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**Flores et al.**

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(54) **INTRABODY SURGICAL FLUID TRANSFER ASSEMBLIES WITH ADJUSTABLE EXPOSED CANNULA TO NEEDLE TIP LENGTH, RELATED SYSTEMS AND METHODS**

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**Related U.S. Application Data**

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**A61M 25/00** (2006.01)  
**A61B 90/11** (2016.01)  
**A61M 39/10** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **A61M 25/0084** (2013.01); **A61B 90/11** (2016.02); **A61M 25/0023** (2013.01); (Continued)

(58) **Field of Classification Search**

CPC ..... A61M 25/0084; A61M 25/0023; A61M 25/0097; A61M 39/10; A61M 2025/0089; A61B 90/11

See application file for complete search history.

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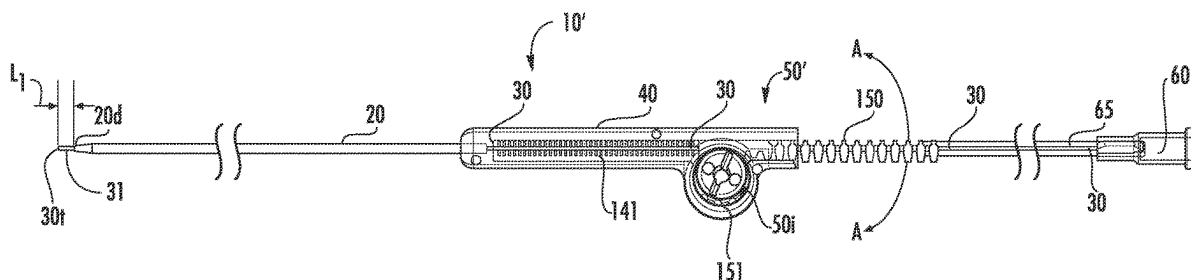
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(57) **ABSTRACT**

Devices for transferring fluid to or from a subject include an elongate tubular cannula having opposing proximal and distal ends with an axially extending lumen. The devices also include an elongate needle having opposing proximal and distal ends. The elongate needle is configured so that the distal end of the needle extends out of the distal end of the cannula a suitable adjustable distance. The devices also include a housing with a length adjustment mechanism that adjusts a length between the tip of the needle and the distal end of the tubular cannula.

**20 Claims, 25 Drawing Sheets**



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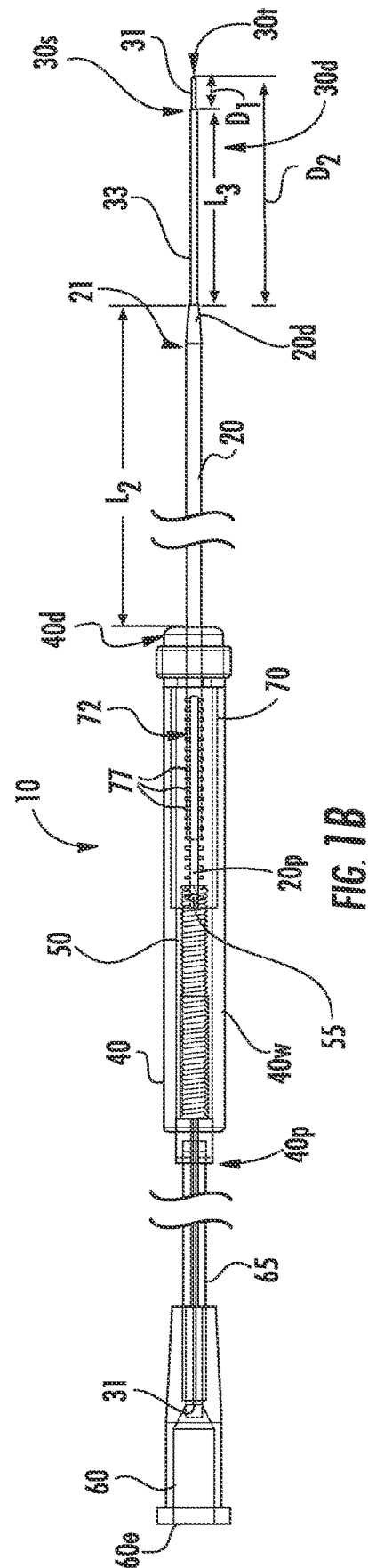
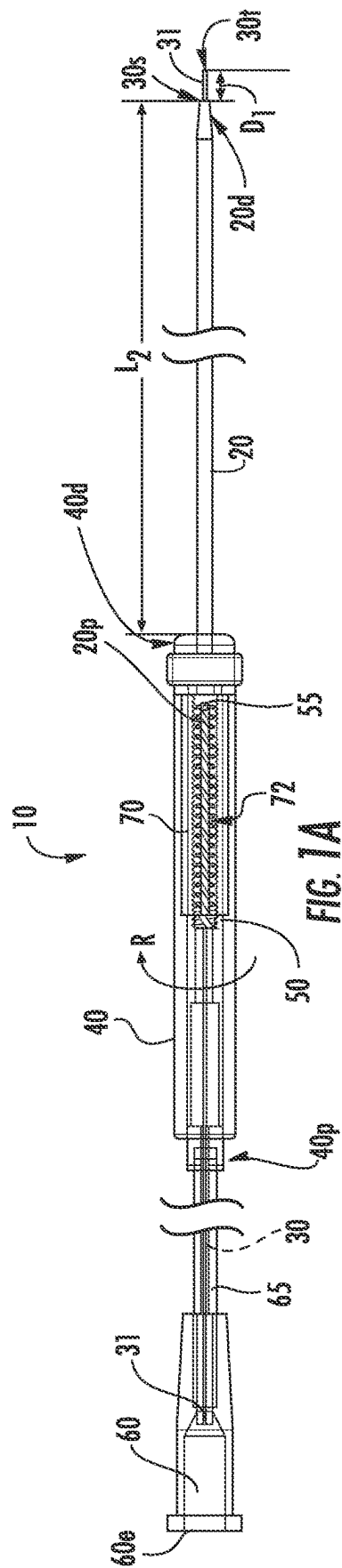
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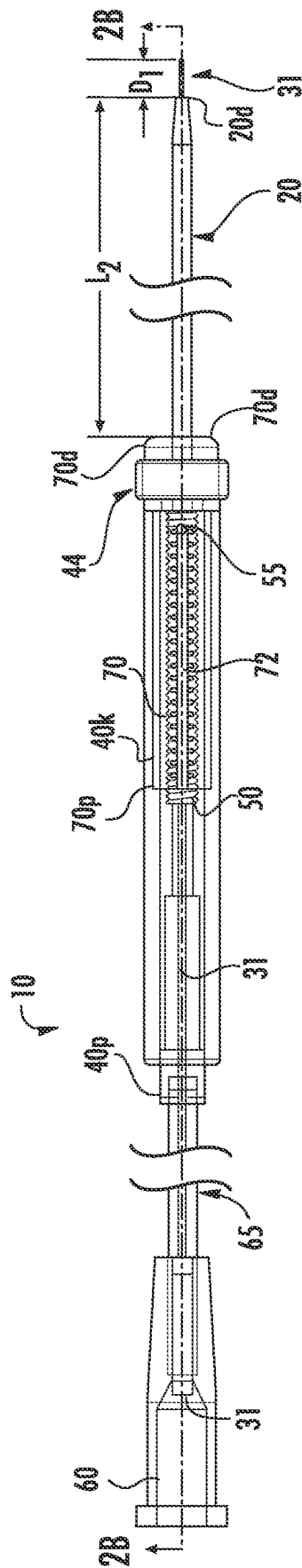


FIG. 2A

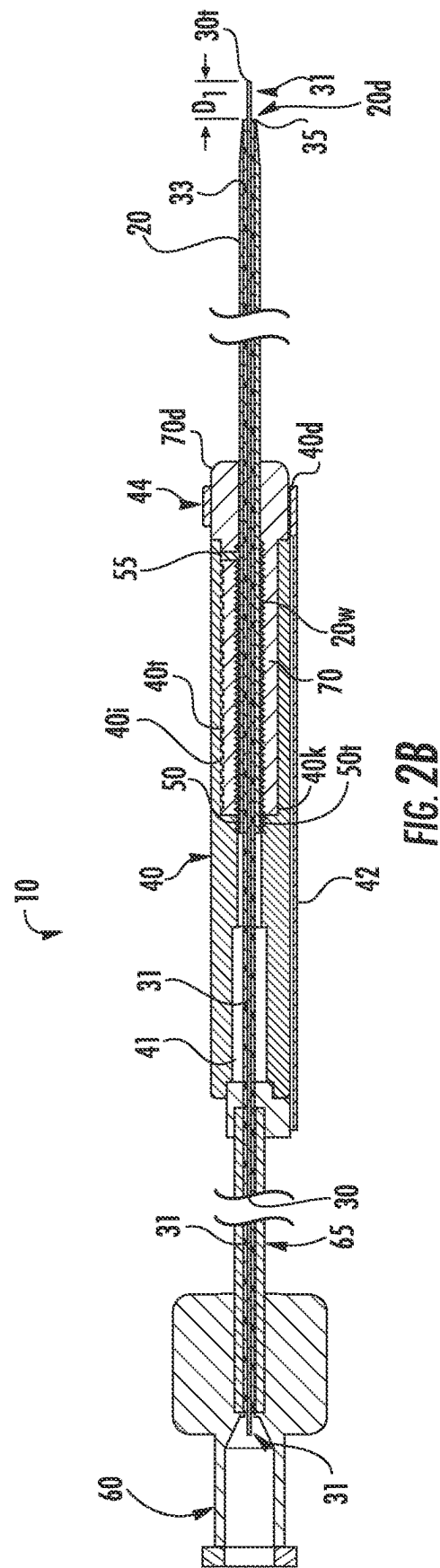
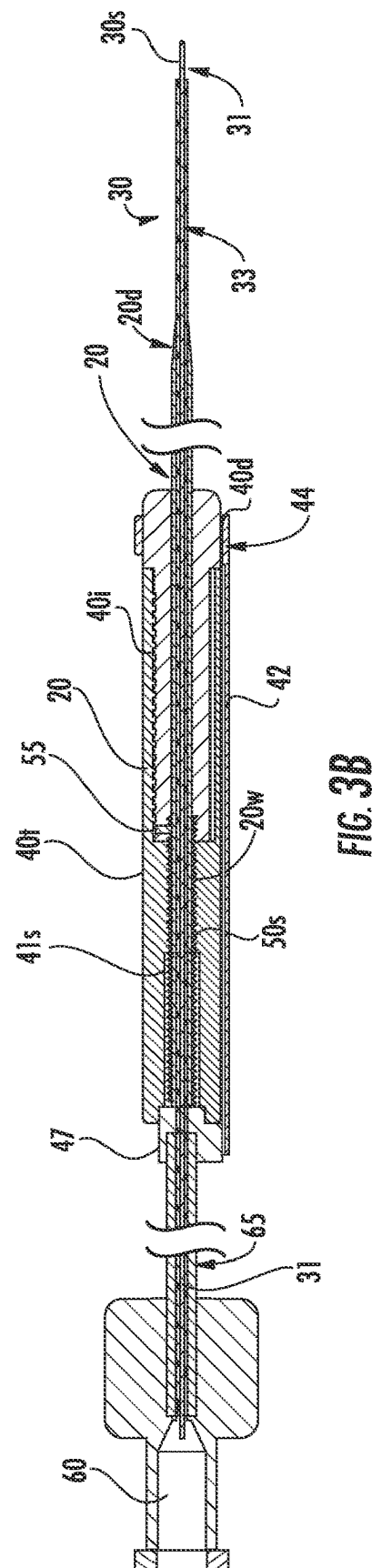
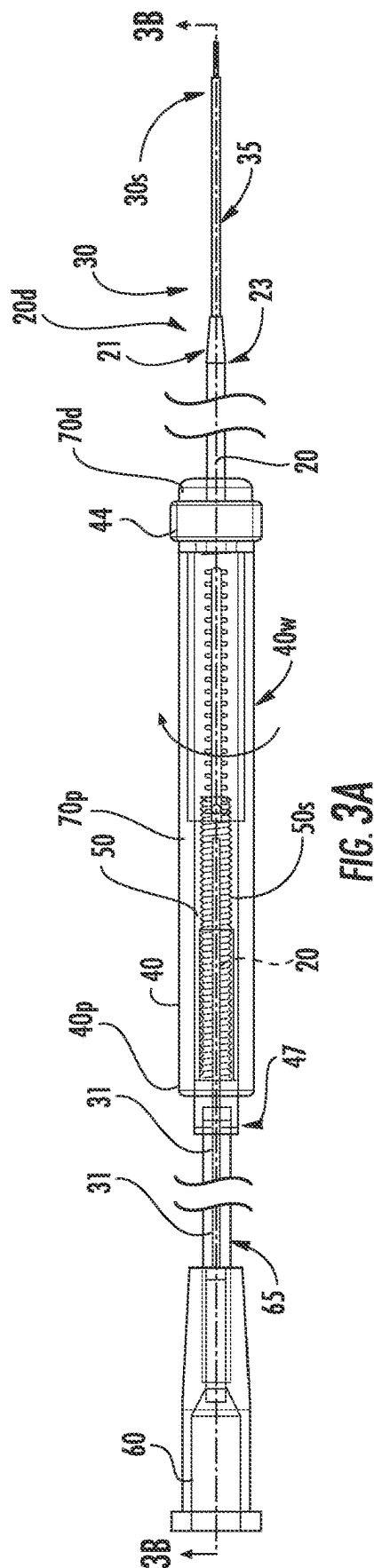
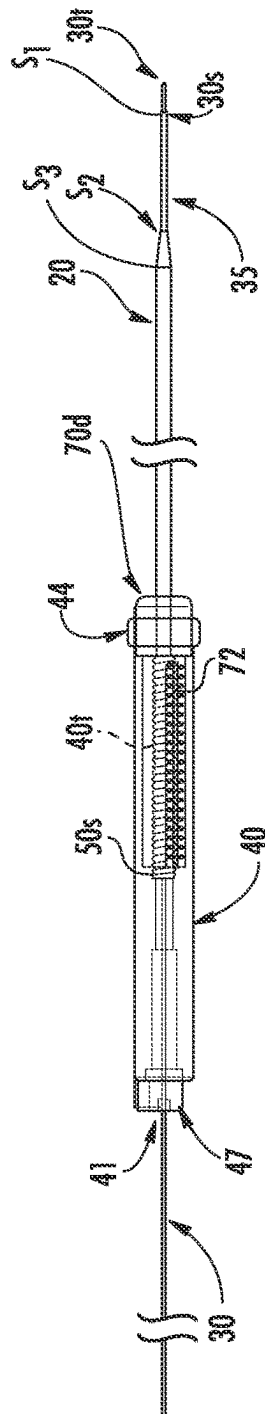
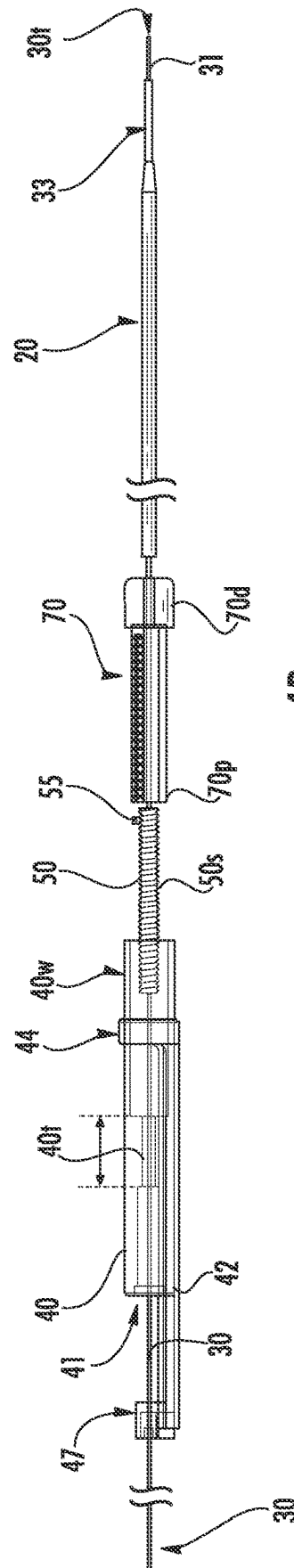


FIG. 2B



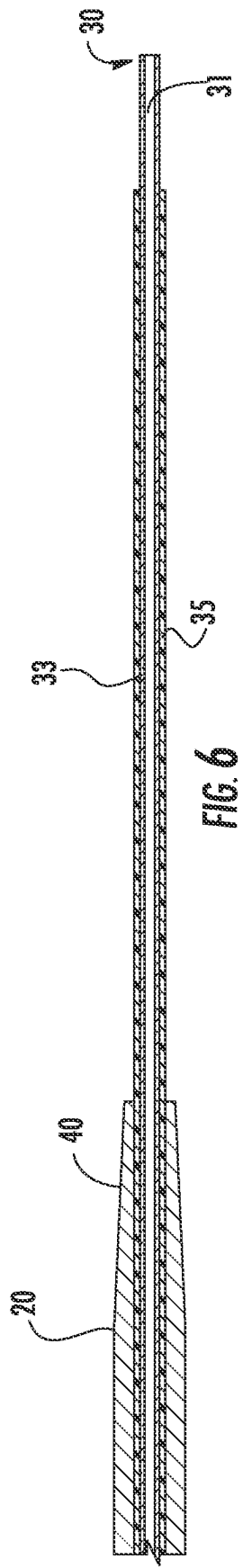
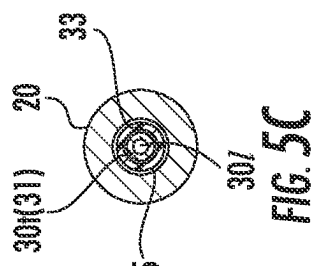
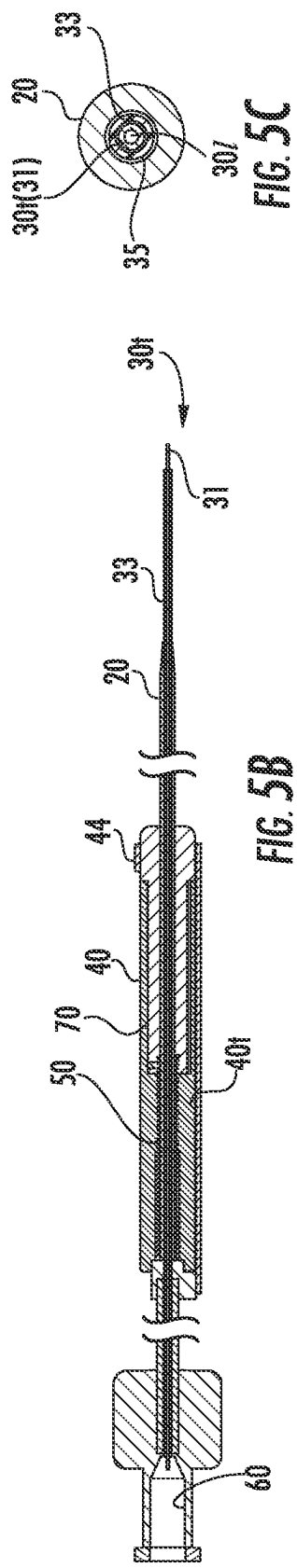
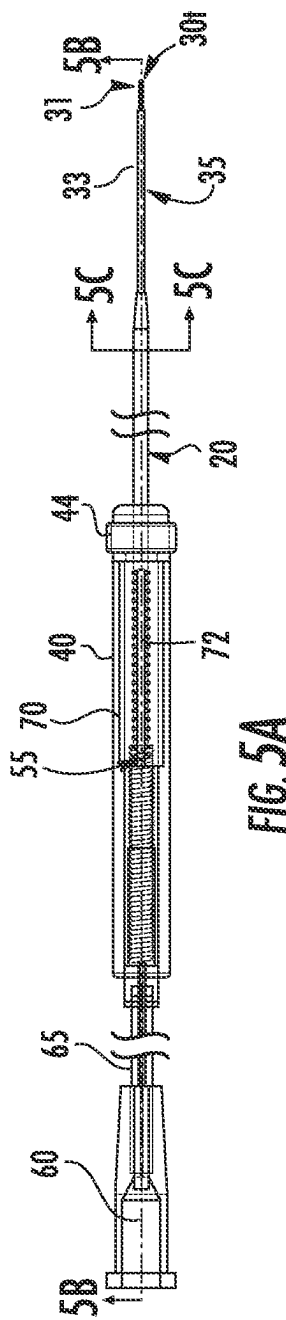


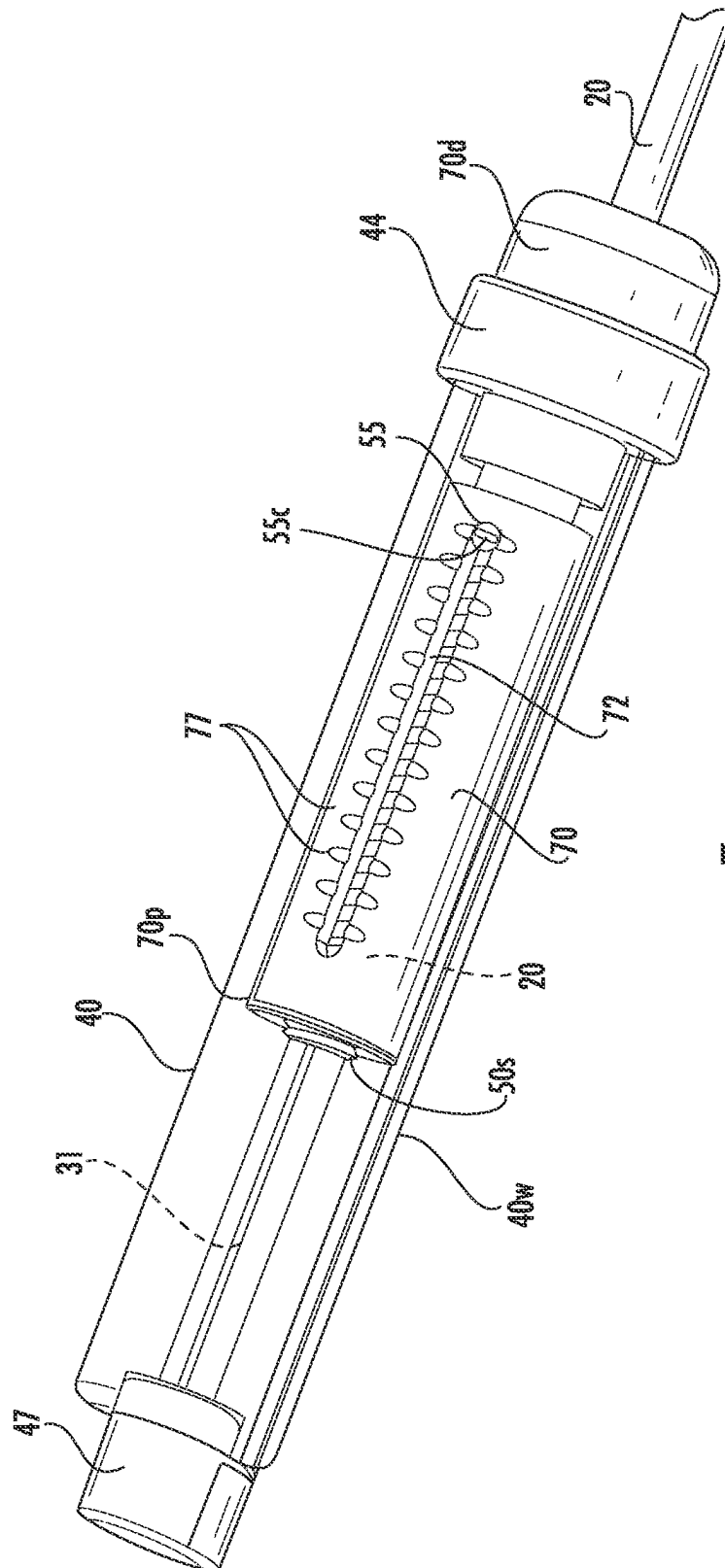
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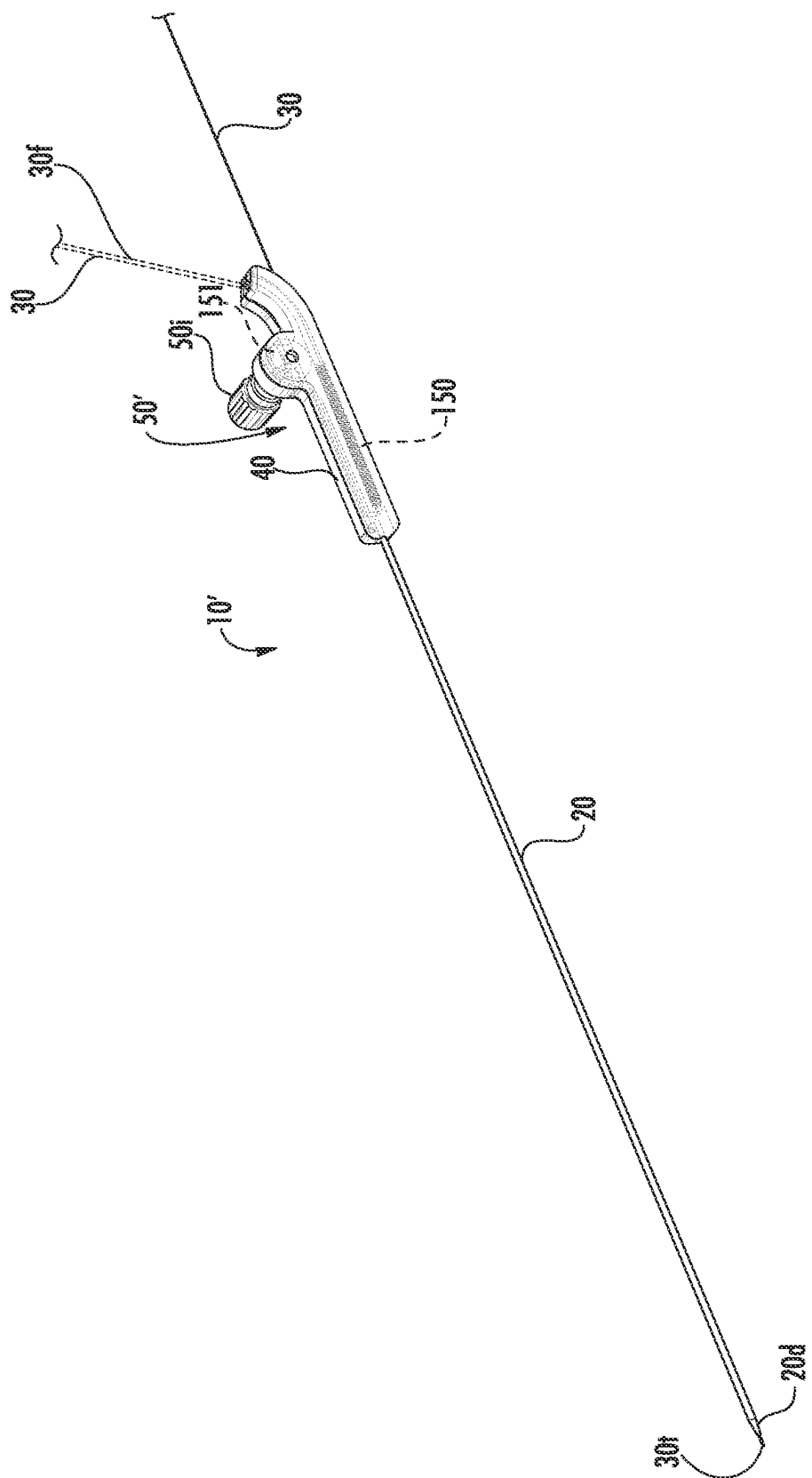
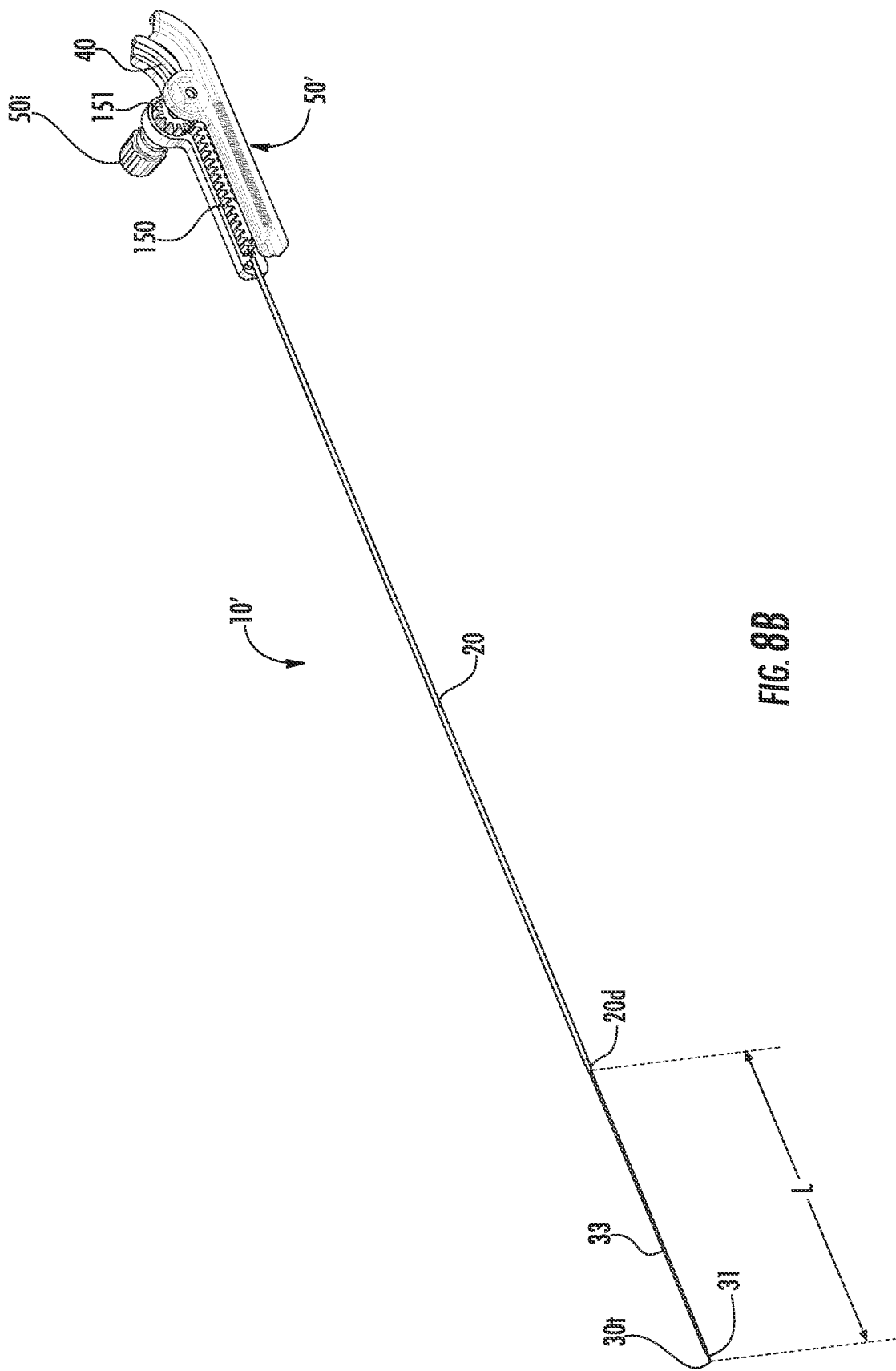


FIG. 8A



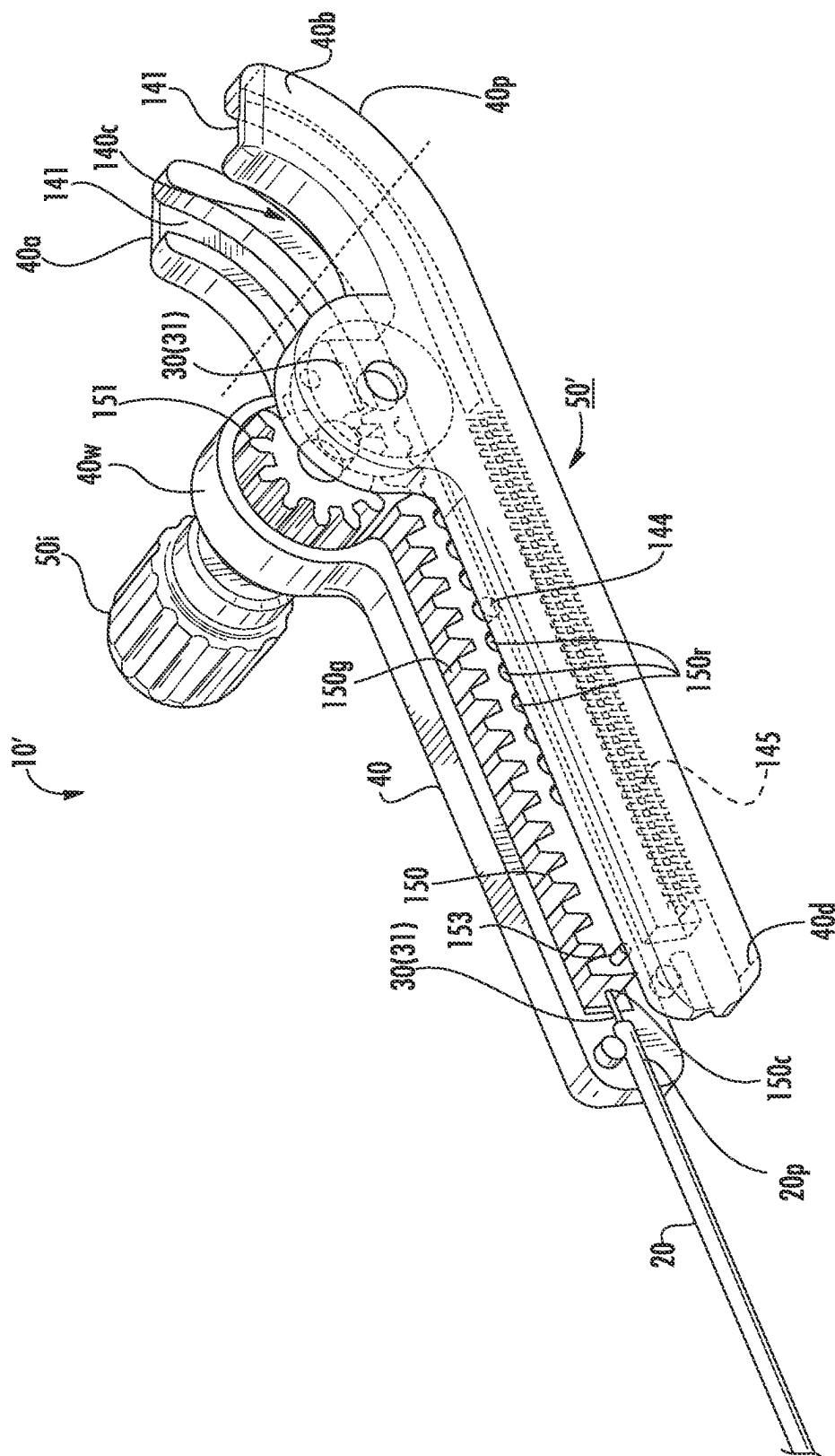
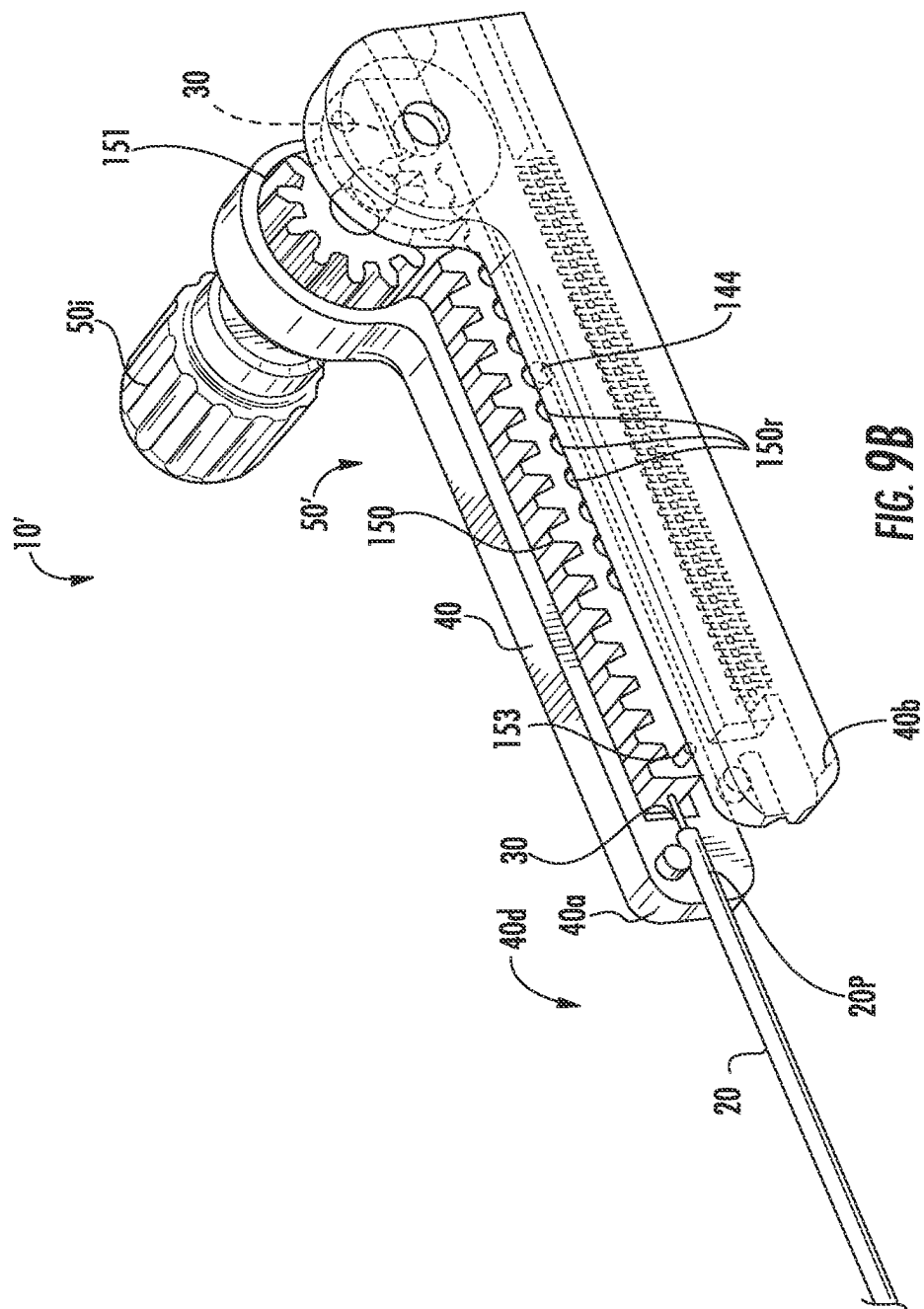


FIG. 9A



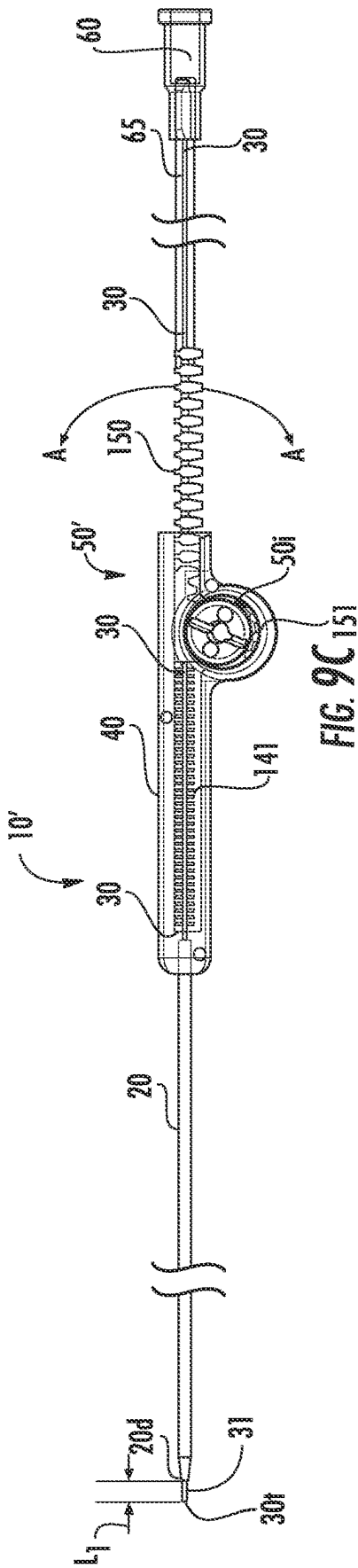


FIG. 9C

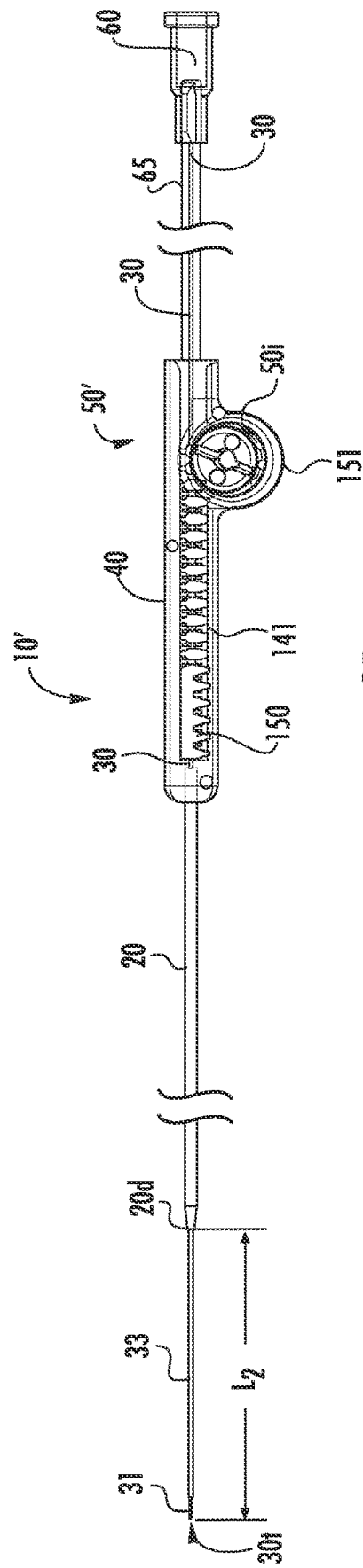
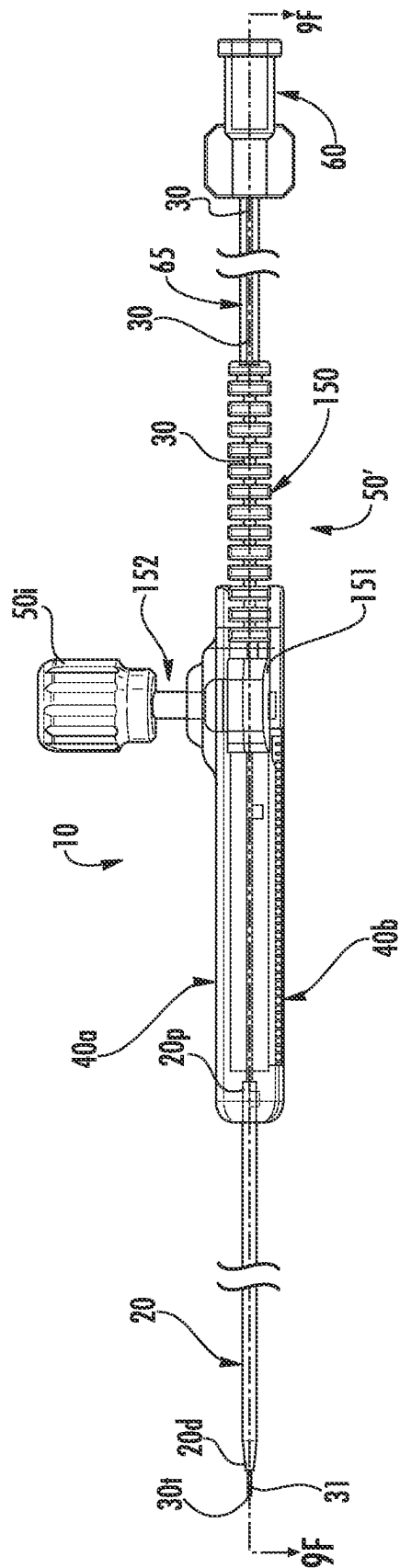
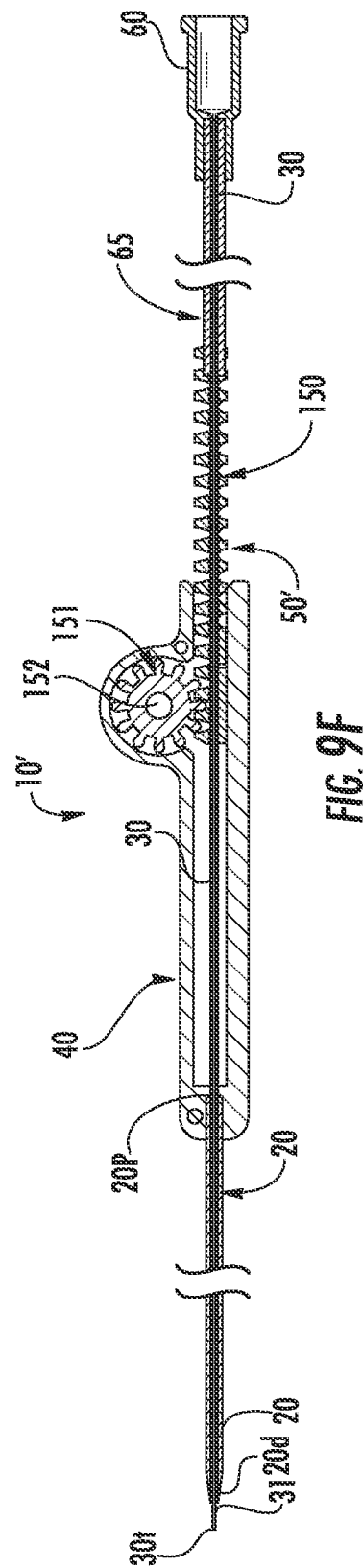


FIG. 9D

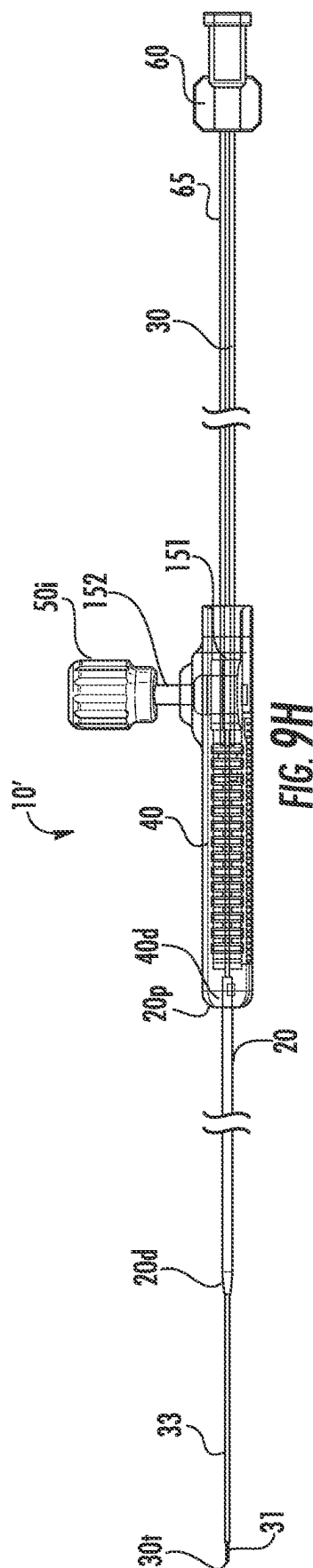
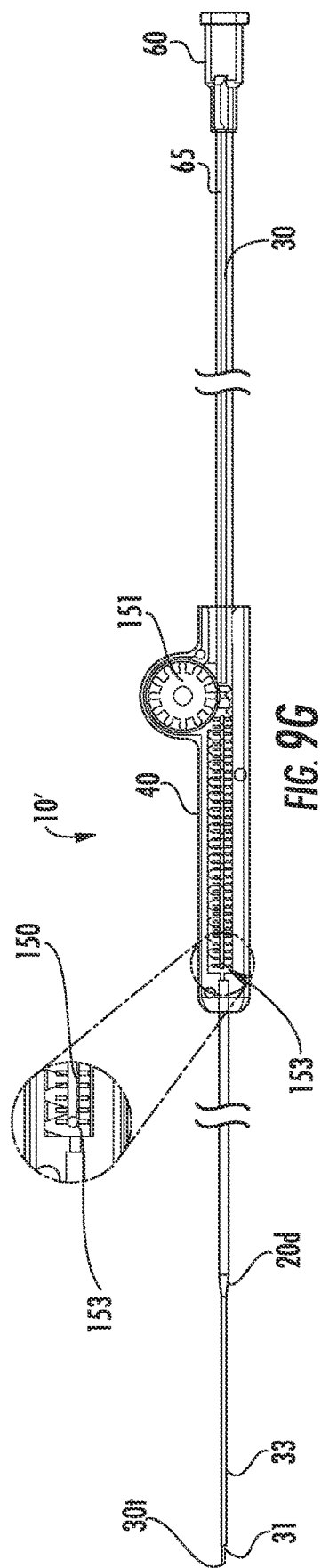


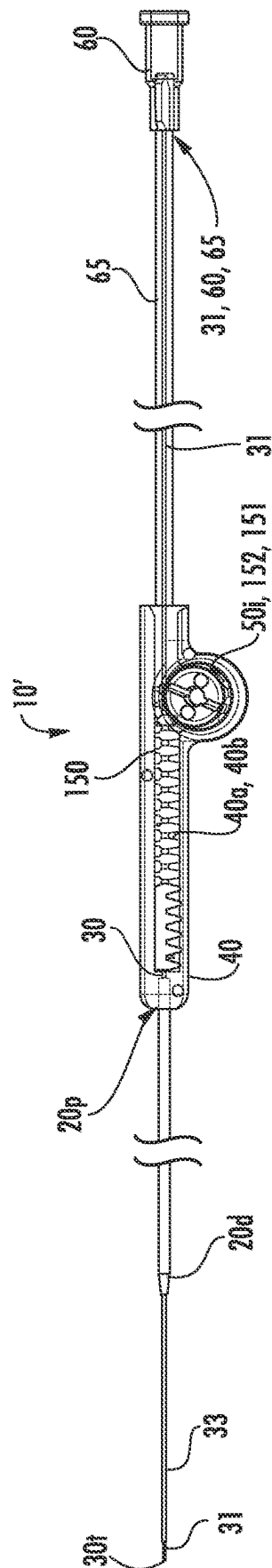
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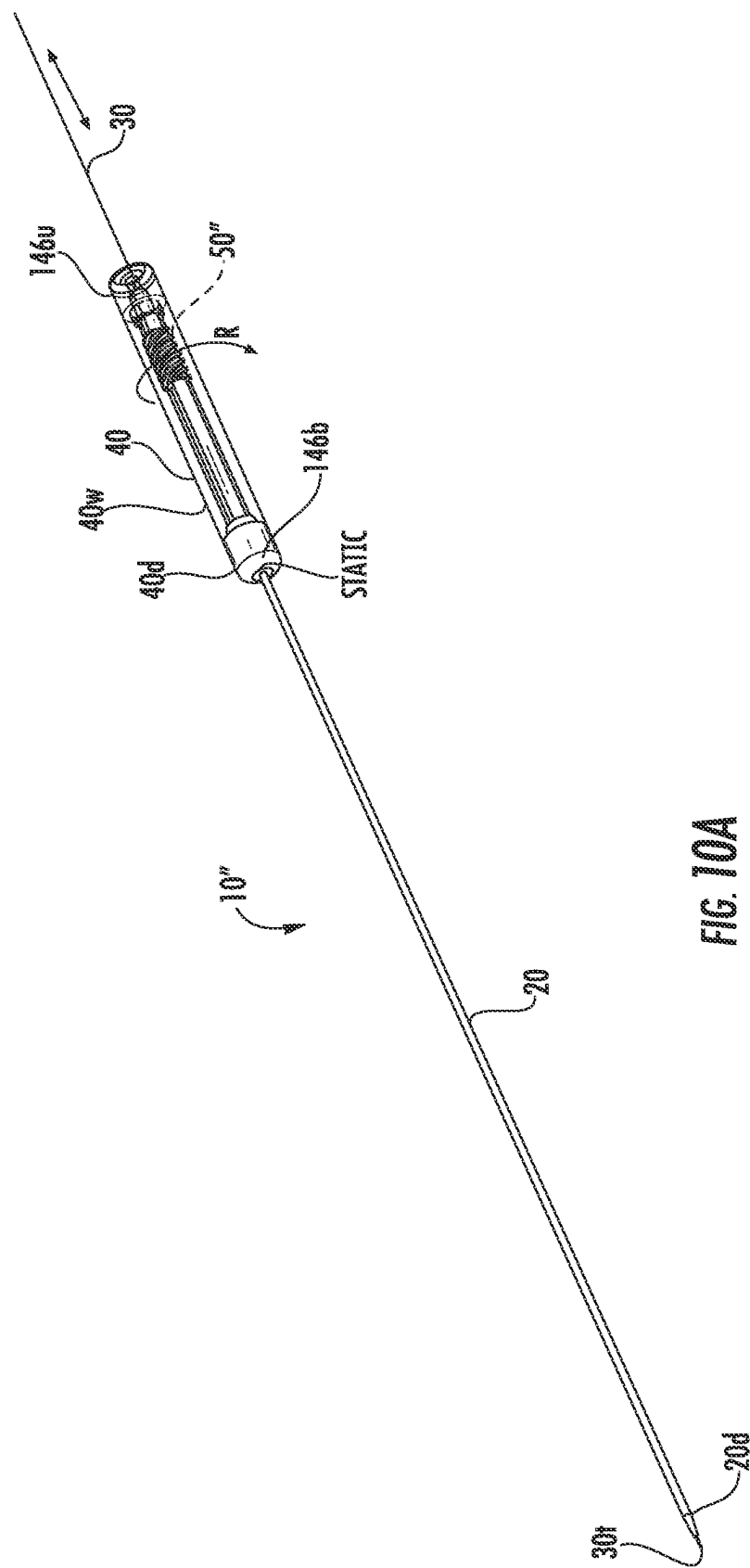
96







916



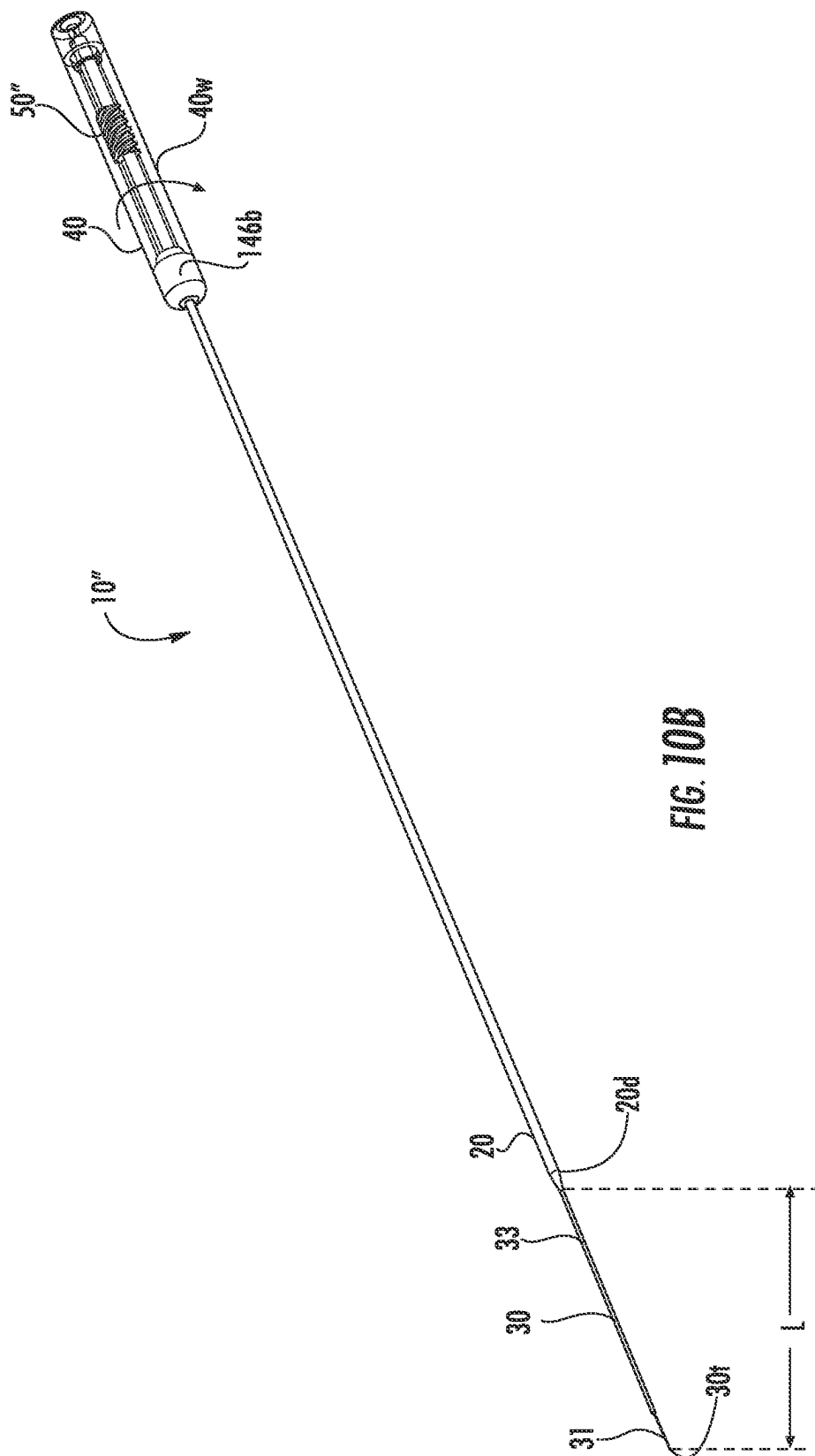


FIG. 10B

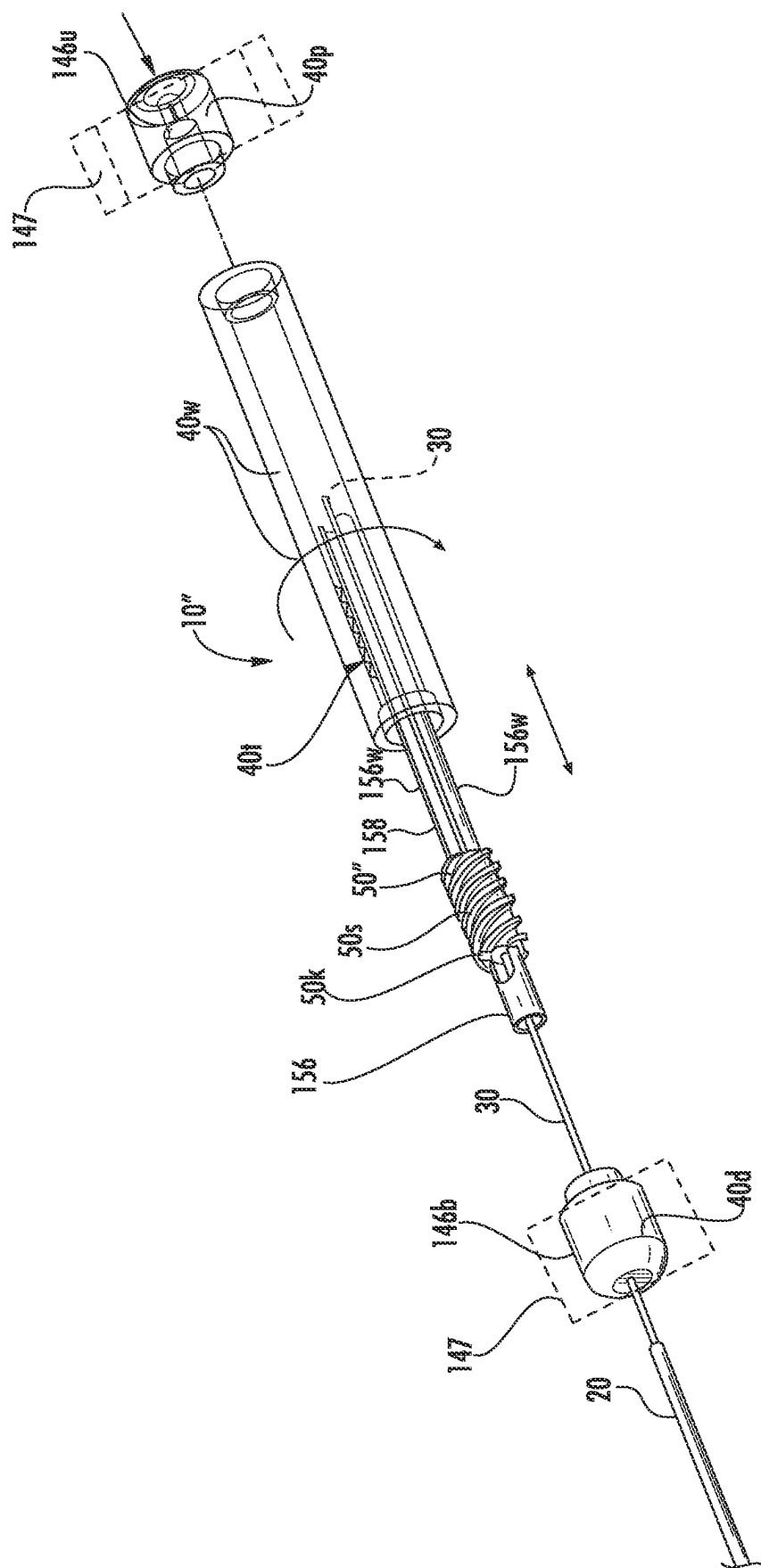


FIG. 17A

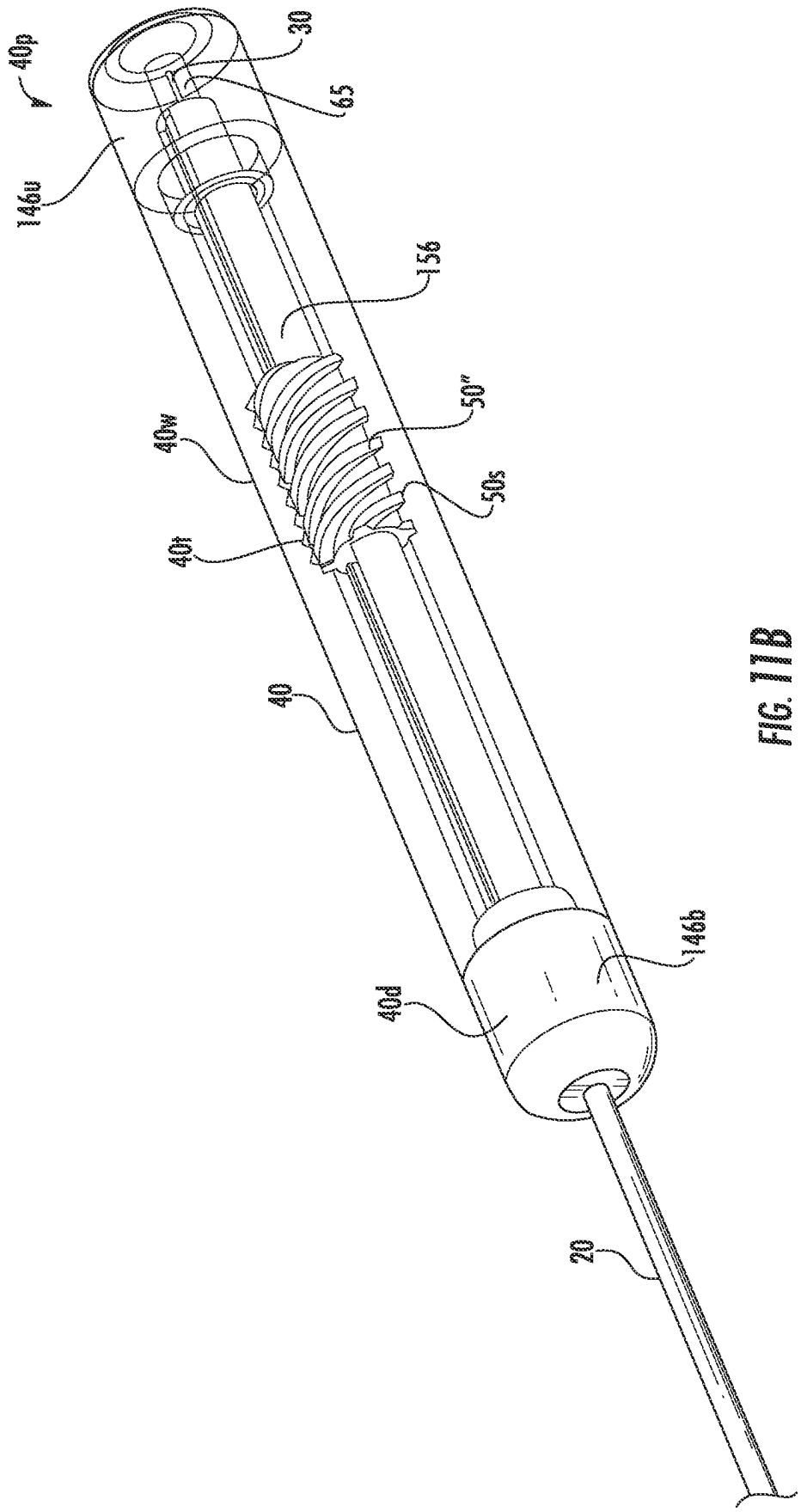
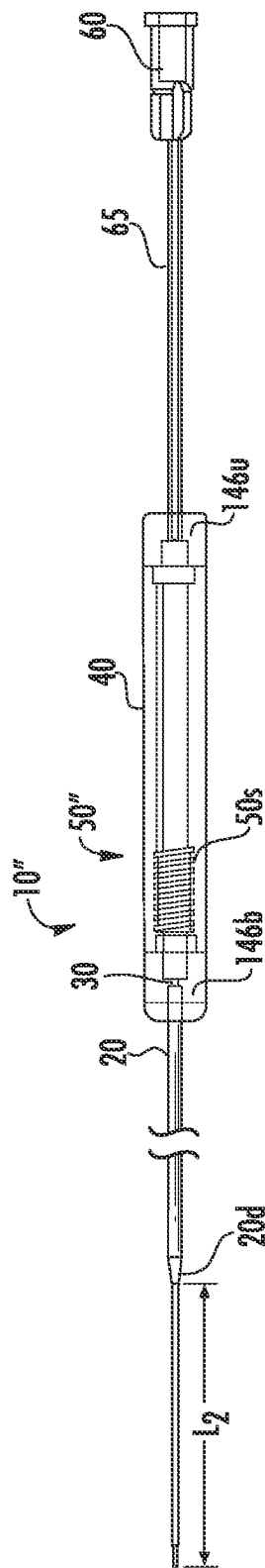
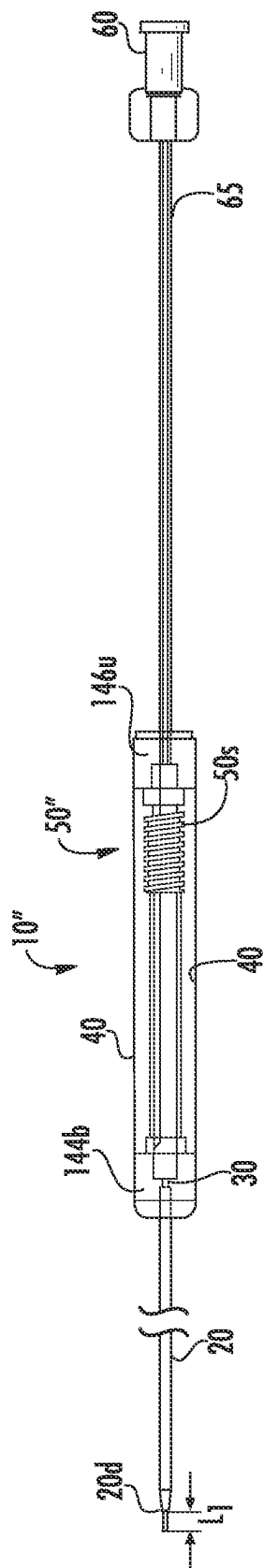
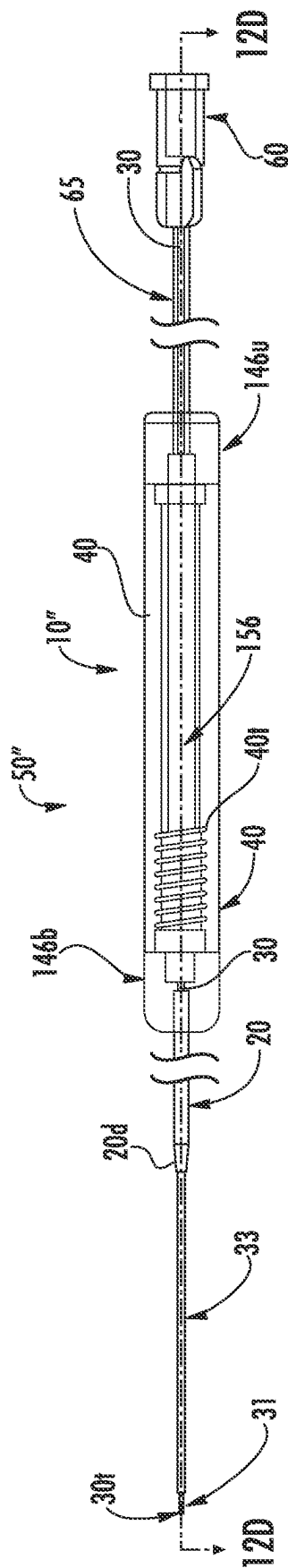
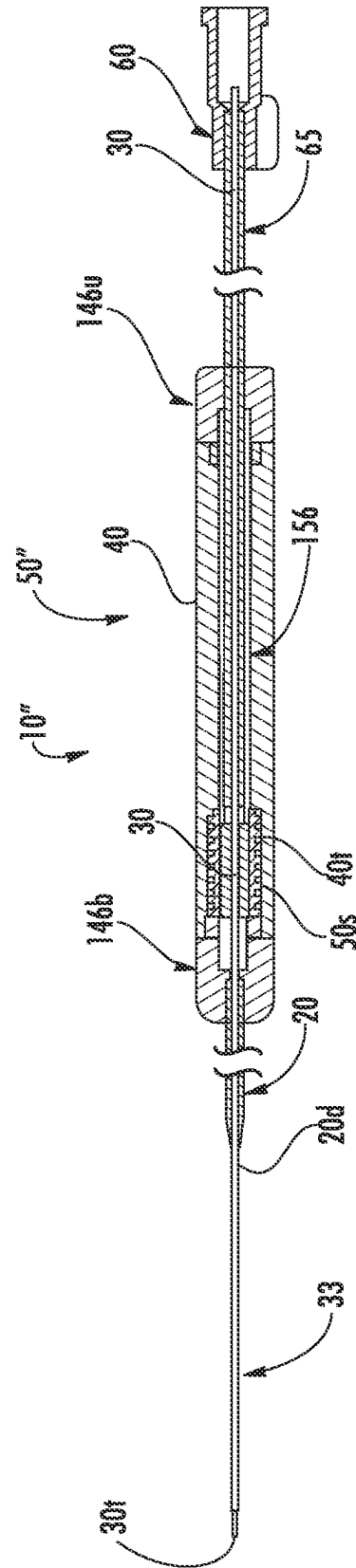


FIG. 11B



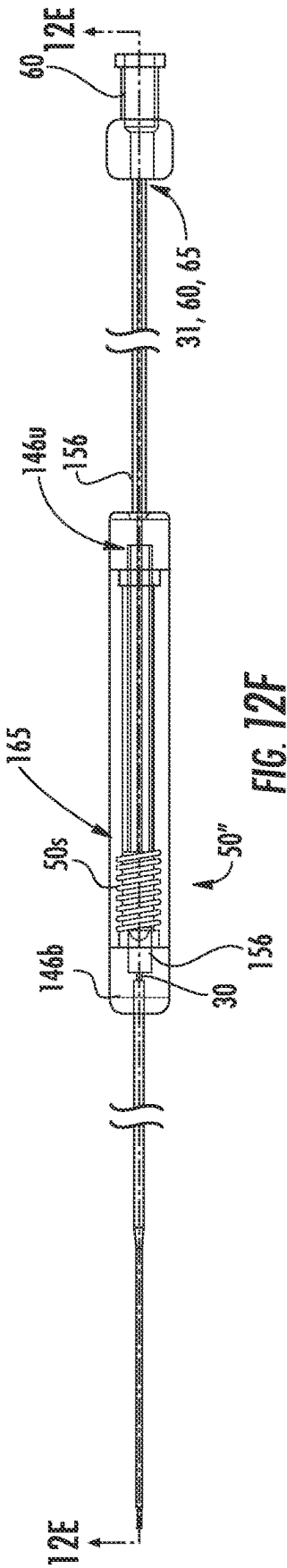
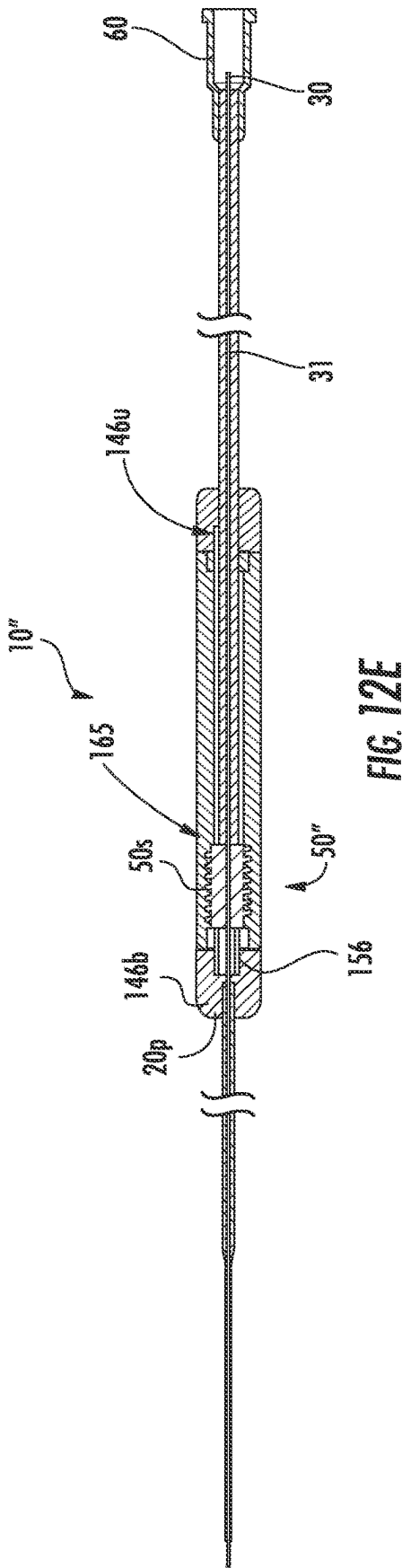


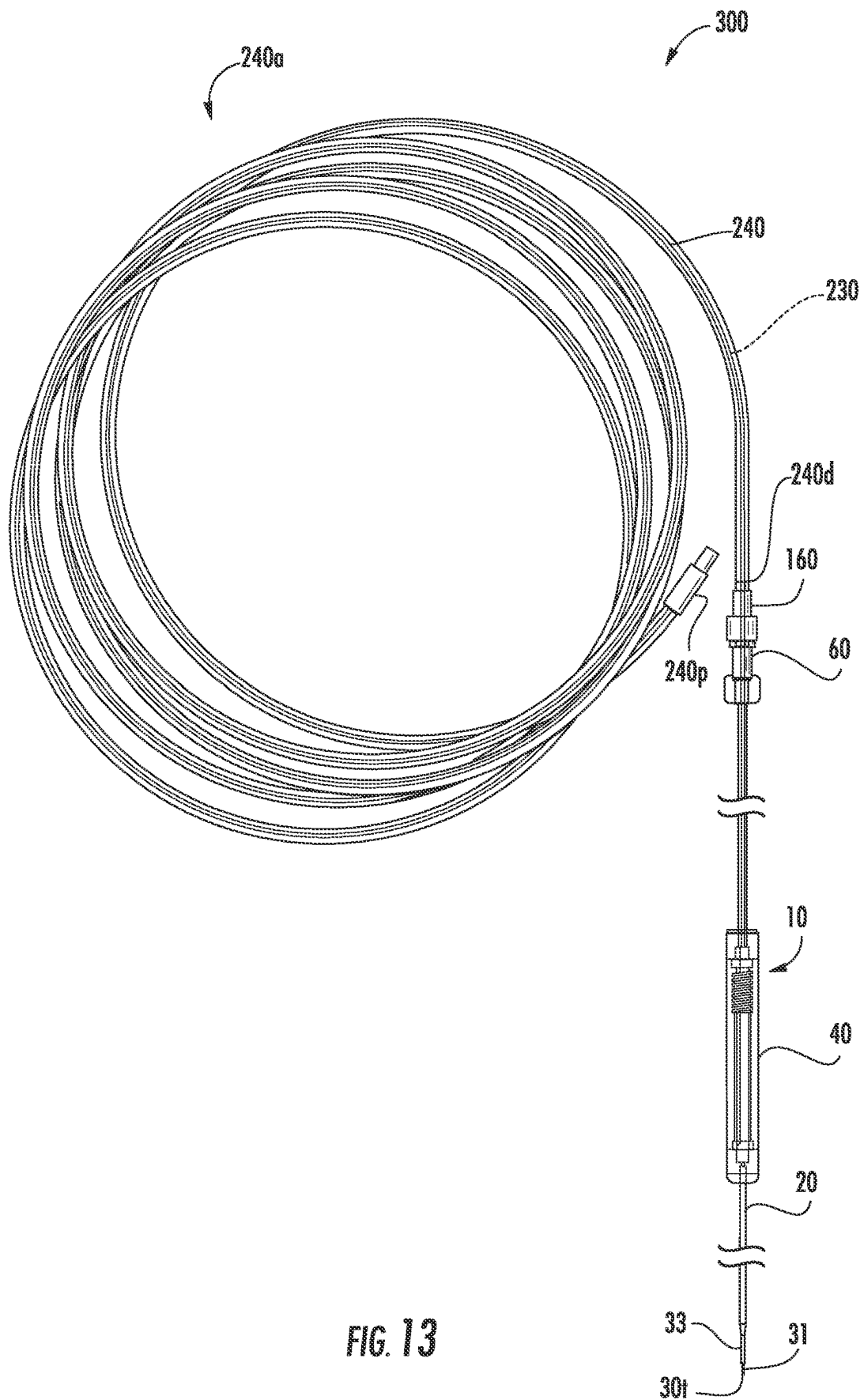
726

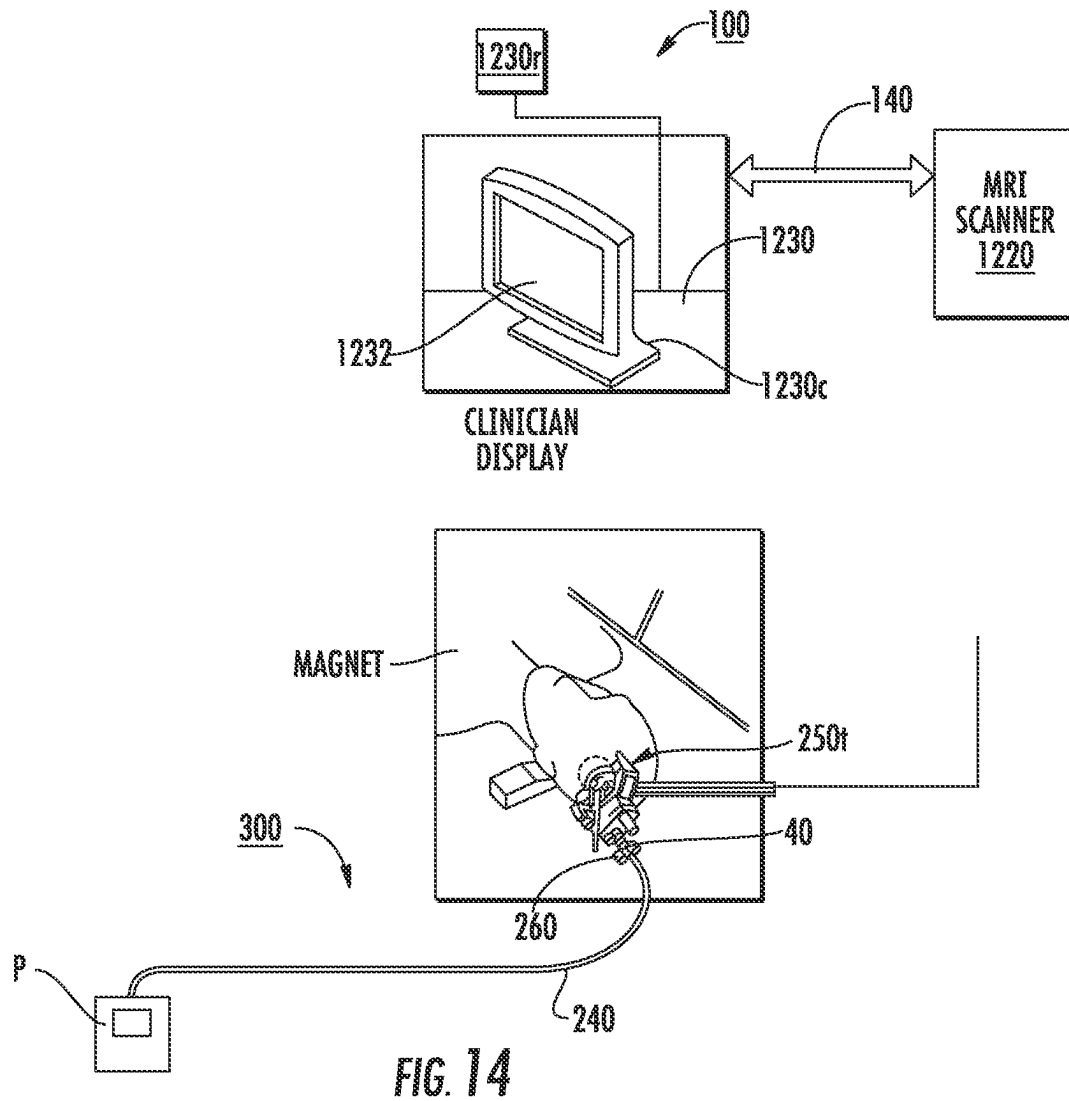


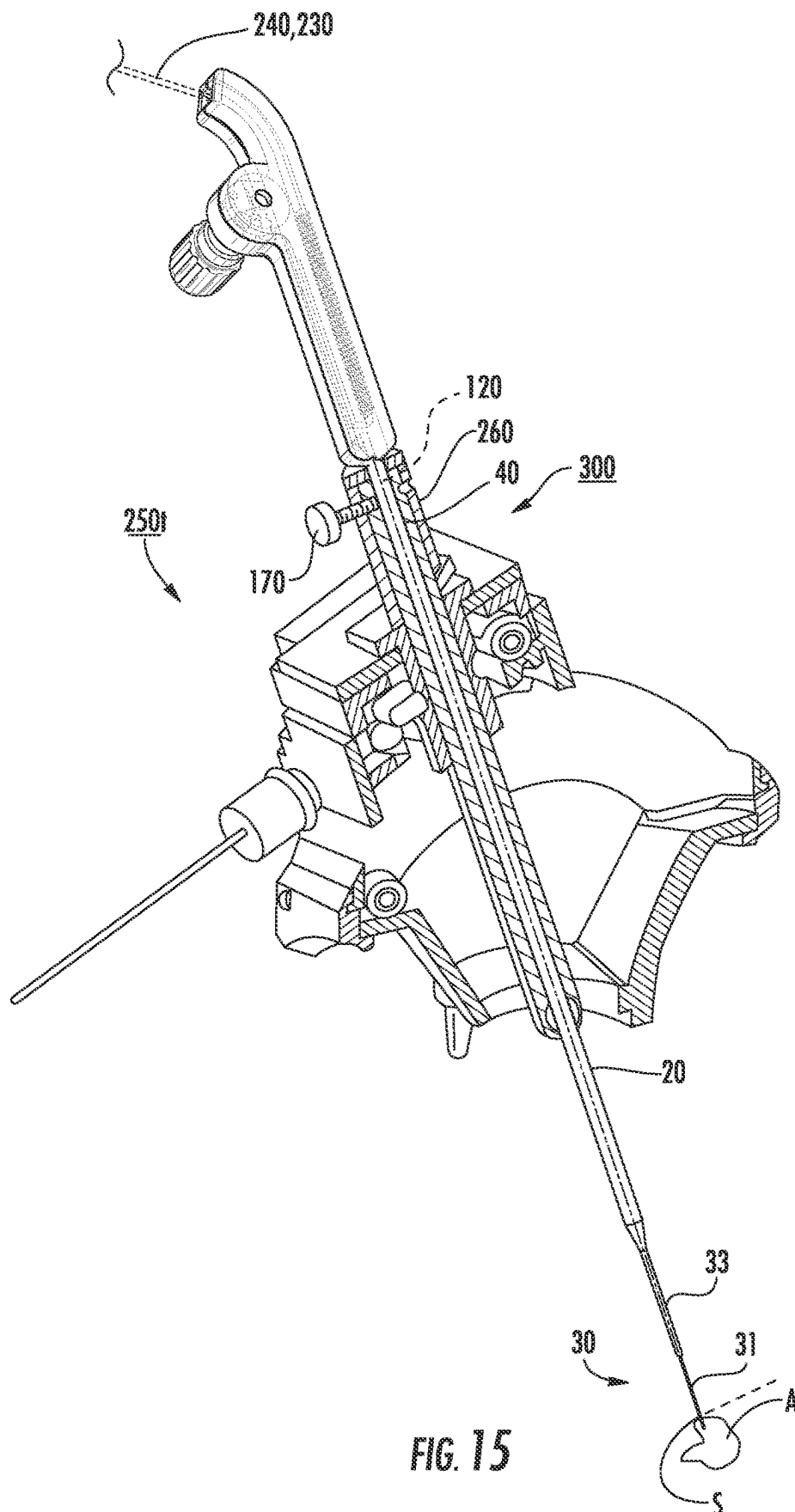
216











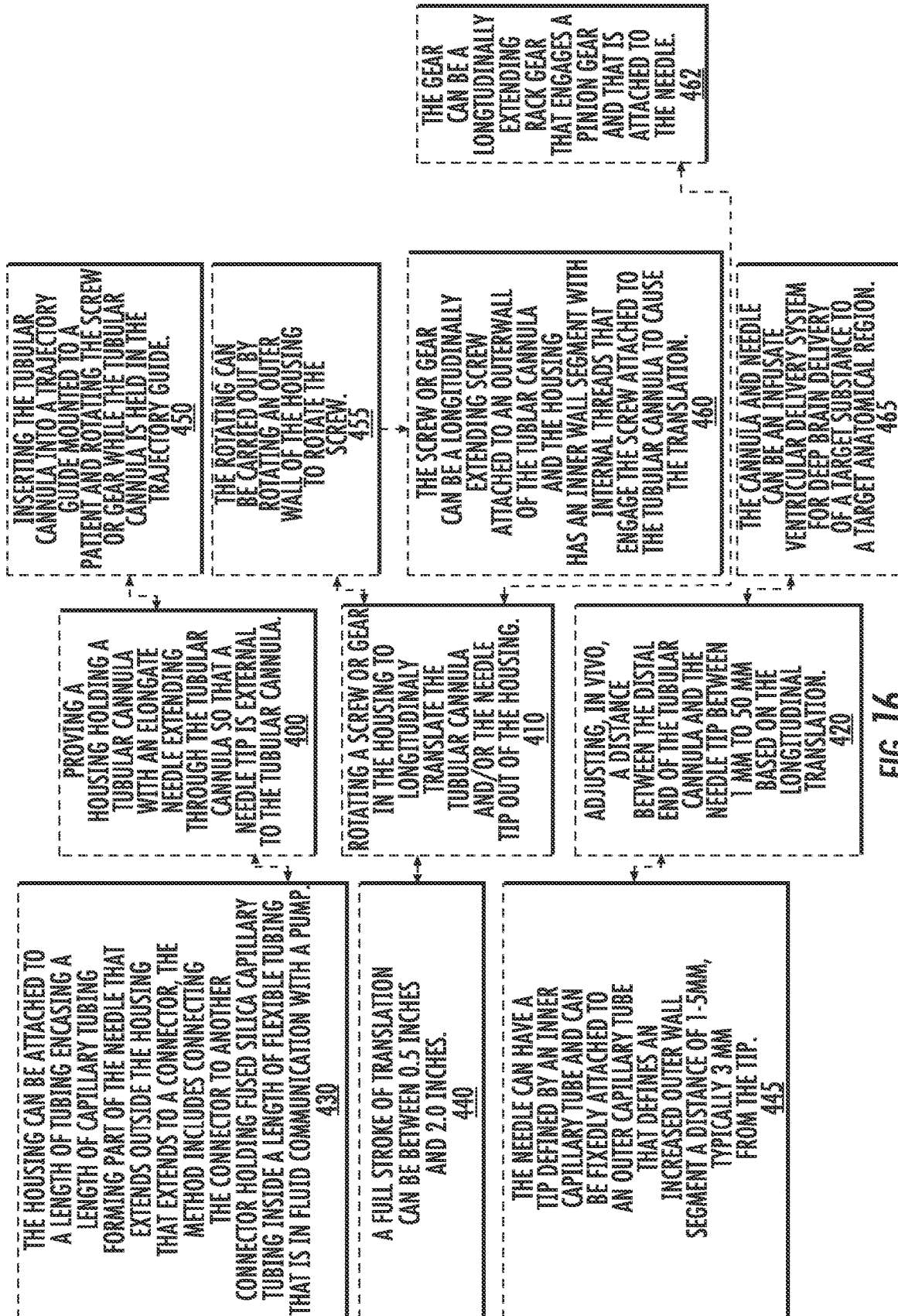


FIG. 16

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# INTRABODY SURGICAL FLUID TRANSFER ASSEMBLIES WITH ADJUSTABLE EXPOSED CANNULA TO NEEDLE TIP LENGTH, RELATED SYSTEMS AND METHODS

## RELATED APPLICATIONS

This application is a continuation application of U.S. patent application Ser. No. 16/740,586, filed Jan. 13, 2020, which is a divisional application of U.S. patent application Ser. No. 15/420,685, filed Jan. 31, 2017 and claims the benefit of and priority to U.S. Provisional Application Ser. No. 62/296,323, filed Feb. 17, 2016, and U.S. Provisional Application Ser. No. 62/382,434, filed Sep. 1, 2016, the contents of which are hereby incorporated by reference as if recited in entirety herein.

## FIELD OF THE INVENTION

The present invention relates generally to medical devices and systems and, more particularly, to devices and systems for delivering and/or withdrawing substances in vivo.

## BACKGROUND

Various therapeutic and diagnostic procedures require that a substance be delivered (e.g., infused) into a prescribed region of a patient, such as to an intrabody target using a delivery device. It may be important or critical that the substance be delivered with accuracy to the target region in the patient and without undue trauma to the patient.

## SUMMARY

It should be appreciated that this Summary is provided to introduce a selection of concepts in a simplified form, the concepts being further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of this disclosure, nor is it intended to limit the scope of the invention.

Embodiments of the invention are directed to intrabody fluid transfer assemblies with adjustable exposed tubular cannula to needle tip length, related systems and methods.

Embodiments of the invention are directed to a surgical device for transferring fluid to or from a subject. The device includes a tubular cannula (which may be referred to as an elongate guide cannula) having opposing proximal and distal ends with an open axially extending lumen. The device also includes an elongate needle (which can also be referred to as a "capillary" or "capillary tube") having opposing proximal and distal ends. The elongate needle is configured to extend through (typically slidably insertable into) the tubular cannula lumen so that the distal end of the needle extends a distance out of the distal end of the tubular cannula. The device also includes a length adjustment housing for positional adjustment of length between the distal end of the tubular cannula and the exposed tip of the needle.

The tubular cannula and/or needle can be held in the housing to be retracted and extended from the housing.

The length adjustment housing can reside external of a patient when the distal end portion of the tubular cannula and needle are in the patient.

The housing can rotate in a defined direction to extend at least one of the needle or the cannula.

A portion of the needle resides in and/or is attached to or attachable to a length of flexible tubing. The elongate needle

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can be formed of fused silica glass. The distal end of the needle can have a stepped configuration with a first segment having a first outer diameter that merges into a second end segment having a second smaller outer diameter, the second segment having a length that extends to a tip of the needle.

The needle may comprise an inner capillary member and an outer capillary member of a larger diameter than the inner capillary tube but a smaller diameter than the cannula tube.

The outer capillary tube can comprise a shrink fit sleeve to sealably engage the inner wall of the lumen of the tubular cannula.

The distance that the needle tip extends out of the distal end of the tubular cannula is between about 2 mm to about 30 mm and this length can be extended or retracted relative to the tubular cannula when the tubular cannula and needle tip are in the body of a patient (i.e., a brain).

The tubular cannula can be formed of and/or include a ceramic material.

The tubular cannula can have an outer polymeric coating and/or sleeve.

The distal end of the tubular cannula can be tapered so that it has a smaller outer diameter at a tip relative to an outer diameter of the tubular cannula more proximal or rearward of the tapered distal end.

The elongate needle can be an infusate needle that has a stepped distal end configuration and is integrally attached to the flexible tubing as a subassembly.

The needle and tubular cannula can be MRI compatible for use in an MRI guided procedure.

The intrabody devices can be particularly suitable for withdrawing/introducing fluid from/into the ventricular brain.

The tubular cannula can be formed of or include a ceramic material.

The tubular cannula can have an outer polymeric coating and/or sleeve.

The distal end of the tubular cannula can be tapered so that it has a smaller outer diameter at a tip relative to an outer diameter of the tubular cannula at a more medial or proximal portion and/or rearward of the tapered distal end.

The tubular cannula can be formed of and/or include a ceramic material.

The tubular cannula and the outer capillary can each comprise a conformal outer polymeric sleeve.

The distal end portion of the needle that extends out of the tubular cannula can have at least first and second co-axially disposed segments having different outer diameters, with a smallest sized outer diameter of the first segment extending to a tip thereof.

The tubular cannula can have an exterior surface on a distal end portion thereof that tapers down in size to a tip thereof to define a third coaxially disposed stepped segment that resides a distance rearward of the second segment and has a larger outer diameter than both the first and second co-axially disposed segments.

The needle can have a fused glass silica body.

An outer surface of the tubular cannula can have a size and geometry adapted for use with a stereotactic frame.

The needle can have an inner diameter of between about 100  $\mu$ m to about 750  $\mu$ m.

The first smallest outer diameter segment can have a longitudinal length of between about 1 mm to about 10 mm. The second segment can have a longitudinal length of between about 2 mm to about 20 mm. The distal tip of the guide cannula can reside a distance between 3 mm to about 30 mm from a distal tip of the needle.

Yet other embodiments are directed to methods of transferring a substance to and/or from a patient, the methods include: providing a tubular cannula with an axially extending interior lumen and a needle having an internal lumen with a distal end of the needle extending out of the tubular cannula at a target site; then transferring the substance to or from the target site through the needle lumen.

The needle can be an infusion needle. The transferring the substance to or from the target site can be carried out by infusing a substance into target tissue such as into the brain or into the heart, for example.

It is noted that aspects of the invention described with respect to one embodiment may be incorporated in a different embodiment although not specifically described relative thereto. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination. Applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to be able to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner. These and other objects and/or aspects of the present invention are explained in detail below.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a side view of an exemplary intrabody fluid transfer assembly shown in an exemplary first position according to embodiments of the present invention.

FIG. 1B is a side view of the exemplary intrabody fluid transfer assembly shown in an exemplary second position, with the needle tip further away from a distal end of the tubular cannula than in the first position, according to embodiments of the present invention.

FIG. 2A is a side view of the assembly shown in FIG. 1A in the first position.

FIG. 2B is a section view taken along lines 2B-2B in FIG. 2A according to embodiments of the present invention.

FIG. 3A is a side view of the assembly shown in FIG. 1B in the second position.

FIG. 3B is a section view taken along lines 3B-3B in FIG. 3A according to embodiments of the present invention.

FIG. 4A is a side view of some components of the assembly shown in FIG. 1B.

FIG. 4B is a partial exploded view of the components shown in FIG. 4A according to embodiments of the present invention.

FIG. 5A is a side view of the assembly shown in FIG. 1B in the second position according to embodiments of the present invention.

FIG. 5B is a section view taken along lines 5B-5B in FIG. 5A of the assembly shown in FIG. 5A.

FIG. 5C is a section view taken along lines 5C-5C in FIG. 5A.

FIG. 6 is an enlarged section view of components of the assembly shown in FIG. 5A according to some embodiments of the present invention.

FIG. 7 is a greatly enlarged side perspective view of a housing of an assembly with a length adjustment mechanism/mechanism according to embodiments of the present invention.

FIG. 8A is a side perspective view of another embodiment of an intrabody fluid transfer assembly according to embodiments of the present invention.

FIG. 8B is a side perspective view of the assembly shown in FIG. 8A but illustrating the exposed needle tip further extended according to embodiments of the present invention.

FIG. 9A is a greatly enlarged partially transparent view of the housing assembly shown in FIGS. 8A and 8B.

FIG. 9B is a greatly enlarged partially transparent view of another embodiment of a housing for the assembly shown in FIGS. 8A and 8B according to embodiments of the present invention.

FIG. 9C is a side partially exposed view of the infusion assembly shown in FIG. 9B illustrating a needle tip to tubular cannula retracted configuration with the gear outside the housing according to embodiments of the present invention.

FIG. 9D is a side partially exposed view of the infusion assembly shown in FIG. 9C illustrating a needle tip to tubular cannula extended configuration with the gear inside the housing according to embodiments of the present invention.

FIG. 9E is a top view with the housing shown partially transparent of the transfer assembly shown in FIG. 9C.

FIG. 9F is a section view taken along line 9F-9F in FIG. 9E.

FIGS. 9G, 9H and 9I illustrate exemplary attachment regions of various components of the fluid transfer assembly shown in FIGS. 9D and 9E according to embodiments of the present invention.

FIG. 10A is a side perspective view of another embodiment of an intrabody fluid transfer assembly according to embodiments of the present invention.

FIG. 10B is a side perspective view of the assembly shown in FIG. 10A but illustrating the exposed needle tip further extended according to embodiments of the present invention.

FIG. 11A is a side perspective, partially exploded view of the intrabody fluid transfer assembly shown in FIG. 10A.

FIG. 11B is a greatly enlarged partial assembly view of the portion of the intrabody fluid transfer assembly shown in FIG. 11A.

FIG. 12A is a side partially exposed view of the infusion assembly shown in FIG. 10A illustrating a needle tip to tubular cannula retracted configuration with the gear outside the housing according to embodiments of the present invention.

FIG. 12B is a side partially exposed view of the infusion assembly shown in FIG. 12A illustrating a needle tip to tubular cannula extended configuration with the gear inside the housing according to embodiments of the present invention.

FIG. 12C is a top view with the housing shown partially transparent of the transfer assembly shown in FIG. 9C.

FIG. 12D is a section view taken along line 12D-12D in FIG. 12C.

FIGS. 12E and 12F illustrate exemplary attachment regions of various components of the fluid transfer assembly shown in FIGS. 12A-12D according to embodiments of the present invention.

FIG. 13 is a top view of an exemplary intrabody fluid transfer assembly according to embodiments of the present invention.

FIG. 14 is a schematic illustration of an MRI-guided interventional system in which embodiments of the present invention may be utilized.

FIG. 15 is a sectional view of the trajectory guide of the MRI-guided system of FIG. 14 with an exemplary needle

and surgical cannula for transferring a substance (e.g., an infusate, etc.) to an intrabody target region of a patient.

FIG. 16 is a flow chart of exemplary actions that can be carried out according to embodiments of the present invention.

#### DETAILED DESCRIPTION

The present invention now is described more fully hereinafter with reference to the accompanying drawings, in which some embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

Like numbers refer to like elements throughout. In the figures, the thickness of certain lines, layers, components, elements or features may be exaggerated for clarity. The terms “FIG.” and “Fig.” are used interchangeably with the word “Figure” in the specification and/or figures.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the specification and relevant art and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein. Well-known functions or constructions may not be described in detail for brevity and/or clarity.

It will be understood that when an element is referred to as being “on,” “attached” to, “connected” to, “coupled” with, “contacting,” etc., another element, it can be directly on, attached to, connected to, coupled with or contacting the other element or intervening elements may also be present. In contrast, when an element is referred to as being, for example, “directly on,” “directly attached” to, “directly connected” to, “directly coupled” with or “directly contacting” another element, there are no intervening elements present. It will also be appreciated by those of skill in the art that references to a structure or feature that is disposed “adjacent” another feature may have portions that overlap or underlie the adjacent feature.

Spatially relative terms, such as “under,” “below,” “lower,” “over,” “upper” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the

figures is inverted, elements described as “under” or “beneath” other elements or features would then be oriented “over” the other elements or features. Thus, the exemplary term “under” can encompass both an orientation of “over” and “under”. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly. Similarly, the terms “upwardly,” “downwardly,” “vertical,” “horizontal” and the like are used herein for the purpose of explanation only unless specifically indicated otherwise.

The term “about,” as used herein with respect to a value or number, means that the value or number can vary by  $\pm$  twenty percent (20%).

The term “monolithic” means that the component (e.g., needle) is formed of a single uniform material.

The term “MRI visible” means that a device is visible, directly or indirectly, in an MRI image. The visibility may be indicated by the increased SNR of the MRI signal proximate to the device (the device can act as an MRI receive antenna to collect signal from local tissue) and/or that the device actually generates MRI signal itself, such as via suitable hydro-based coatings and/or fluid (typically aqueous solutions) filled channels or lumens.

The term “MRI compatible” means that a device is safe for use in an MRI environment and/or can operate as intended in an MRI environment without generating MR signal artifacts, and, as such, if residing within the high-field strength region of the magnetic field, is typically made of a non-ferromagnetic MRI compatible material(s) suitable to reside and/or operate in a high magnetic field environment.

The term “high-magnetic field” refers to field strengths above about 0.5 T (Tesla), typically above 1.0 T, and more typically between about 1.5 T and 10 T.

The term “near real time” refers to both low latency and high frame rate. Latency is generally measured as the time from when an event occurs to display of the event (total processing time). For tracking, the frame rate can range from between about 100 fps to the imaging frame rate. In some embodiments, the tracking is updated at the imaging frame rate. For near “real-time” imaging, the frame rate is typically between about 1 fps to about 20 fps, and in some embodiments, between about 3 fps to about 7 fps. The low latency required to be considered “near real time” is generally less than or equal to about 1 second. In some embodiments, the latency for tracking information is about 0.01 s, and typically between about 0.25-0.5 s when interleaved with imaging data. Thus, with respect to tracking, visualizations with the location, orientation and/or configuration of a known intrabody device can be updated with low latency between about 1 fps to about 100 fps. With respect to imaging, visualizations using near real time MR image data can be presented with a low latency, typically within between about 0.01 ms to less than about 1 second, and with a frame rate that is typically between about 1-20 fps. Together, the system can use the tracking signal and image signal data to dynamically present anatomy and one or more intrabody devices in the visualization in near real-time. In some embodiments, the tracking signal data is obtained and the associated spatial coordinates are determined while the MR image data is obtained and the resultant visualization(s) with the intrabody device (e.g., stylet) and the near RT MR image(s) are generated.

The term “sterile,” as used herein, means that a device, kit, and/or packaging meets or exceeds medical/surgical cleanliness guidelines, and typically is free from live bacteria or other microorganisms.



Embodiments of the present invention can be utilized with various diagnostic or interventional devices and/or therapies to any desired internal region of an object using any suitable imaging modality, typically an MRI and/or in an MRI scanner or MRI interventional suite. However, CT or other imaging modalities may be used. The object can be any object, and may be particularly suitable for animal and/or human subjects for e.g., animal studies and/or veterinarian or human treatments. Some embodiments deliver therapies to the spine. Some embodiments deliver therapies to treat or stimulate a desired region of the sympathetic nerve chain. Other uses, inside or outside the brain, nervous system or spinal cord, include stem cell placement, gene therapy or drug delivery for treating physiological conditions, chemotherapy, drugs including replicating therapy drugs. Some embodiments can be used to treat tumors.

The term “substance,” as used herein, refers to a liquid for treating or facilitating diagnosis of a condition and can include bions, stem cells or other target cells to site-specific regions in the body, such as neurological, nerves or other target sites and the like. In some embodiments, stem cells and/or other rebuilding cells or products can be delivered into spine, brain or cardiac tissue, such as a heart wall via a minimally invasive MRI guided procedure, while the heart is beating (i.e., not requiring a non-beating heart with the patient on a heart-lung machine). Examples of known stimulation treatments and/or target body regions are described in U.S. Pat. Nos. 6,708,064; 6,438,423; 6,356,786; 6,526,318; 6,405,079; 6,167,311; 6,539,263; 6,609,030 and 6,050,992, the contents of which are hereby incorporated by reference as if recited in full herein.

The term “infusion” and derivatives thereof refers to the delivery of a substance (which can be a single substance or a mixture) at a relatively slow rate so that the substance can infuse about a target region. Thus, the term “infusate” refers to a substance so delivered.

Embodiments of the present invention will now be described in further detail below with reference to the figures. FIGS. 1A and 1B illustrate an exemplary intrabody fluid transfer assembly 10 with a tubular cannula 20, a needle 30 and a housing 40 with a length adjustment mechanism 50 attached (directly or indirectly) to one or both of the tubular cannula 20 and needle 30 to be able to extend and retract one or both relative to the distal end 40d of the housing. The term “needle” refers to a relatively small device with an open lumen (30l, FIG. 5C) extending to its tip 30t to release or intake fluid.

The tubular cannula 20 can comprise a different material than the needle 30. Where the needle 30 comprises inner and outer capillary tubes 31, 33, the outer capillary tube 33 can be shorter than the inner capillary tube 31 and may terminate inside the housing 40. By way of example only, the tubular cannula 20 can be a ceramic tube that has increased rigidity relative to the needle and the needle 30 can be formed of fused silica.

The length adjustment mechanism 50 is configured to adjust a distance or length  $D_1$  between the distal end 20d of the tubular cannula and the exposed tip 30t of the needle. The length adjustment mechanism 50 can be configured to provide a maximal stroke length of between 0.5 inches and 3 inches, more typically between about 0.75 inches to about 1 inch (2.5 cm) such as about 0.79 inches. The length adjustment can be carried out in vivo while the housing remains external of a patient with the distal end of the cannula 20d and needle tip 30t in the body of the patient.

The distal end of the housing 40d can reside at a distance that is between 4-10 inches from the needle tip 30t, more typically between 4 and 5 inches. This length can remain fixed in some embodiments.

The needle 30 may comprise an inner capillary tube 31 with a length sufficient to define the tip 30t and may have an outer capillary tube 33 that resides a distance rearward from the tip 30t to form at least one stepped distal end portion 30s (so that the needle 30 merges from a larger diameter to a smaller diameter at a distal end portion thereof, toward the tip 30t) of the needle 30. This stepped portion can define a surface that is orthogonal to the cannula/needle axis.

As shown in FIGS. 1A and 1B, the tubular cannula 20 can have opposing proximal and distal ends 20p, 20d, respectively. The tubular cannula 20 can have an external exposed stepped and/or tapered segment 21 (the outer diameter becoming smaller in a direction of the needle tip 30t). The distance between the distal end of the tubular cannula 20d and the needle tip 30t can be adjusted by a user to position the tapered segment 21 closer or further away from the needle tip 30t.

As shown in FIGS. 1A, 2A and 2B, for example, in a first configuration, the needle tip 30t resides at a short distance “ $D_1$ ” from the distal end of the cannula 20d while in FIG. 1B, in a second configuration, the distal end of the cannula 20d resides at a longer distance  $D_2$  from the needle tip 30t.  $D_2$  can be between about 0.5 inches and about 3 inches, more typically between about 0.5 inches and about 1.1 inch.  $D_1$  can be between about 1 mm to about 50 mm, typically between 1 mm and 10 mm, and in some embodiments between about 2 mm to about 4 mm, such as about 3 mm.

The needle tip 30t may be configured to reside at a fixed extended length from the distal end 20d of the housing which may be between about 4 and 6 inches, more typically between about 4.8 and about 5 inches, in some particular embodiments.

In some particular embodiments, the distal end of the tubular cannula 20d can reside at a length  $L_2$  that is about 4.7 inches in a fully extended position (FIG. 1A) and at about 3.93 inches in a fully retracted position (FIG. 1B). However, other stroke distances and extended and retracted lengths may be used.

Referring to FIG. 1B, the distal end portion of the needle 30d can have at least one stepped segment 30s that can have an increased outer diameter relative to the tip 30t. The stepped segment 30s can reside in the distal end of the cannula 20d in the configuration shown in FIGS. 1A, 2A and 2B.

The stepped segment 30s can reside a fixed length  $D_1$  from the tip 30t.  $D_1$  can be, for example, between about 1 mm to about 50 mm, typically between 1 mm and 10 mm, and in some embodiments between about 2 mm to about 4 mm, such as about 3 mm. In the configuration shown in FIG. 1B, for example, the needle 30 can have an exposed length  $L_3$  that extends rearward from the stepped segment 30s with the increased outer diameter out of the distal end of the tubular cannula 20d.  $L_3$  can be longer than  $D_1$  and can be between about 2 mm and 20 mm. The distal end portion of the needle 30d may include more than two co-axially aligned (concentric) stepped segments 30s.

The tubular cannula 20 can have a length  $L_2$  that extends out of the housing 40 that varies to provide the positional adjustment relative to the tip. In other embodiments, the tubular cannula 20 can remain fixed in position in the housing 40 and the needle 30 can be extended and retracted relative to the housing 40. In yet other embodiments, the

tubular cannula **20** and the needle **30** can each be extendable and retractable out of the distal end of the housing **40d**.

The length  $D_2$  of the distal end portion of the needle **30** outside the cannula **20** during delivery can be between about 3 mm to 30 mm. These lengths can be selected to inhibit reflux and/or provide a desired delivery path during infusion.

The needle **30** can have a stepped distal end portion that cooperates with the cannula **20** to form co-axially disposed step segments (the orthogonally extending end face at the distal end **20d** of the cannula, and the stepped segment **30s** of the needle. There can be three different outer diameters that are longitudinally separated with steps on one or more of end faces  $S_1$ ,  $S_2$ ,  $S_3$  (FIG. 4A). One or some of the steps  $S_1$ ,  $S_2$ ,  $S_3$  can serve to reduce or prevent reflux of the delivered substance. The end face at taper segment  $S_3$  can be a conical face rather than an orthogonal end face provided at  $S_1$  and  $S_2$  (orthogonal to the axial direction of the needle axial direction and the tubular cannula axial direction).

According to some embodiments, the inner diameter of the needle **30** is in the range of from about 10  $\mu$ m to 1 mm and, in some particular embodiments, is between about 100  $\mu$ m to about 750  $\mu$ m, such as about 200  $\mu$ m. According to some embodiments, the outer diameter at the tip **30t** is in the range of from about 75  $\mu$ m to 1.08 mm and, in some embodiments, is about 360  $\mu$ m.

In some embodiments, as shown in FIGS. 1A and 1B, for example, an outer wall **40w** of the housing **40** can be (manually or electro-mechanically) rotated in a first direction (indicated by the arrow with the letter "R") to retract the length adjustment mechanism **50** in the housing **40**, which, in turn, exposes a larger length of the distal end of the needle **30** (FIGS. 1B, 3A, 3B). The rotation can be in either direction for the retraction and is typically manually carried out. The rotation of the outer wall of the housing **40w** can retract the tubular cannula **20** and/or extend the needle **30**.

The rotatable outer wall **40w** can be the entire outer wall or a portion of the outerwall. The rotatable outer wall **40w** can be between about 1 about 6 inches long and may have a small diameter, greater than the diameter of the outer wall of the tubular cannula **20** and less than about 0.3 inches, in some embodiments. The rotatable outer wall **40w** can be cylindrical.

According to some embodiments, at least part of an exposed length of the tubular cannula **20** has an outer surface comprising a polymeric support sleeve **23** (FIG. 3A) which can comprise a shrink tube and may have a thickness in the range of from about 40  $\mu$ m to about 60  $\mu$ m.

While different sizes may be appropriate for different uses, the tubular cannula **20** can, in some embodiments, have an outer diameter that is between about 0.2 inches and 0.015 inches, such as, in some particular embodiments about 0.061 inches and an inner diameter that is between 0.10 inches and 0.001 inches, such as, in some particular embodiments, about 0.029 inches. The tubular cannula **20** can have a lower portion with a smaller outer diameter than an upper or proximal portion or may have a constant outer diameter over its length to the tapered segment **21**.

The needle **30** can be fused silica and may also include an outer wall covered by sleeve **35** which can comprise a shrink tube or other polymeric sleeve or coating, typically starting at the stepped segment **30s** and extending a length over the outer capillary **33** as shown, for example in FIGS. 3A and 5C, to facilitate a suitably fluid-tight interface at the distal end of the tubular guide cannula **20d** to inhibit or reduce fluid entry into this interface/space during delivery or intake.

The sleeve **35** can be polyester and can have a thickness that is between about 0.00125 inches and 0.00150 inches, in some embodiments.

As shown in FIGS. 1A, 1B, 2A and 2B, for example, the assembly **10** can have a connector **60**, such as a female or male luer connector (shown as female) that resides a distance away from the housing **40**, typically a length that positions an upper/outer end **60e** a distance between 3-20 inches away from the proximal end of the housing **40p**, more typically between about 6-10 inches. The needle **30** (typically only the inner capillary **31** without the outer capillary **33**, where used) can extend through the housing **40** to an internal portion of the connector **60** to be in fluid communication with the connector **60**. Tubing **65**, such as PVC tubing, can extend between a proximal end of the housing **40p** to the connector **60** about the needle **30**. The needle **30** can have a total length between the connector **60** and tip **30t** that can be at between about 10-20 inches, typically about 15.65 inches.

Referring to FIGS. 3A, 3B, 4A and 4B, in some embodiments, the length adjustment mechanism **50** can comprise a longitudinally extending screw **50s** that resides in the housing **40** and that can controllably translate in an axial direction to provide the positional adjustment of the distance between the distal end of the tubular cannula **20d** and the needle tip **30t**. However, it is contemplated that other length adjustment mechanisms may be used, such as, for example, gears such as worm gears, planetary gears, rack and pinions and the like, cams, ratchets, frictional slides, and/or linkages.

The housing **40** can include an internal, longitudinally extending threaded segment **40t** that engages threads **50t** of the length adjustment screw member **50s**. Thus, the outer wall of the housing **40w** can rotate and act as a nut to be able to threadably engage and rotate the screw **50s**. The screw **50s** can have a relatively fine pitch configuration, such as a thread configuration of 3-48 (48 threads per inch). The screw **50s** can be of brass for MRI compatibility, but other materials may be used as well as other pitch configurations.

In the embodiment shown in FIGS. 2B, 3A and 3B, for example, an outer wall **20w** of the tubular cannula can be fixably attached to the screw **50s**, typically bonded, so that the threads form the outerwall of a portion of the tubular cannula **20w** (typically a proximal end portion of the cannula **20p**) but other fixation configurations may be used.

In some embodiments, the outerwall of the tubular cannula **20w** can have the thread pattern formed directly therein. In some embodiments, the needle **30** can be fixably attached to the screw **50s** (not shown) to allow length adjustment. In some embodiments, more than one internal screw can be used, one attached to the tubular cannula **20** and one attached to the needle **30** and separate portions of the housing **40** or members held by the housing **40** can be used to selectively move each of the cannula **20** and the needle **30** to provide adjustable exposed lengths (not shown).

Referring to FIGS. 2B, 3B, 4A and 4B, the housing **40** can have an axially extending lumen **41** and an inner, longitudinally extending wall or surface **41s** extending about the lumen, at least a longitudinally extending segment of which can be threaded **40t**, typically for a sub-length of the overall length of the housing **40** residing between the proximal and distal ends of the housing. The threads **40t** can be configured to define hard stops at fully retracted and fully extended positions which can be associated with a short linear distance of between about 0.5 inches and 1.25 inches.

The housing **40** can be manually held by a finger(s) or hand of a user during use to allow for manual rotation of the

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housing outer wall **40w** or other user input to the screw **50s** or may be supported by a support frame or member (not shown).

The device **10** may also include a handle body **70** held in the housing **40** that has a longitudinally extending slot **72** that allows a laterally extending pin **55** attached to the screw **50s** and/or tubular cannula **20** in the embodiment shown, to move therein. The handle body **70** and/or outer surface of the housing **40** thereat can include visual indicia of position **77** such as symmetrically spaced apart marks and/or a graduated scale, for example. The pin **55** can include a color-contrast segment **55c** (FIG. 7) that extends across the slot **72** at or above an outer surface of a wall at the slot **72** to align with aligned spaced apart visual indicia marks **77** across the slot to facilitate visual recognition of the extended or retracted length position (distance between the needle tip **30t** and distal end of the guide cannula **20d**).

The handle body **70** can have an elongate cylindrical shape with an axially extending interior cavity surrounding the tubular cannula **20** and may be encased in the housing **40**. The housing **40** can have a transparent or visually transmissive outer wall **40w**. The handle body **70** can have a proximal end **70p** that resides in the housing **40**, typically abutting a ledge forming a pocket **40k** (FIGS. 2B, 3B) and a larger distal end **70d** that defines the distal end of the housing **40d** allowing the tubular cannula **20** to extend therethrough when assembled (FIGS. 2A, 2B, 3A and 3B, for example).

In some embodiments, the handle body **70** can provide some or all of the internal threads **40i** that cooperate with the screw **50s**. In some embodiments, the handle body **70** is devoid of internal threads and merely allows the tubular cannula **20** and/or threaded member **50s** to longitudinally (slidably) translate closely spaced thereto in the cavity of the handle body **70**.

The handle body **70** can be attached to an innerwall **40i** of the housing (FIGS. 2B, 3B) and/or may be held in the pocket **40k** (FIG. 2B) extending between a medial to a distal end portion of the housing **40**. A support member **44** can be affixed to a distal end of the housing **40d** to lock the handle body **70** in position while allowing the lower end portion of the tubular cannula **20** to extend out from the housing. The handle body **70** can be static and can allow the pin **55** to move up and down along the slot **72** to inhibit rotation of the handle body **70** during rotation of the screw **50s**.

A proximal support member **47** can be attached at a top of the housing **40**. The proximal support member **47** can have a small rigid tubular projection that attaches to the flex tubing **65** that extends a distance such as between 1-10 inches, typically about 3-8 inches, between the support member **47** and connector **60**. In other embodiments, the connector **60** can be directly attached to the end member **47** and/or housing **40** (not shown).

The support end members **44**, **47** and the handle body **70** can all remain stationary during use as the outerwall **40w** is rotated. The end support members **44**, **47** can capture the housing **40** therebetween, which can rotate in response to a user's direction clockwise and or counterclockwise to cause the translation and adjust the needle tip **30t** to the distal end of the cannula **20** length. Thus, the wall of the housing **40** and the screw **50s** can rotate to move the tubular cannula **20** (as shown) and/or the needle **30** (not shown).

The outer wall of the housing **40w** can include an elongate bracket **42** (FIGS. 2B, 4B) that is adjacent but laterally spaced apart from the rotatable outer wall **40w** and can be attached to each end member **44**, **47**.

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Referring now to FIGS. 3A, 3B, 5A, 5B, 5C and 6, for example, and in some exemplary embodiments, the needle **30** can comprise the inner capillary tube **31** and the outer capillary tube **33** and the tubes **31**, **33** can be fixably attached, typically bonded together, so that they have a fixed configuration relative to each other such that the inner capillary **31** extends about 3 mm from the distal end of the outer capillary **33**. An external polymeric conformable tube (i.e., a polyester shrink wrap tube) **35** can reside over the outer capillary tube **33** at least for a distance that can be external of the housing and/or distal end of the cannula **20d**.

The length adjustment mechanism **50** can be fixably attached (typically bonded) to the needle **30** or the tubular cannula **20**. The external polymeric conformable tube (i.e., a shrink wrap tube) **23** can reside over an exposed length of the cannula **20**, typically over a distal end thereof **20d** with the tapered end **21**. The pin **55** can also be attached (i.e., bonded) to the screw **50s** and/or tubular cannula **20**. The screw **50s** can be affixed to a proximal end portion of the tubular cannula **20p**, typically for a length between about 0.5 inches and 2 inches, more typically between about 0.75 inches and 1.1 inches, in some embodiments. The tubular cannula **20** and outer capillary **33** can terminate inside the housing **40**, typically adjacent the proximal end **70p** of the handle body). The upper end support **47** can be fixably attached (i.e., bonded) to the housing proximal end **40p** and the support tube **65** can be affixed to the end support **47**. The end support member **44** can be affixed (i.e., bonded) to the distal end portion of the handle body **70d**. The support tube **65** with inner capillary tube **31** can also be fixably attached (i.e., bonded) to the connector **60**.

Referring to FIGS. 8A, 8B, 9A and 9B, the assembly **10'** can have a length adjustment mechanism **50'** that can include an external user interface member **50'** (shown as a thumb-wheel) that extends laterally outward a distance beyond the housing **40** that is attached to the housing **40**. As shown, this mechanism **50'** includes a pinion gear **151** that engages a longitudinally extending internal rack gear **150** inside the housing **40**. FIG. 8A illustrates a retracted configuration of the needle tip **30t** and FIG. 8B illustrates an exemplary extended position of the needle tip **30t** relative to the distal end **20d** of the tubular cannula **20**. Thus, the outer wall **40w** is not required to rotate. The rack gear **150** can be bonded or otherwise fixedly attached to the needle **30** (typically the inner capillary tube **31**). The tubular cannula **20** can be rigid and held by a distal end **40d** of the housing **40** to have a fixed length (i.e., it does not move).

Referring to FIGS. 9A and 9B, the rack gear **150** can have longitudinally extending gear teeth **150g** on one side that face the pinion gear **151** and can have a series of longitudinally spaced apart recesses **150r** (shown as arcuate recesses) along a length of the other opposing longitudinally extending side that can slidably engage a pin **144** extending laterally inside a cavity **140c** provided by mating first and second housing members **40a**, **40b**. The housing members **40a**, **40b** can include a longitudinally extending slot **141** that cooperate to hold the rack gear **150** in position. The rack gear **150** can pull the needle **30** up and down relative to the housing and the tubular cannula **20** to adjust the position of the exposed needle tip **30t**. The rack gear **150** can optionally include alignment tabs **153** that can engage alignment slots **145** in the inner wall of one or both of the housing members **40a**, **40b**.

The rack gear **150** can be flexible (meaning it can be compressed or bent side to side or front to back using a small bending force or pressure). The rack gear **150** can have sufficient rigidity to have a self-supporting three dimen-

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sional shape but can flex in any direction when outside the housing 40. FIG. 9C illustrates by the arrows above the gear with an exemplary flex axis A, that the gear 150 can bend side to side relative to the housing 40 when extended from the housing 40 with the needle 30 (typically inner capillary 31) extending out each longitudinally extending end thereof. The rack gear 150 can comprise a polymer such as a nylon or polycarbonate and may be injection molded.

As shown by the broken line extension 30f of the needle in FIG. 8A, the extension of the needle 30 can be flexible and can loop and/or bend when held loose and not supported by a support member. The pinion gear 151 may also be flexible or may comprise a different material than the rack gear and may be rigid, semi-rigid or be less flexible than the rack gear 150.

FIGS. 8A, 8B and 9A illustrate that the housing 40 can curve (be arcuate, concave or convex) typically having a straight segment that can optionally curve above the external length adjustment mechanism 50' and/or pinion gear 151. The internal slots 141 can direct the rack gear 150 to take on a conformal curved shape when it travels into this space.

FIG. 9B shows that the housing 40 can be shorter and straight, relative to the configuration shown in FIG. 9A, for example.

FIGS. 9C, 9F and 9E illustrate a needle tip 30t to distal end of tubular cannula 20 in a retracted configuration (the needle tip 30t is closer to the distal end of the tubular cannula 20 than in an extended configuration/position) with the gear 150 outside the housing 40 according to embodiments of the present invention. The gear 150 can be exposed but typically extends and retracts in adjacent tubing 240 (FIG. 13) with the inner capillary 31 and/or other needle 30 and/or capillary member. The needle 30 can travel longitudinally maximally a stroke distance between extended and retracted positions between 1-6 inches, such as between 2-4 inches, while the tubular cannula 20 is fixed in its length relative to the needle and/or housing 40.

FIG. 9D illustrates a needle tip 30t to distal end 20d of the tubular cannula in an extended configuration with the gear 150 totally inside the housing 40 and its distal end closer to the bottom member 146b than in the position shown in FIG. 9E, for example.

FIGS. 9C-9F also illustrate that the fluid transfer assembly 10' can include a tube 65 that encloses the needle 30 and that extends above the housing 40 to a connector 60, typically a luer connector as discussed above.

FIGS. 9E and 9F illustrate that the rotatable user interface member 50i can include a drive shaft 152 that is attached to a center of the pinion 151 so that rotation of the member 50i rotates the pinion 151, which moves the rack gear 150 holding the needle 30.

FIGS. 9G, 9H and 9I illustrate exemplary attachment configurations of components of the assembly 10'. The pin 153 can be affixed, typically bonded, to the gear 150. The proximal end of the tubular cannula 20p can be bonded or otherwise affixed to the distal end of the housing 40d. The gear 150 can be affixed, typically bonded, to the needle 30, typically the inner capillary 31. The needle 30 can extend through and out each end of the gear 150, typically via a longitudinally extending medial slot, channel or aperture in the gear 150. The housing members 40a, 40b can be matably attached, typically bonded, with the gear 150 and needle 30, typically the inner capillary 31, therein.

The tube 65, attached to the screw 50s and the needle 30 (i.e., inner capillary 31) can form a unitary assembly so that the screw 50s, tube 65 and needle 30 can move as a unit in the housing 40 to extend and retract the needle tip 30t.

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FIGS. 10A, 10B, 11A and 11B illustrate another embodiment of the assembly 10". In this embodiment, similar to the embodiment shown in FIG. 1A, the outer wall 40w of the housing 40 can rotate to engage the length adjustment mechanism 50" which can comprise a longitudinally extending internal screw 50s. The internal wall can comprise threads 40t that engage the internal screw 50s so that when a user rotates the outer wall 40w (i.e., a cylindrical "knob"), the screw 50s moves longitudinally up and down. In some embodiments, the screw 50s is bonded or otherwise affixed to the needle 30 and does not rotate to move the needle 30 up and down relative to the tubular cannula 20. The housing 40 can have upper and lower members 146u, 146b that are static and do not rotate or move in a longitudinal direction. In operation, a user can hold onto one or both of these members 146u, 146b and rotate the intermediate outer wall segment 40w to move the screw 50s up or down and therefore move the needle 30 up or down relative to the tubular cannula 20. A proximal end of the tubular cannula 20p can terminate inside of and typically at a distal end of the housing 40d.

Referring to FIG. 11A, the screw 50s can be held by a hollow internal tubular shaft 156 that can guide the screw 50s up and down in the housing 40. The shaft 156 can have a wall 156w that has an open longitudinally extending segment 158. The open segment can extend circumferentially between about 15 to about 90 degrees. The shaft 156 can connect/attach to the upper and lower stationary members 146u, 146b. The longitudinally extending open segment 158 can be a cut out that is keyed to a matable internal anti-rotation feature. The screw 50s can have a radially extending key feature 50k that can engage a slot in the housing 40 to provide anti-rotational support.

Referring again to FIG. 11A, the upper and/or lower member 146u, 146b can have user-tactile engagement features 147 such as be knurled, have a raised surface pattern and/or have a larger outer dimension or feature (i.e., greater diameter, finger engagement member such as a projection or fin or body with a larger radial or lateral extent) relative to the rotatable cylindrical outer wall segment 40w that can provide ease of user touch and hold during use.

FIGS. 12A-12D also illustrate that the fluid transfer assembly 10" can include a tube 65 that encloses the needle 30 and that extends above the housing 40 to a connector 60, typically a luer connector as discussed above.

Referring to FIGS. 12A-12D, the screw 50s can reside closer to the distal end of the housing 40d when the needle tip 30t is extended, compare, for example, FIGS. 12B-12D with the retracted configuration shown in FIG. 12A.

FIGS. 12E and 12F illustrate exemplary attachment configurations of components of the assembly 10". The tube 65 can be attached to an upper end of the screw 50s and can reside in the support shaft 156. The opposing ends of the support shaft 156 can be affixed to the respective upper and lower members 146u, 146b of the housing 40.

Optionally, the needle 30 can travel longitudinally maximally a stroke distance between extended and retracted positions between 1-6 inches, such as between 2-4 inches, while the tubular cannula 20 is fixed in its length relative to the needle and/or housing 40.

Referring to FIG. 13, in some embodiments, the assembly 10, 10', 10" can be used with a length of flexible (extension) tubing 240 which may be provided as an integrated subassembly 240a. In other embodiments, the tubing 240 can be provided as a component separate from the assembly 10, 10', 10" for assembly prior to or during a procedure. If so, the ends of the tubing 240 and/or connectors 60 and 160 may be

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capped or held in sterile sleeves or otherwise package to maintain sterility or cleanliness.

In some embodiments, a length of the needle **30** or a cooperating (fused silica) capillary tube **230** can be encased in the flexible tubing **240**. The length may be a short or long length. The flexible tubing **240** can protect a long length of the proximal end of the needle **30**, the length above and outside the housing **40**, or another downstream cooperating needle and/or capillary **230** attached thereto where such a configuration is used.

In some embodiments, the long needle segment **230** can be one continuous piece of fused silica glass that goes from the distal end **240d** of the tubing **240** at the connector **160** to the very proximal end **240p**, typically between about 4 feet to about 10 feet long. The tubing **240** with the capillary/needle segment **230** can be used to connect the needle **30** to the pump P (FIG. 9) or other pressurized source and the delivery substance A can flow through the tubing **240** to the needle **30** for delivery. Further, other MRI compatible needle materials may be used. According to some embodiments, the tubing **240** is flexible PVC tubing. According to some embodiments, the tubing **240** is silicone tubing. The tubing **240** may have various lengths. For example, in some embodiments, the tubing may be between about four to about ten feet (4 ft-10 ft) in length, although other lengths are possible.

The tubular cannula **20** can have a rigid body. The cannula **20** may comprise alumina/ceramic that can be MRI visible. The cannula **20** can have an outer surface having a lubricious coating and/or sleeve **23**. The coating and/or sleeve can be a substantially transparent polymeric material. Where a sleeve is used, the sleeve **23** can be a thin flexible polymeric sleeve that can be conformably attached to the underlying cannula body. The coating and/or sleeve can be configured with sufficient strength to be able to retain components of the cannula should the cannula fracture. The sleeve can be an elastomeric shrink wrap or tube that can be heat-shrink applied to the underlying body.

The assembly **10**, **10'**, **10''** can be configured to flowably introduce and/or inject a desired therapy substance (e.g., antigen, gene therapy, chemotherapy or stem-cell or other therapy type).

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The connector **160** can be configured as a luer lock to lock to the connector **60** and the needle/tubing **240/230** can be operatively coupled to an infusion pump P which supplies a mass flow of the desired substance or material to be delivered into the patient.

As shown in FIGS. **14** and **15**, the tubular cannula **20** can extend through a tubular support **260** of a trajectory guide **250t** that can be held by a base or frame, e.g., a stereotactic frame that can be secured to the patient or that can be secured to a holder residing over the patient. See, e.g., U.S. Pat. Nos. 8,315,689, 8,175,677 and 8,374,677 and US Patent Application Publication No. 2010/0198052 (Ser. No. 12/694,865) for descriptions of patient planning and entry protocols and frames and trajectory guides, the contents of which are hereby incorporated by reference as if recited in full herein.

In some embodiments, the needle **30** is configured to deliver a drug therapy to the brain. The drug therapy can comprise substance S (FIG. **15**) delivered to the target site or region A through the tubular cannula **20** and cooperating needle **30** may be any suitable and desired substance for drug discovery, animal or human clinical trials and/or approved medical procedures. According to some embodiments, the substance S is a liquid or slurry. In the case of a tumor, the substance may be a chemotherapeutic (cytotoxic) fluid. In some embodiments, the substance can include certain types of advantageous cells that act as vaccines or other medicaments (for example, antigen presenting cells such as dendritic cells). The dendritic cells may be pulsed with one or more antigens and/or with RNA encoding one or more antigen. Exemplary antigens are tumor-specific or pathogen-specific antigens. Examples of tumor-specific antigens include, but are not limited to, antigens from tumors such as renal cell tumors, melanoma, leukemia, myeloma, breast cancer, prostate cancer, ovarian cancer, lung cancer and bladder cancer. Examples of pathogen-specific antigens include, but are not limited to, antigens specific for HIV or HCV. In some embodiments, the substance S may comprise radioactive material such as radioactive seeds. Substances S delivered to a target area in accordance with embodiments of the present invention may include, but are not limited to, the following drugs (including any combinations thereof) listed in Table 1:

TABLE 1

DRUG (generic name)	DISORDER(S)
Caprylidene	Alzheimer's disease
Donepezil	Alzheimer's disease
Galantamine	Alzheimer's disease
Memantine	Alzheimer's disease
Tacrine	Alzheimer's disease
vitamin E	Alzheimer's disease
ergoloid mesylates	Alzheimer's disease
Riluzole	Amyotrophic lateral sclerosis
Metoprolol	Benign essential tremors
Primidone	Benign essential tremors
Propanolol	Benign essential tremors
Gabapentin	Benign essential tremors & Epilepsy
Nadolol	Benign essential tremors & Parkinson's disease
Zonisamide	Benign essential tremors & Parkinson's disease
Carmustine	Brain tumor
Lomustine	Brain tumor
Methotrexate	Brain tumor
Cisplatin	Brain tumor & Neuroblastoma
Ioversol	Cerebral arteriography
Mannitol	Cerebral Edema
Dexamethasone	Cerebral Edema & Neurosarcoidosis
Baclofen	Cerebral spasticity
Ticlopidine	Cerebral thrombosis/embolism
Isoxsuprine	Cerebrovascular insufficiency

TABLE 1-continued

DRUG (generic name)	DISORDER(S)
Cefotaxime	CNS infection & Meningitis
Acyclovir	Encephalitis
Foscarnet	Encephalitis
Ganciclovir	Encephalitis
interferon alpha-2a	Encephalitis
Carbamazepine	Epilepsy
Clonazepam	Epilepsy
Diazepam	Epilepsy
divalproex sodium	Epilepsy
Ethosuximide	Epilepsy
Ethotoin	Epilepsy
Felbamate	Epilepsy
Fosphenytoin	Epilepsy
Levetiracetam	Epilepsy
Mephobarbital	Epilepsy
Paramethadione	Epilepsy
Phenytoin	Epilepsy
Trimethadione	Epilepsy
Pregabalin	Epilepsy & Neuralgia
immune globulin intravenous	Guillain-Barre Syndrome
interferon beta-1b	Guillain-Barre Syndrome & Multiple sclerosis
Azathioprine	Guillain-Barre Syndrome & Multiple sclerosis & Neurosarcoidosis
Risperidone	Head injury
Tetrabenazine	Huntington's disease
Acetazolamide	Hydrocephalus & Epilepsy
Alteplase	Ischemic stroke
Clopidogrel	Ischemic stroke
Nimodipine	Ischemic stroke & Subarachnoid hemorrhage
Aspirin	Ischemic stroke & Thromboembolic stroke
Amikacin	Encaphalitis
Ampicillin	Encaphalitis
ampicillin/sulbactam	Encaphalitis
Ceftazidime	Encaphalitis
Ceftizoxime	Encaphalitis
Cefuroxime	Encaphalitis
Chloramphenicol	Encaphalitis
cilastatin/imipenem	Encaphalitis
Gentamicin	Encaphalitis
Meropenem	Encaphalitis
Metronidazole	Encaphalitis
Nafcillin	Encaphalitis
Oxacillin	Encaphalitis
Piperacillin	Encaphalitis
Rifampin	Encaphalitis
sulfamethoxazole/trimethoprim	Encaphalitis
Tobramycin	Encaphalitis
Triamcinolone	Encaphalitis
Vancomycin	Encaphalitis
Ceftriaxone	Encaphalitis & Neurosyphilis
Penicillin	Encaphalitis & Neurosyphilis
Corticotropin	Multiple sclerosis
Dalfampridine	Multiple sclerosis
Glatiramer	Multiple sclerosis
Mitoxantrone	Multiple sclerosis
Natalizumab	Multiple sclerosis
Modafinil	Multiple sclerosis
Cyclophosphamide	Multiple sclerosis & Brain tumor & Neuroblastoma
interferon beta-1a	Multiple sclerosis & Neuritis
Prednisolone	Multiple sclerosis & Neurosarcoidosis
Prednisone	Multiple sclerosis & Neurosarcoidosis
Amantadine	Multiple sclerosis & Parkinson's disease
Methylprednisolone	Neuralgia
Desvenlafaxine	Neuralgia
Nortriptyline	Neuralgia
Doxorubicin	Neuroblastoma
Vincristine	Neuroblastoma
Albendazole	Neurocystercosis
chloroquine phosphate	Neurosarcoidosis
Hydroxychloroquine	Neurosarcoidosis
Infliximab	Neurosarcoidosis
Pentoxifylline	Neurosarcoidosis
Thalidomide	Neurosarcoidosis
Apomorphine	Parkinson's disease
Belladonna	Parkinson's disease
Benzotropine	Parkinson's disease
Biperiden	Parkinson's disease
Bromocriptine	Parkinson's disease

TABLE 1-continued

DRUG (generic name)	DISORDER(S)
Carbidopa	Parkinson's disease
carbidopa/entacapone/levodopa	Parkinson's disease
carbidopa/levodopa	Parkinson's disease
Entacapone	Parkinson's disease
Levodopa	Parkinson's disease
pergolide mesylate	Parkinson's disease
Pramipexole	Parkinson's disease
Procyclidine	Parkinson's disease
Rasagiline	Parkinson's disease
Ropinirole	Parkinson's disease
Rotigotine	Parkinson's disease
Scopolamine	Parkinson's disease
Tolcapone	Parkinson's disease
Trihexyphenidyl	Parkinson's disease
Selegiline	Parkinson's disease
Rivastigmine	Parkinson's disease & Alzheimer's disease
Anisindione	Thromboembolic stroke
Warfarin	Thromboembolic stroke
5-hydroxytryptophan	Depression & Anxiety & ADHD
Duloxetine	Depression & Anxiety & Bipolar disorder
Escitalopram	Depression & Anxiety & Bipolar disorder
Venlafaxine	Depression & Anxiety & Bipolar disorder & Autism & Social anxiety disorder
Desvenlafaxine	Depression & Anxiety & PTSD & ADHD
Paroxetine	Depression & Anxiety & PTSD & Social anxiety disorder
fluoxetine/olanzapine	Depression & Bipolar disorder
l-methylfolate	Depression & BPD
Amitriptyline	Depression & PTSD
Sertraline	Depression & PTSD & Bipolar disorder & Social anxiety disorder
Fluvoxamine	Depression & PTSD & Social anxiety disorder
Olanzapine	Depression & Schizophrenia & Bipolar disorder
Paliperidone	Depression & Schizophrenia & Bipolar disorder
Aripiprazole	Depression & Schizophrenia & Bipolar disorder & Autism
Quetiapine	Depression & Schizophrenia & PTSD & BPD & Bipolar disorder
Risperidone	Depression & Schizophrenia & PTSD & BPD & Bipolar disorder & Autism
Amisulpride	Depression & Social anxiety disorder
Chlorpromazine	Psychosis
Droperidol	Psychosis
Fluphenazine	Psychosis
Periciazine	Psychosis
Perphenazine	Psychosis
Thiothixene	Psychosis
Triflupromazine	Psychosis
Haloperidol	Psychosis & Dementia
Prazosin	PTSD
Clozapine	Schizophrenia
Flupenthixol	Schizophrenia
lloperidone	Schizophrenia
Loxapine	Schizophrenia
Mesoridazine	Schizophrenia
Promazine	Schizophrenia
Reserpine	Schizophrenia
Thioridazine	Schizophrenia
Zuclopenthixol	Schizophrenia
Asenapine	Schizophrenia & Bipolar disorder
Levomepromazine	Schizophrenia & Bipolar disorder
Ziprasidone	Schizophrenia & Bipolar disorder
Molindone	Schizophrenia & Psychosis
Pimozide	Schizophrenia & Psychosis
Thioridazine	Schizophrenia & Psychosis
Cytarabine	Chemotherapy, hematological malignancies

According to some embodiments, the assembly **10**, **10'**, **10''** is configured as an infusate delivery system that is delivered to a patient at an infusion rate in the range of from about 1 to 3  $\mu\text{L}/\text{minute}$ .

Insertion of the surgical tubular cannula **20** (or any other surgical, e.g., delivery, cannula) can be tracked in near real time by reference to a void in the patient tissue caused by the cannula **20** and reflected in the MR image. In some embodiments, one or more MRI-visible fiducial markers may be provided on the surgical cannula **20** or housing **40**, MR

scanned and processed, and displayed on the UI. In some embodiments, the surgical cannula **20** may itself be formed of an MRI-visible material, MR scanned and processed, and displayed on the UI.

According to some embodiments, the surgical cannula **20** may include an embedded intrabody MRI antenna that is configured to pick-up MRI signals in local tissue during an MRI procedure. The MRI antenna can be configured to reside on a distal end portion of the surgical cannula. In some embodiments, the antenna has a focal length or signal-

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receiving length of between about 1-5 cm, and typically is configured to have a viewing length to receive MRI signals from local tissue of between about 1-2.5 cm. The MRI antenna can be formed as comprising a coaxial and/or triaxial antenna. However, other antenna configurations can be used, such as, for example, a whip antenna, a coil antenna, a loopless antenna, and/or a looped antenna. See, e.g., U.S. Pat. Nos. 5,699,801; 5,928,145; 6,263,229; 6,606,513; 6,628,980; 6,284,971; 6,675,033; and 6,701,176, the contents of which are hereby incorporated by reference as if recited in full herein. See also U.S. Patent Application Publication Nos. 2003/0050557; 2004/0046557; and 2003/0028095, the contents of which are also hereby incorporated by reference as if recited in full herein.

While the surgical cannula **20** and needle **30** have been described by way of example as delivery devices and methods for delivering a substance to a patient, in accordance with some embodiments of the invention, the cannula **20** and needle **30** and associated methods can be used to withdraw a substance (e.g., spinal fluid, cardiac fluid or neuro fluid) from a patient. Thus, it will be appreciated that the devices and methods as disclosed herein can be used to transfer a substance into and/or from a patient.

While the devices have been described herein primarily with reference to MRI-guided insertion and infusion procedures, in some embodiments the devices can be used in procedures without MRI guidance.

While the surgical tubular cannula **20** has been described in use with a trajectory guide **250t**, the cannula **20** may be used with other types of trajectory guidance or stereotactic frames or without a stereotactic frame or trajectory guide.

FIG. **14** illustrates an MRI-guided interventional system **100** with an MRI scanner **1220**, a clinician workstation **1230** with at least one circuit **1230c**, at least one display **1232**, an MRI compatible trajectory guide **250t** and a fluid transfer assembly **300** (including the assembly **10**, **10'**, **10"** and tubing **240** (FIG. **13**). In some embodiments, the fluid exchange (i.e., delivery) assembly **300** can cooperate with an automated infusion pump **P** or, less preferably, a manual syringe, or another pressurized delivery source.

The system **100** can be configured to render or generate near real time or real time visualizations of the target anatomical space using MRI image data and predefined data of at least one surgical tool (e.g., tubular cannula **20**, housing **40** and/or trajectory guide **250t**) to segment the image data and place the trajectory guide **250t** and the cannula **20** in the rendered visualization in the correct orientation and position in 3D space (which is the MRI surgical space for MRI embodiments), anatomically registered to a patient. The trajectory guide **250t** and the cannula **20** can include or cooperate with tracking, monitoring and/or other interventional components.

An exemplary trajectory guide **250t** is illustrated in FIG. **14** in an exemplary (head) position on a patient. However, the trajectory guide can be used for any target location including, for example, the spine. The trajectory guide **250t** can be mounted over or on an object, e.g., patient or subject, so that the upper receiving tube/support column **260** (FIG. **15**) is oriented substantially perpendicular to the entry location (typically for spinal uses) or may be mounted to extend outward from the patient entry location at an angle as shown in FIG. **14**.

The trajectory guide **250t** typically provides X-Y adjustment and pitch and roll adjustment in order to accurately position the cannula **20** at a desired location within a patient. For additional discussion of examples of suitable trajectory guides, see U.S. Pat. No. 8,374,677, the contents of which

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are hereby incorporated by reference as if recited in full herein. However, it is noted that other trajectory guide configurations may be used and embodiments of the invention are not limited by the examples of the trajectory guides herein.

According to some embodiments, the systems are configured to provide a substantially automated or semi-automated and relatively easy-to-use MRI-guided system with defined workflow steps and interactive visualizations. In particular embodiments, the systems define and present workflow with discrete steps for finding target and entry point(s), guiding the alignment of the targeting cannula to a planned trajectory, monitoring the insertion of the tubular (guide) cannula **20**, and adjusting the (X-Y) position in cases where the placement needs to be corrected. During steps where specific MR scans are used, the circuit or computer module can display data for scan plane center and angulation to be entered at the console. The workstation/circuit can passively or actively communicate with the MR scanner. The system can also be configured to use functional patient data (e.g., fiber tracks, fMRI and the like) to help plan or refine a target surgical site and/or access path.

The system **100** may also include a decoupling/tuning circuit that allows the system to cooperate with an MRI scanner **1220** and filters and the like. See, e.g., U.S. Pat. Nos. 6,701,176; 6,904,307 and U.S. Patent Application Publication No. 2003/0050557, the contents of which are hereby incorporated by reference as if recited in full herein.

FIG. **16** is a flow chart of exemplary actions that can be carried out according to embodiments of the present invention. A housing holding a tubular cannula with an elongate needle extending through the tubular cannula is provided so that a needle tip is external to the tubular cannula (block **400**). A screw or gear in the housing is rotated to longitudinally translate the tubular cannula and/or the needle tip out of the housing (block **410**). Adjusting, in vivo, a distance between the distal end of the tubular cannula and the needle tip based on the longitudinal translation (block **420**).

The housing can be attached to a length of tubing encasing a length of capillary tubing forming part of the needle that extends outside the housing that extends to a connector, the method includes connecting the connector to another connector holding fused silica capillary tubing inside a length of flexible tubing that is in fluid communication with a pump (block **430**).

A full stroke of translation can be between 0.5 inches and 2 inches or about 1.6 inches, such as about 1.25 inches (block **440**).

The needle can have a tip defined by an inner capillary tube and can be fixedly attached to an outer capillary tube that defines an increased outer wall segment a distance of 1-5 mm, typically 3 mm from the tip (block **445**).

Inserting the tubular cannula into a trajectory guide mounted to a patient and rotating the screw while the tubular cannula held in the trajectory guide (block **450**).

The rotating can be carried out by rotating an outer wall of the housing to rotate the screw (block **455**).

The screw can be or gear can comprise a longitudinally extending screw attached to an outerwall of the tubular cannula and the housing has an inner wall segment with internal threads that engage the screw attached to the tubular cannula to cause the translation (block **460**).

The screw or gear can comprise a longitudinally extending rack gear that is attached to the needle and that can move the needle relative to the tubular cannula in response to rotation of an external thumb wheel that rotates a pinion that engages the rack gear (block **462**).



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The cannula and needle can be an infusate ventricular delivery system for brain delivery of a target substance to a target anatomical region (block 465). For example, the device can be configured to allow a single intrabody insertion of the needle 30 to a target anatomical region in the brain (such as tissue generally in-line with and between the nose and back of the head and, starting dispensing/infusing from the back of the head while translating the needle frontward to treat a large volume through one intrabody insertion of the needle).

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.

That which is claimed is:

1. A surgical assembly for intrabrain therapy, comprising:
  - a tubular cannula having opposing proximal and distal ends;
  - a needle that is elongate and has opposing proximal and distal ends, wherein a length of the needle extends through the tubular cannula so that the distal end of the needle extends out of the distal end of the tubular cannula to provide a tip of the needle that is exposed;
  - a length adjustment mechanism coupled to the needle, the tubular cannula or to both the needle and the tubular cannula, wherein at least one of the needle or the tubular cannula is configured to controllably move longitudinally to adjust a length between the distal end of the tubular cannula and the tip of the needle that is exposed, wherein the length adjustment mechanism comprises a flexible rack gear, and wherein the needle extends through and is attached to the flexible rack gear;
  - a container comprising a therapeutic agent in fluid communication with the needle; and
  - a length of tubing coupled to the container at a first end portion thereof and coupled to a connector extending about the proximal end of the needle at an opposing second end portion of the length of tubing.
2. The surgical assembly of claim 1, wherein the surgical assembly is configured for an MRI-guided surgery.
3. The surgical assembly of claim 1, wherein the therapeutic agent comprises a drug therapy, a cell therapy and/or a gene therapy.
4. The surgical assembly of claim 1, wherein a segment of the needle that extends through the flexible rack gear is distal to the proximal end of the needle and proximal to the distal end of the needle, and wherein the length adjustment mechanism further comprises a rotatable externally accessible knob that is coupled to a pinion gear that is rotatably coupled to the flexible rack gear to controllably slidably advance and retract the needle attached to the flexible rack gear.
5. The surgical assembly of claim 1, wherein the needle is defined by an inner tube bonded to an outer tube to define at least first and second co-axially disposed segments having different outer diameters, with the inner tube being longer than the outer tube and defines the tip of the needle that is exposed, and wherein the inner tube is directly affixed to the flexible rack gear of the length adjustment mechanism.

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6. The surgical assembly of claim 1, wherein the length adjustment mechanism is configured to provide a maximal stroke length of between 0.5 inches and 3 inches.

7. The surgical assembly of claim 1, wherein the needle has an inner diameter in a range of about 100  $\mu$ m to about 750  $\mu$ m.

8. The surgical assembly of claim 7, wherein an outer diameter of the needle at the exposed tip is in the range of about 75  $\mu$ m to 1.08 mm.

9. The surgical assembly of claim 1, wherein the tubular cannula has an outer diameter that is between about 0.2 inches and 0.015 inches and an inner diameter that is between 0.10 inches and 0.001 inches, and wherein the distal end of the tubular cannula has a smaller outer diameter than an upper or proximal portion thereof.

10. The surgical assembly of claim 1, wherein the connector extending about the proximal end of the needle is a luer connector, and wherein the proximal end of the needle extends into an internal portion of the connector to be in fluid communication with a tubing connector attached to the second end portion of the tubing.

11. The surgical assembly of claim 1, wherein the needle has a total length between the connector and the exposed tip in a range of about 10-20 inches.

12. The surgical assembly of claim 1, wherein the tubing encloses an internal needle provided as a continuous piece of fused silica glass and has a length in a range of about 4 feet to about 10 feet.

13. The surgical assembly of claim 1, further comprising a trajectory guide, wherein the tubular cannula is configured to extend through a tubular support of the trajectory guide secured to a patient or secured to a holder residing about the patient, wherein the flexible rack gear resides above the cannula and above the trajectory guide.

14. The surgical assembly of claim 1, wherein the flexible rack gear comprises a flexible body with a longitudinally extending through-channel and with external gear teeth arranged to extend in a longitudinal direction, and wherein a segment of the needle distal to the proximal end of the needle extends through the through-channel.

15. A surgical assembly for intrabrain therapy, comprising:

- a tubular cannula having opposing proximal and distal ends;
  - a needle that is elongate and has opposing proximal and distal ends, wherein a length of the needle extends through the tubular cannula so that the distal end of the needle extends out of the distal end of the tubular cannula to provide a tip of the needle that is exposed;
  - a length adjustment mechanism coupled to the needle, the tubular cannula or to both the needle and the tubular cannula, wherein at least one of the needle or the tubular cannula is configured to controllably move longitudinally to adjust a length between the distal end of the tubular cannula and the tip of the needle that is exposed;
  - a container comprising a therapeutic agent in fluid communication with the needle; and
  - a length of tubing coupled to the container at a first end portion thereof and coupled to a connector extending about the proximal end of the needle at an opposing second end portion of the length of tubing,
- wherein the length adjustment mechanism comprises a flexible rack gear comprising a flexible body with a through-channel that holds a segment of the needle,

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wherein the length adjustment mechanism is configured to longitudinally translate the flexible rack gear to adjust the length.

16. The surgical assembly of claim 15, wherein the flexible rack gear is positioned proximal to the proximal end of the tubular cannula and has sufficient rigidity to have a self-supporting three-dimensional shape but is configured to flex from a straight longitudinally extending orientation to a curvilinear orientation outside and proximal to the tubular cannula, and wherein the needle extends through the flexible rack gear to extend out of opposing proximal and distal ends of the flexible rack gear.

17. The surgical assembly of claim 15, wherein the therapeutic agent comprises cells.

18. A surgical assembly for intrabody therapy, comprising:

- a tubular cannula having opposing proximal and distal ends;
- a needle that is elongate and has opposing proximal and distal ends, wherein a length of the needle extends through the tubular cannula so that the distal end of the needle extends out of the distal end of the tubular cannula to provide a tip of the needle that is exposed;

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a length adjustment mechanism comprising a rack gear having a flexible body that is attached to a segment of the needle and with the needle positioned so that the needle extends proximally and distally from the rack gear, and wherein the length adjustment mechanism is configured to controllably move the rack gear longitudinally to adjust a length between the distal end of the tubular cannula and the tip of the needle that is exposed;

a container comprising a therapeutic agent in fluid communication with the needle; and

a length of tubing coupled to the container at a first end portion thereof and coupled to a connector extending about the proximal end of the needle at an opposing second end portion of the length of tubing.

19. The surgical assembly of claim 18, wherein the length adjustment mechanism comprises a housing configured to provide a pinion gear coupled to the rack gear whereby the rack gear translates relative to the housing while the needle extends proximally and distally from the housing.

20. The surgical assembly of claim 18, wherein the therapeutic agent provides a drug therapy, a cell therapy and/or a gene therapy.

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