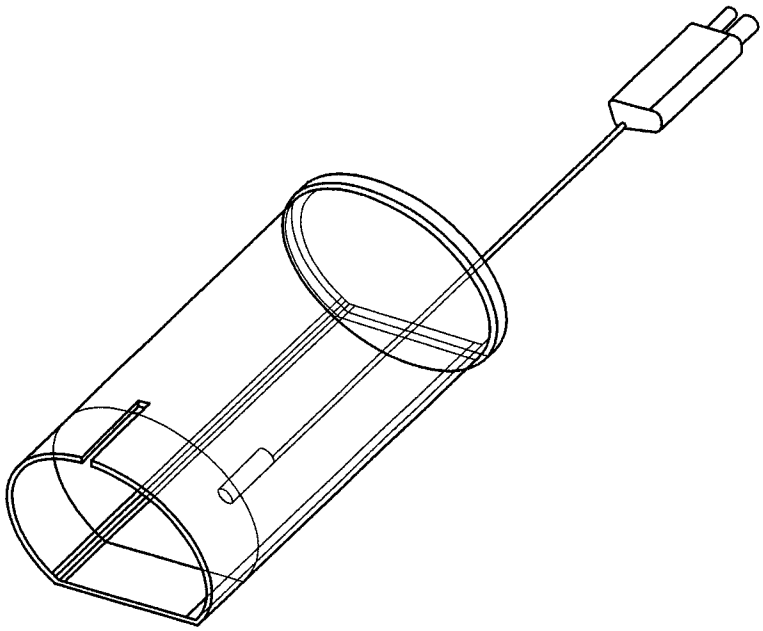


FIG.16

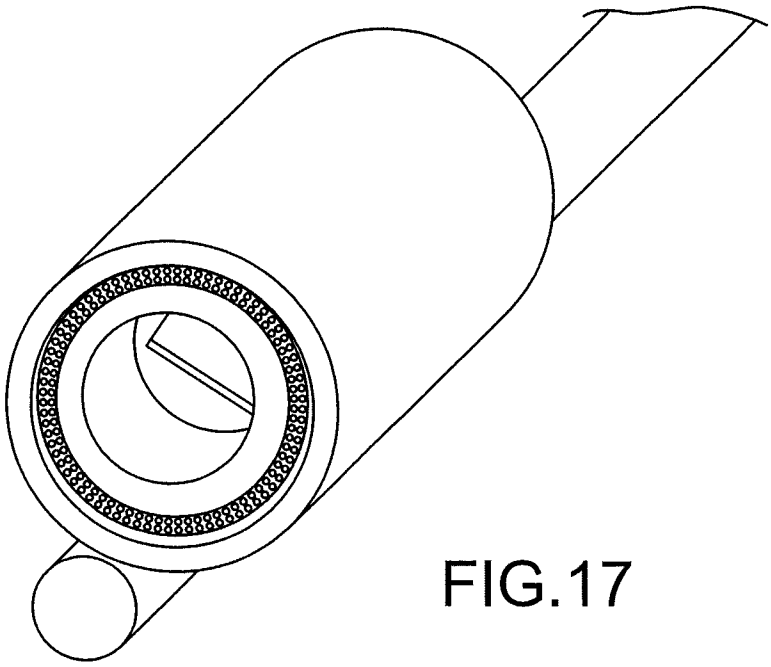


FIG.17

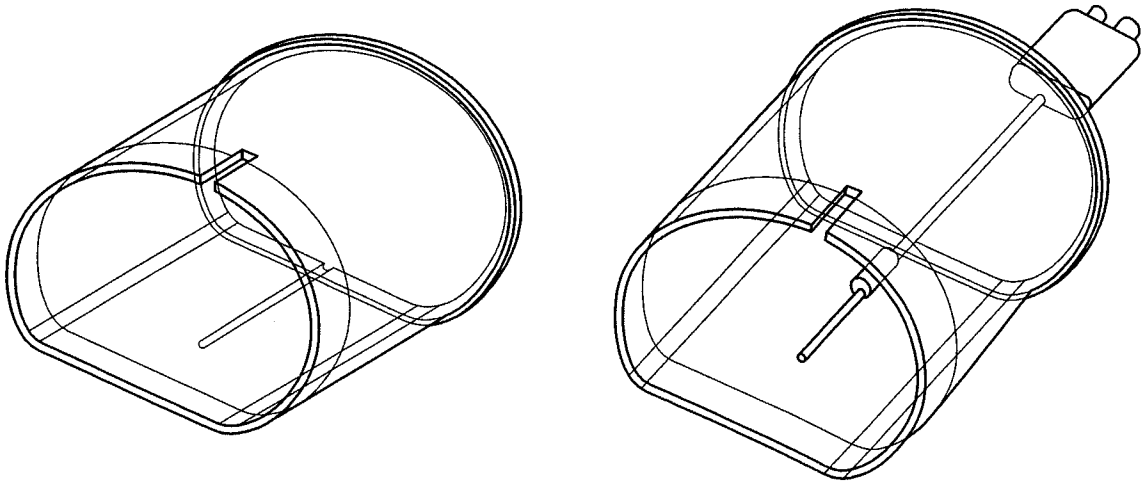


FIG.18

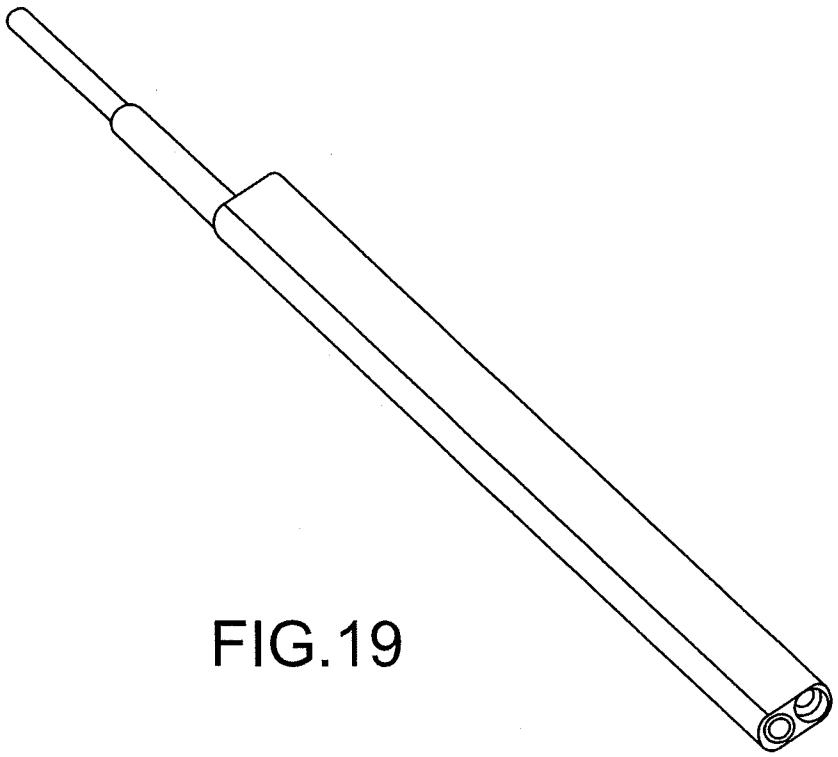


FIG.19

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/021159

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - A61B 1/04 (2012.01)
USPC - 600/112
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - A61B 1/04 (2012.01)
USPC - 600/104, 106, 109, 112; 604/264
ECLA- A61B 1/04D (2012.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 2008/0195128 A1 (ORBAY et al) 14 August 2008 (14.08.2008) entire document	25 --- 26
Y	US 2002/0022764 A1 (SMITH et al) 21 February 2002 (21.02.2002) entire document	1-24, 27-31
Y	US 2008/0147018 A1 (SQUILLA et al) 19 June 2008 (19.06.2008) entire document	1-24, 26
Y	US 6,564,078 B1 (MARINO et al) 13 May 2003 (13.05.2003) entire document	15-17, 27-31
Y	US 2007/0270639 A1 (LONG) 22 November 2007 (22.11.2007) entire document	14
Y	US 2005/0191046 A1 (DEHMEL et al) 01 September 2005 (01.09.2005) entire document	7
Y	US 3,900,021 A (MAKEPEACE et al) 19 August 1975 (19.08.1975) entire document	8
Y	US 2007/0088326 A1 (KENNEDY, II) 19 April 2007 (19.04.2007) entire document	2-5
Y	US 2006/0074307 A1 (IGARASHI et al) 06 April 2006 (06.04.2006) entire document	6, 10, 28

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 April 2012	23 MAY 2012
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774