

**ROBOTIC DEVICES AND SYSTEMS FOR PERFORMING SINGLE INCISION
PROCEDURES AND NATURAL ORIFICE TRANSLUMENAL ENDOSCOPIC
SURGICAL PROCEDURES, AND METHODS OF CONFIGURING ROBOTIC
DEVICES AND SYSTEMS**

Cross-reference to related applications

[0001] This application is a continuation-in-part of U.S. Application No. 14/693,207, filed on April 22, 2015, which claims priority to U.S. Provisional Application No. 61/982,717, filed on April 22, 2014, the contents of all of which are hereby expressly incorporated by reference in their entirety, including the contents and teachings of any references contained therein.

Background

[0002] The present disclosure relates generally to systems, devices, and methods, and more specifically, relates to systems, devices, and methods for use in performing procedures via a single incision or a natural orifice.

[0003] Conventional surgical procedures will generally require one or more large incisions to a patient in order for the surgical team to perform a surgical action. With the advancement of medical science and technology, most conventional open surgical procedures have been largely replaced with minimally invasive surgery (MIS) procedures. Recent developments in respect to computer-assisted and/or robotic surgical technology have contributed to advancements in MIS, including the ability to translate a surgeon's desired actions into movements of robotic instruments inside the body cavity of a patient.

Brief Summary

[0004] Despite recent developments in modern medical science and technology, it is recognized in the present disclosure that one or more problems are encountered in modern surgical technology and methodology. For example, a typical MIS procedure requires multiple incisions to a patient in order to allow access via the incisions for the insertion of a camera and various other laparoscopic instruments into the body cavity of the patient.

[0005] As another example, surgical robotic devices oftentimes encounter difficulties during surgical procedures due to insufficient anchoring and/or reactive forces to stabilize against forces that are desired and/or necessary to be applied during surgical actions.

[0006] It is also recognized in the present disclosure that surgical robotic systems face difficulties in providing an instrument, such as a cutting or gripping instrument attached to the end of a surgical robotic arm, with access to all or even most parts, areas, and/or quadrants of abdominal cavity of a patient. That is, after the surgical robotic arm is inserted in the abdominal cavity of the patient and ready to perform a surgical action, the instrument attached to the end of the surgical robotic arm is typically limited to access only certain parts, areas, and quadrants of the abdominal cavity of the patient.

[0007] In yet another example, known surgical robotic systems typically provide only between one to two surgical robotic arms per access or opening (such as an incision or a natural orifice) of the patient. In this regard, one or more additional incisions will be required for the insertion of a camera and various laparoscopic instruments into the abdominal cavity of the patient.

[0008] As another example, while known surgical robotic systems have been designed for use in an abdominal cavity of a patient to perform forward-directed surgical procedures, such systems have not been designed for and may encounter problems when applied in situations requiring reverse-directed surgical procedures. For example, such known surgical robotic systems have not been designed for deployment through a natural orifice, such as a rectum or vagina, for performing natural orifice transluminal endoscopic surgery (or NOTES), such as pelvic gynecological and/or urological procedures. Such systems may encounter one or more problems, such as the inability to access certain organs, tissues, or other surgical sites upon insertion into the natural orifice.

[0009] Present example embodiments relate generally to systems, devices, and methods for addressing one or more problems in surgical robotic systems, devices, and methods, including those described above and herein.

[0010] In an exemplary embodiment, a surgical system is described in the present disclosure. The surgical system may comprise a port assembly and an instrument arm assembly. The port assembly may be an elongated structure and having a first end section and a second end section. The first end section may include a first end channel and a first gate assembly. The first gate assembly may be configurable to transition between an open position to allow access through the first end channel and a closed position to prevent access through the first end channel. The second end section may include a second end channel, a second gate assembly, and an anchor port. The second end channel may be substantially aligned with the first end channel. The second gate assembly may be configurable to transition between an open position to allow access through the second end channel and a closed position to prevent access through the

second end channel. The instrument arm assembly may include a shoulder section securable to the anchor port of the second end section, a first arm section secured to the shoulder section, an elbow section secured to the first arm section, a second arm section secured to the elbow section, a wrist section secured to the second arm section, and an end effector section secured to the wrist section. The end effector section may include an end effector.

[0011] In another exemplary embodiment, a port assembly is described. The port assembly may be for use in a surgical system. The surgical system may include one or more instrument arm assemblies for performing a surgical action. The port assembly may comprise a first end section and a second end section. The first end section includes a first end channel and a first gate assembly. The first gate assembly may be configurable to transition between an open position to allow access through the first end channel and a closed position to prevent access through the first end channel. The second end section may include a second end channel, a second gate assembly, and an anchor port. The second end channel may be substantially aligned with the first end channel. The second gate assembly may be configurable to transition between an open position to allow access through the second end channel and a closed position to prevent access through the second end channel. The anchor port may be configurable to be securable to one of the instrument arm assembly. The first end section may be configurable to secure to an external anchor. The first end channel and second end channel may be operable to cooperate with the first gate assembly and second gate assembly to allow and not allow access of the instrument arm assembly through the port assembly.

[0012] In another exemplary embodiment, a method of configuring a surgical system is described. The method may include providing a port assembly. The port assembly may be an elongated structure and having a first end section and a second end section. The first end section may include a first end channel and a first gate assembly. The first gate assembly may be configurable to transition between an open position to allow access through the first end channel and a closed position to prevent access through the first end channel. The second end section may include a second end channel, a second gate assembly, and an anchor port. The second end channel may be substantially aligned with the first end channel. The second gate assembly may be configurable to transition between an open position to allow access through the second end channel and a closed position to prevent access through the second end channel. The method may further include providing an instrument arm assembly. The instrument arm assembly may comprise a shoulder section at a first end of the instrument arm assembly, a first arm section secured to the shoulder section, an elbow section secured to the first arm section, a second arm section secured to the elbow section, a wrist section secured to the second arm section, and an end effector section at a second end of the instrument arm assembly opposite to the first end of the instrument arm assembly. The end effector section may be secured to the wrist section. The end effector section may include an end effector. The method may further include inserting at least a portion of the second end section of the port assembly into a cavity of a patient. The method may further include securing a position of the port assembly by securing the first end section of the port assembly to an external anchor. The external anchor may be secured to a fixedly positioned object. The method may further include configuring at least one of the first gate assembly and the

second gate assembly to be in the closed position so as to block at least one of the first end channel and the second end channel, respectively. The method may further include performing an insufflation of the cavity of the patient. The method may further include configuring the first gate assembly to be in the open position and the second gate assembly to be in the closed position. The method may further include inserting the instrument arm assembly through the first end channel. The method may further include configuring the first gate assembly to be in the closed position after the instrument arm assembly is inserted through the first gate assembly. The method may further include configuring the second gate assembly to be in the open position. The method may further include inserting the instrument arm assembly through the second gate assembly. The method may further include configuring the second gate assembly to be in the closed position after the instrument arm assembly has passed through the second gate assembly. The method may further include securing the shoulder section of the instrument arm assembly to one of the plurality of anchor ports of the port assembly.

Brief Description of the Drawings

[0013] For a more complete understanding of the present disclosure, example embodiments, and their advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which like reference numbers indicate like features, and:

[0014] **Figure 1A** is illustration of a perspective view of an example embodiment of an external anchor;

[0015] **Figure 1B** is another illustration of a perspective view of an example embodiment of an external anchor attached to an example embodiment of a port assembly;

[0016] **Figure 2A** is an illustration of a perspective view of an example embodiment of a surgical device configured in a reverse-directed position with one port assembly, one instrument arm assembly, and one image capturing assembly;

[0017] **Figure 2B** is an illustration of a perspective view of an example embodiment of a surgical device configured in a forward-directed position with one port assembly, one instrument arm assembly, and one image capturing assembly;

[0018] **Figure 3A** is another illustration of a perspective view of another example embodiment of a surgical device configured in a reverse-directed position with one port assembly, one instrument arm assembly, and one image capturing assembly;

[0019] **Figure 3B** is another illustration of a perspective view of another example embodiment of a surgical device configured in a forward-directed position with one port assembly, one instrument arm assembly, and one image capturing assembly;

[0020] **Figure 4A** is an illustration of a perspective exploded view of an example embodiment of a port assembly;

[0021] **Figure 4B** is an illustration of a side view of an example embodiment of a port assembly;

[0022] **Figure 4C** is an illustration of a cross-sectional view of an example embodiment of a port assembly with a first or second gate assembly in the open position;

[0023] **Figure 4D** is an illustration of a cross-sectional view of an example embodiment of a port assembly with a first or second gate assembly in the closed position;

[0024] **Figure 5A** is an illustration of a side view of an example embodiment of an instrument arm assembly;

[0025] **Figure 5B** is another illustration of a side view of an example embodiment of an instrument arm assembly;

[0026] **Figure 6A** is an illustration of a perspective view of an example embodiment of an image capturing assembly;

[0027] **Figure 6B** is an illustration of a cross sectional view of another example embodiment of an image capturing assembly having an internal temperature control assembly;

[0028] **Figure 6C** is an illustration of perspective views of another example embodiment of an image capturing assembly having internal temperature control assemblies;

[0029] **Figure 6D** is an illustration of a perspective view of the system in operation in a cavity of a patient, including a second image capturing assembly;

[0030] **Figure 7** is a flow diagram of an exemplary method for configuring a surgical device;

[0031] **Figures 8A-8E** are illustrations of a side view of an example embodiment of a method of configuring a surgical device in a forward-directed position;

[0032] **Figures 8F-8K** are illustrations of a side view of an example embodiment of a method of configuring a surgical device in a reverse-directed position;

[0033] **Figure 9A** is an illustration of a perspective view of an example embodiment of a surgical device system;

[0034] **Figure 9B** is an illustration of a perspective view of another example embodiment of a surgical device system;

[0035] **Figure 10A** is an illustration of a perspective view of an example embodiment of an external anchor; and

[0036] **Figure 10B** is an illustration of a perspective view of another example embodiment of an external anchor.

[0037] Although similar reference numbers may be used to refer to similar elements in the figures for convenience, it can be appreciated that each of the various example embodiments may be considered to be distinct variations.

Detailed Description

[0038] Example embodiments will now be described with reference to the accompanying drawings, which form a part of the present disclosure, and which illustrate example embodiments which may be practiced. As used in the present disclosure and the appended claims, the terms "example embodiment," "exemplary embodiment," and "present embodiment" do not necessarily refer to a single embodiment, although they may, and various example embodiments may be readily combined and/or interchanged without departing from the scope or spirit of example embodiments. Furthermore, the terminology as used in the present disclosure and the appended claims is for the purpose of describing example embodiments only and is not intended to be limitations. In this respect, as used in the present disclosure and the appended claims, the term "in" may include "in" and "on," and the terms "a," "an" and "the" may include singular and plural references. Furthermore, as used in the present disclosure and the appended claims, the

term "by" may also mean "from," depending on the context. Furthermore, as used in the present disclosure and the appended claims, the term "if" may also mean "when" or "upon," depending on the context. Furthermore, as used in the present disclosure and the appended claims, the words "and/or" may refer to and encompass any and all possible combinations of one or more of the associated listed items.

[0039] It is recognized in the present disclosure that, despite recent developments in medical science and technology, one or more problems are encountered in modern surgical technology and methodology, including MIS. For example, a typical MIS procedure requires multiple incisions to a patient in order to allow access via the incisions for the insertion of a camera and various other laparoscopic instruments into the body cavity of the patient.

[0040] In addition to the aforementioned disadvantages pertaining to the multiple and rather large incisions, it is recognized in the present disclosure that surgical robotic systems, including surgical robotic arms (and those instruments attached to them), developed for performing robotic-assisted MIS surgical procedures also suffer from one or more problems. For example, it is recognized herein that a major technical challenge for a surgical robotic system is the difficulty in providing sufficient anchoring and/or reactive forces to stabilize against forces that are desired and/or necessary to be applied to the patient by the surgical robotic system during a surgical action. In this regard, certain surgical actions for known surgical robotic systems may require tremendous effort and time, and may not be performed properly or at all as a result of the problem of insufficient anchoring and/or reactive forces.

[0041] Another example of a problem recognized in the present disclosure as being encountered by surgical robotic systems is the difficulty in providing an instrument, such as a cutting and/or gripping instrument attached to the end of a surgical robotic arm, with access to all or even most parts, areas, and quadrants of an abdominal cavity of a patient after the surgical robotic system has been set up (or installed) and is ready to perform a surgery. That is, after the surgical robotic arm of the system has been inserted, attached, and properly set up in the abdominal cavity of the patient and is ready to perform a surgical action, the instrument attached to the end of the surgical robotic arm is typically limited to access only certain parts, areas, and quadrants of the abdominal cavity of the patient. It is recognized in the present disclosure that such problems result in large from the limited number of possible degrees of freedom that can be provided by known surgical robotic systems and arms, and more specifically, the limited number of *in vivo* degrees of freedom (i.e. the degrees of freedom provided within an abdominal cavity of a patient) of known surgical robotic systems and arms. In this regard, surgical robotic systems typically provide only between 2 to 4 *in vivo* degrees of freedom for each surgical robotic arm.

[0042] As another example, while known surgical robotic systems have been designed for use in an abdominal cavity of a patient to perform forward-directed surgical procedures, such systems have not been designed for and may encounter problems when applied in situations requiring reverse-directed surgical procedures. For example, such known surgical robotic systems have not been designed for deployment through a natural orifice, such as a rectum or vagina, for performing natural orifice transluminal endoscopic surgery (or NOTES), such as trans-vaginal gynecological procedures in

women and trans-rectal urological procedures in men. Such systems may encounter one or more problems, such as the inability to access certain organs, tissues, or other surgical sites upon insertion into the natural orifice.

[0043] Surgical systems, devices, and methods, including those for use in MIS and natural orifice transluminal endoscopic surgery (or NOTES), are described in the present disclosure for addressing one or more problems of known surgical systems, devices, and methods, including those described above and in the present disclosure. It is to be understood that the principles described in the present disclosure can be applied outside of the context of MIS and/or NOTES, such as performing scientific experiments and/or procedures in environments that are not readily accessible by humans, including in a vacuum, in outer space, and/or under toxic and/or dangerous conditions, without departing from the teachings of the present disclosure.

[0044] The Surgical System (e.g., surgical device 200)

[0045] An illustration of an example embodiment of a surgical device or system (e.g., surgical device or system 200) operable to be inserted into an abdominal cavity of a patient through a single access or opening (e.g., a single incision (such as an incision in or around the umbilical area) or through a natural orifice (such as a rectum or vagina, for performing natural orifice transluminal endoscopic surgery (or NOTES), hereinafter referred to as an "opening")) of the patient is depicted in **FIGURE 2A** and **FIGURE 2B**. The surgical device may then be anchored so as to position the surgical device 200 in the opening. The surgical device 200 may comprise a port assembly 210 and an instrument arm assembly 230. The surgical device 200 may also comprise other elements, such as

one or more other instrument arm assemblies, one or more image capturing assemblies, one or more assistant arm assemblies, etc.

[0046] As illustrated in **FIGURE 1A** and **FIGURE IB**, the surgical device 200 may be provided with an external anchor 1 attachable to the port assembly 210. The external anchor 1 may comprise a configurable assembly of segments 2, 6, 10, and 14 in communication with one another via joints or connecting portions 4, 8, and 12, and external anchor connector 16. The external anchor 1 may be operable to securely fix the position and/or orientation (hereinafter "position") of the port assembly 210 in or about the single opening of the patient, and may also be operable to provide sufficient anchoring and/or reactive forces to stabilize against forces desired and/or necessary to be applied by at least one or more elements of the surgical device 200, including the instrument arm assembly 230, during a surgical action or procedure. The external anchor 1, which may also be in the form of the controllable swivel assembly 1000 illustrated in **FIGURE 10A** and **FIGURE 10B**, may be operable to cooperate with the port assembly 210 to provide one or more *in vitro* degrees of freedom. For example, the external anchor 1 may be configurable to provide 3 *in vitro* degrees of freedom. In example embodiments, the one or more *in vitro* degrees of freedom may include a torsional movement, pivotal movement, telescopic movement, and/or other movements of the port assembly 210 relative to the external anchor 1. For example, a torsional movement of the port assembly 210, as illustrated by arrow A in Figure IB, may allow one or more attached instruments, including an instrument arm assembly 230, to re-position during a surgical procedure (i.e. after set up or installation) so as to access other parts, areas, and/or all quadrants of the abdominal cavity of the patient. As another example, a pivotal

movement of the port assembly 210, as illustrated by arrow B in Figure 1B, may allow the port assembly 210 to be positioned in one of a plurality of angles with respect to opening of the patient, and may also allow attached instruments, including the instrument arm assembly 230, to re-position during a surgical procedure (i.e. after set up or installation) so as to access distal areas of the abdominal cavity of the patient. The other joint portions of the external anchor 1 may also be operable to cooperate and/or assist in desired movements of the port assembly 210. The external anchor 1 may be anchored to one or more stationary or fixedly positioned objects, such as a side rail 300 of a surgical table/bed illustrated in Figure 1A. Figures 10A and 10B illustrate other example movements that provide for additional *in vitro* degrees of freedom via an example embodiment of the external anchor (controllable swivel assembly) 1000. The controllable swivel assembly 1000 will be further described below in at least the section "(1) Providing the external anchor and installing the port assembly."

[0047] The surgical device 200 may further comprise one or more additional instrument arm assemblies, such as a second instrument arm assembly 240 illustrated in **FIGURES 3A and 3B**, attachable to the port assembly 210. One or more of the instrument arm assemblies, including the first instrument arm assembly 230, the second instrument arm assembly 240, a third instrument arm assembly (not shown), a fourth instrument arm assembly (not shown), etc., may be attachable or securable to the port assembly 210. Such instrument arm assemblies may be operable to access and perform one or more surgical actions in/on any and all parts, areas, and/or quadrants within a cavity of the patient. For example, surgical device 200 may be configurable to perform surgical actions in a forward direction (or "forward-directed position" or "forward

position") (e.g., as illustrated in Figures 2B and 3B). As another example, surgical device 200 may be configurable to perform surgical actions in a reverse direction (or "reverse-directed position" or "reverse position") (e.g., as illustrated in Figures 2A and 3A).

[0048] The surgical device 200 may also comprise one or more image capturing assemblies, such as image capturing assembly 220. The surgical device 200 may further comprise one or more assistant arm assemblies, such as a retractor arm assembly 250, as illustrated in Figures 2A, 2B, 3A, and 3B. Furthermore, the surgical device 200 may comprise one or more other instrument arm assemblies, such as suction/irrigation assembly 260, illustrated in Figures 2A, 2B, 3A, and 3B, that can be inserted into the opening of the patient via the port assembly 210 before, during, and/or after performing a surgical action or procedure. It is to be understood in the present disclosure that the surgical device 200 may be configurable in a plurality of configurations and arrangements, including having more or less than two instrument arm assemblies (such as third, fourth, fifth, etc. instrument arm assemblies), more than one image capturing assembly (such as second, third, etc. image capturing assemblies), more or less than one assistant arm assembly (such as second, third, etc. assistant arm assemblies), and/or more or less than one other laparoscopic tool in example embodiments without departing from the teachings of the present disclosure.

[0049] The port assembly (e.g., port assembly 210)

[0050] An example embodiment of the port assembly (e.g., port assembly 210) is illustrated in Figures 2A, 2B, 3A, 3B, **FIGURE 4A, FIGURE 4B, FIGURE 4C, and FIGURE 4D**. The port assembly 210 may be configurable to be inserted in or about a single opening of the patient (such as a single incision or a natural orifice) and fixed in

position by at least the external anchor (such as the external anchor 1 illustrated in Figures 1A and 1B and the controllable swivel assembly 1000 illustrated in Figures 10A and 10B).

[0051] The port assembly 210 may be an elongated structure having a central access channel 210a formed through the port assembly 210. The central access channel 210a may be for use in inserting and removing instruments, such as one or more instrument arm assemblies 230, 240, one or more image capturing assemblies 220, one or more assistant arm assemblies 250, 260, etc. In an example embodiment, the port assembly 210 may include a first end section 212 and a second end section 214. The first end section 212 and second end section 214 may be fixably attachable to one another or formed as a unitary article. The port assembly 210 may also include a mid section 213 between the first end section 212 and the second end section 214. The first end section 212, second end section 214, and mid section 213 may be fixably attachable to one another, as illustrated in Figures 4A and 4B, or two or more of these sections may be formed as a unitary article. In an example embodiment, the first end section 212 may be the portion of the port assembly 210 that is secured to the external anchor 1, and the port assembly 210 may be fixed in position at an angle Θ relative to the single opening of the patient of between about 0 to ± 90 degrees. These and other elements of the port assembly 210 will now be described below and with reference to Figures 2A, 2B, 3A, 3B, and 4A-D.

[0052] As illustrated in at least Figures 4A and 4B, the port assembly 210 may comprise a first end section 212. The first end section 212 may have a first end channel 212a formed through the first end section 212. The first end channel 212a may be

considered as a part of the central access channel 210a. The first end section 212 may also include a portion operable to be secured to the external anchor 1, such as a portion on an exterior portion of the first end section 212.

[0053] The first end section 212 may also include a first gate assembly 212b, as illustrated in Figures 4A, 4C, and 4D. The first gate assembly 212 may be configurable to control access through the first end channel 212a. For example, the first gate assembly 212b may be configurable to be in an open position, as illustrated in Figure 4C, so as to allow access through the first end channel 212a. The first gate assembly 212b may also be configurable to be in a closed position, as illustrated in Figure 4D, so as to prevent or restrict access through the first end channel 212a. The first gate assembly 212b may also be configurable to be in a partially closed (or partially opened) position (not shown). The first gate assembly 212b may also be configurable to transition between the closed position and the open position.

[0054] In an example embodiment, the first gate assembly 212b may be provided within the first end section 212 in such a way that, when the first gate assembly 212b is configured to be in the open position, as illustrated in Figure 4C, the first end channel 212a is substantially or completely unobstructed by the first gate assembly 212b. The first gate assembly 212b may be configured to be in the open position when a surgeon desires to insert (or remove) an instrument into (or out of) the cavity of the patient via the first end channel 212a (and the rest of the central access channel 210a).

[0055] Similarly, the first gate assembly 212b may be provided within the first end section 212 in such a way that, when the first gate assembly 212b is configured to be in the closed position, as illustrated in Figure 4D, the first end channel 212a is substantially

or completely obstructed by the first gate assembly 212b. The first gate assembly 212b may be configured to be in the closed position when a surgeon desires to maintain an insufflation of the cavity of the patient and/or when the surgeon does not need to insert (or remove) an instrument into (or out of) the cavity of the patient via the first end channel 212a.

[0056] The first gate assembly 212b may include a first expandable portion 212b configurable to expand when the first gate assembly 212b is configured to the closed position, as illustrated in Figure 4D. When the first gate assembly 212b is configured to the closed position, the first expandable portion 212b may be operable to substantially or completely block, among other things, a gas medium (and/or other medium) from passing through the first end channel 212a. For example, if the cavity of the patient is being insufflated using a gas, such as carbon dioxide (CO_2), the first gate assembly 212b (i.e., the first expandable portion 212b) may be configurable to substantially prevent the carbon dioxide gas from leaving the cavity of the patient through the first end channel 212a.

[0057] The first expandable portion 212b may include one or more first expandable members. For example, the first expandable portion 212b may include six expandable members, as illustrated in Figures 4C and 4D. It is to be understood that the first expandable portion 212b may include more or less than six expandable members without departing from the teachings of the present disclosure. Some or all of the first expandable members may be integrated together and/or in communication with one another, such as in a manner where some or all of the first expandable members are operable to receive pressure (i.e., gas medium) from a common or same first source 212b'.

For example, when the first gate assembly 212b is configured to the closed position, the first source 212b' may be configurable to provide a positive pressure (i.e., a supply of gas) so as to cause some or all of the first expandable members to expand and block the first end channel 212a (e.g., hermetically block the first end channel 212a). Similarly, when the first gate assembly 212b is configured to the open position, the first source 212b' may be configurable to provide a negative pressure (i.e., remove gas) so as to cause one or more (or all) of the first expandable members to not expand (and/or contract) and unblock the first end channel 212a. It is to be understood that more than one first sources 212b' may provide the positive pressure and negative pressure to the one or more expandable members without departing from the teachings of the present disclosure.

[0058] It is recognized in the present disclosure that the first gate assembly 212b may also include a valve (not shown), or the like, in addition to or in replacement of the first expandable portion 212b. The valve may be configurable to perform substantially the same actions of blocking the first end channel 212a when the first gate assembly 212b is configured to the closed position and unblocking the first end channel 212a when the first gate assembly 212b is configured to the open position. The valve may be any type of valve configurable to perform the actions described above and in the present disclosure. The valve may include, but is not limited to including, a ball valve, gate valve, etc., so long as the valve is configurable to substantially block/unblock the first end channel 212a and prevent a gas medium from passing through the first end channel 212a.

[0059] The port assembly 210 may also include the second end section 214, as illustrated in at least Figures 4A and 4B. The second end section 214 may have a second end channel 214a formed through the second end section 214. The second end channel

214a may be substantially or completely aligned with the first end channel 212a. The second end channel 214a, as well as the first end channel 212a, may be considered as a part of the central access channel 210a in example embodiments. The second end section 214 may also include an insufflation port (not shown) for use in providing insufflation to the cavity of the patient.

[0060] The second end section 214 may also include a second gate assembly 214, as illustrated in Figures 4A, 4C, and 4D. The second gate assembly 214 may be configurable to control access through the second end channel 214a. For example, the second gate assembly 214b may be configurable to be in an open position, as illustrated in Figure 4C, so as to allow access through the second end channel 214a. The second gate assembly 214b may also be configurable to be in a closed position, as illustrated in Figure 4D, so as to prevent or restrict access through the second end channel 214a. The second gate assembly 214b may also be configurable to be in a partially closed (or partially opened) position (not shown). The second gate assembly 214b may also be configurable to transition between the closed position and the open position.

[0061] In an example embodiment, the second gate assembly 214b may be provided within the second end section 212 in such a way that, when the second gate assembly 214b is configured to be in the open position, as illustrated in Figure 4C, the second end channel 214a is substantially or completely unobstructed by the second gate assembly 214b. The second gate assembly 214b may be configured to be in the open position when a surgeon desires to insert (or remove) an instrument into (or out of) the cavity of the patient via the second end channel 214a (and the rest of the central access channel 210a).

[0062] Similarly, the second gate assembly 214b may be provided within the second end section 214 in such a way that, when the second gate assembly 214b is configured to be in the closed position, as illustrated in Figure 4D, the second end channel 214a is substantially or completely obstructed by the second gate assembly 214b. The second gate assembly 214b may be configured to be in the closed position when a surgeon desires to maintain an insufflation of the cavity of the patient and/or when the surgeon does not need to insert (or remove) an instrument into (or out of) the cavity of the patient via the second end channel 214a.

[0063] The second gate assembly 214b may include a second expandable portion 214b configurable to expand when the second gate assembly 214b is configured to the closed position, as illustrated in Figure 4D. When the second gate assembly 214b is configured to the closed position, the second expandable portion 214b may be operable to substantially or completely block, among other things, a gas medium (and/or other medium) from passing through the second end channel 214a. For example, if the cavity of the patient is being insufflated using a gas, such as carbon dioxide (CO_2), the second gate assembly 214b (i.e., the second expandable portion 214b) may be configurable to substantially prevent the carbon dioxide gas from leaving the cavity of the patient through the second end channel 214a.

[0064] The second expandable portion 214b may include one or more second expandable members. For example, the second expandable portion may include six expandable members, as illustrated in Figures 4C and 4D. It is to be understood that the second expandable portion 214b may include more or less than six expandable members without departing from the teachings of the present disclosure. Some or all of the second

expandable members may be integrated together and/or in communication with one another, such as in a manner where some or all of the second expandable members are operable to receive pressure (i.e., gas medium) from a common or same second source 214b'. For example, when the second gate assembly 214b is configured to the closed position, the second source 214b' may be configurable to provide a positive pressure (i.e., a supply of gas) so as to cause some or all of the second expandable members to expand and block the second end channel 214a (e.g., hermetically block the second end channel 214a). Similarly, when the second gate assembly 214b is configured to the open position, the second source 214b' may be configurable to provide a negative pressure (i.e., remove gas) so as to cause some or all of the second expandable members to not expand (and/or contract) and unblock the second end channel 214a. It is to be understood that more than one second sources 214b' may provide the positive pressure and negative pressure to the one or more expandable members without departing from the teachings of the present disclosure. It is also to be understood in the present disclosure that one or more of the first sources 212b' and one or more of the second sources 214b' may be the same or different sources.

[0065] It is recognized in the present disclosure that the second gate assembly 214b may also include a valve (not shown), or the like, in addition to or in replacement of the second expandable portion 214b. The valve may be configurable to perform substantially the same actions of blocking the second end channel 214a when the second gate assembly 214b is configured to the closed position and unblocking the second end channel 214a when the second gate assembly 214b is configured to the open position. The valve may be any type of valve configurable to perform the actions described above and in the

present disclosure. The valve may include, but is not limited to including, a ball valve, gate valve, etc., so long as the valve is configurable to substantially block/unblock the second end channel 214a and prevent a gas medium from passing through the second end channel 214a.

[0066] The second end section 214 may also include one or more anchor ports 216, as illustrated in Figures 4A and 4B. Each of the anchor ports 216 may be operable to enable an instrument arm assembly 230 or 240, image capturing assembly 220, and/or assistant arm assemblies 250 or 260 to be secured to and unsecured from the port assembly 210. Each of the anchor ports 216 may be formed in any one or more of a plurality of shapes, holes, slots, indentations, protrusions, hooks, fasteners, magnets, buckles, or the like, including those described above and in the present disclosure. For example, as illustrated in Figures 4A and 4B, one or more of the anchor ports 216 may include one or more slots, or the like, operable to allow a shoulder section 231 of an instrument arm assembly 230 or 240 to be inserted into and attached.

[0067] In example embodiments, the port assembly 210 may also include the mid section 213, as illustrated in at least Figures 4A and 4B. The mid section 213 may have a mid section channel 213a formed through the mid section 213. The mid section channel 213a may be substantially or completely aligned with the first end channel 212a and/or the second end channel 214a. In this regard, the mid section channel 213a, as well as the first end channel 212a and/or the second end channel 214a, may be considered as a part of the central access channel 210a in example embodiments. The mid section 213 may also include an insufflation port (not shown) in addition to or in replacement of the insufflation port (not shown) of the second end section 214. In some example

embodiments, the mid section 213 may also include a mid section gate assembly (not shown) similar to that of the first gate assembly 212 and second gate assembly 214 described above and in the present disclosure.

[0068] In example embodiments, the mid section channel 213a may be operable to cooperate with the first gate assembly 212b and the second gate assembly 214b to function as or like an isolation chamber for instruments, such as the instrument arm assembly 230 or 240, image capturing assembly 220, assistant arm assembly 250 or 260, etc. For example, when an instrument, such as the instrument arm assembly 230, needs to be inserted into the cavity of the patient via the port assembly 210 (or central access channel 210a) and an insufflation of the cavity of the patient needs to be maintained, the first gate assembly 212b may be configured to the open position to allow the instrument to be inserted into the mid section channel 213a. After the instrument (or most of it) passes through the first gate assembly 212b, the first gate assembly 212b may be configured to the closed position. The second gate assembly 214b may then be configured to the open position to allow the instrument to be further inserted through the port assembly 210. After the instrument (or most of it) passes through the second gate assembly 214b, the second gate assembly 214b may be configured to the closed position.

[0069] In respect to the central access channel 210a, the central access channel 210a may include or be formed by the first end channel 212a, the second end channel 214a, and/or the mid section channel 213a. The central access channel 210a may be operable to provide an access port (i.e. a passageway or channel) to allow an insertion (or removal) of one or more instruments, such as one or more instrument arm assemblies 230 or 240,

one or more image capturing assemblies 220, one or more assistant arm assemblies 250 or 260, etc.

[0070] In an example embodiment, the first end section 212, the second end 214, and/or the mid section 213 may be substantially cylindrical in shape. The first end section 212, the second end section 214, and/or the mid section 213 may also be formed in any one of a plurality of other shapes, sizes, and/or dimensions without departing from the teachings of the present disclosure.

[0071] In example embodiments, an outer diameter of the first end section 212, the second end 214, and/or the mid section 213 may be between about 28 to 35 mm and an inner diameter (unblocked) of the first end section 212, the second end 214, and/or the mid section 213 may be between about 16 to 21 mm. In an example embodiment, the outer diameter of the first end section 212, the second end 214, and/or the mid section 213 may be about 33 mm and the inner diameter (unblocked) of the first end section 212, the second end 214, and/or the mid section 213 may be about 19 mm. The length of the first end section 212 may be between about 80 to 100 mm, the length of the second end section 214 may be between about 80 to 200 mm, and the length of the mid section 213 may be between about 60 to 80 mm. The overall length of the port assembly 210 may be between about 320 to 380 mm. It is to be understood in the present disclosure that the above dimensions are merely an illustration of example embodiments, and as such the dimensions may be smaller or larger than those recited above without departing from the teachings of the present disclosure.

[0072] The port assembly 210, including the first end section 212, the second end section 214, the mid section 213, and/or the anchor ports 216, may be formed using any

one or more of a plurality of materials, such as surgical-grade metals, high-strength aluminum alloys, stainless steel (such as 304/304L, 316/316L, and 420), pure titanium, titanium alloys (such as Ti6Al4V, NiTi), and cobalt-chromium alloys. The first gate assembly 212b and the second gate assembly 214b may be formed using any one or more of a plurality of materials, such as bio-compatible materials (such as silicone rubber and polyurethane). It is to be understood in the present disclosure that other materials may also be used without departing from the teachings of the present disclosure. It is to be understood in the present disclosure that the above materials are merely an illustration of example embodiments, and these and other materials and compositions may be used without departing from the teachings of the present disclosure.

[0073] The image capturing assembly (e.g., image capturing assembly 220)

[0074] In an example embodiment, the surgical device 200 may comprise one or more image capturing assemblies (e.g., image capturing assembly 220) configurable to be inserted into and attach to the port assembly 210. One or more of the image capturing assemblies 220 may comprise at an image capturing body 224, a multi-curvable body 222, and an anchoring portion 220a.

[0075] As illustrated in **FIGURE 6A**, the image capturing body 224 may include one or more cameras 227. Each camera 227 may include a standard and/or high definition 2-dimensional (2D) and/or 3-dimensional (3D) camera operable to capture imaging, such as 2D and/or stereoscopic and/or autostereoscopic 3D imaging, including images, video, and/or audio, and provide in real-time via wired and/or wireless communication the captured imaging, including images, video, and/or audio, to the computing device (or controller or system) of one or more nearby and/or remotely located surgical teams 904,

as described above and in the present disclosure. The computing device (or controller or system) may comprise one or more processors, one or more computer-human interfaces, one or more graphical displays (such as computer screens, television screens, portable devices, wearable devices such as glasses, etc.), and/or other devices and/or systems, an example of which is illustrated in Figures 9A and 9B. The one or more nearby and/or remotely located surgical teams 904 may be operable to view, hear, sense, analyze, and control (such as pan, zoom, process, adapt, mark, change resolution, etc.) the imaging displayed or represented on one or more standard and/or high definition 2D and/or 3D graphical displays 902, such as shown in the illustration of Figures 9A and 9B, and/or portable and/or wearable devices adapted to receive 2D and/or 3D imaging (not shown). The image capturing body 224 may also comprise one or more illumination sources 229, such as an LED, or the like, operable to illuminate or sense at least one or more parts, sections, and/or quadrants of the cavity of the patient, including instruments provided in the cavity of the patient. The image capturing body 224 may further comprise one or more internal temperature control assemblies operable to control (such as reduce) the temperature of one or more components of the image capturing body 224.

[0076] As illustrated in the example embodiment of Figure 6A, one or more of the image capturing assemblies 220 may comprise a multi-curvable body 222 attached to the image capturing body 224. The multi-curvable body 222 may be any elongated multi-curvable, multi-bendable, multi-articulable, and/or snake-like (hereinafter "multi-curvable") body that can be controlled/configured by the surgical team (such as via the computing device/controller) to, among other things, straighten and/or curve (and hold such a straightness and/or curvature) at one or more of a plurality of locations along the

multi-curvable body 222, curve (and hold such a curvature) in one or more of a plurality of curvatures, and/or straighten and/or curve (and hold such a straightness and/or curvature) in one or more of a plurality of directions. For example, as illustrated in Figure 8H, the multi-curvable body 222 may be controllable/configurable by the surgical team (such as via the computing device/controller) to curve at two different locations 222a and 222b along the multi-curvable body 222, and each of the curves may include any curvature and in any direction. It is to be understood that the multi-curvable body 222 may be configurable to curve in more or less than two locations along the multi-curvable body 222 without departing from the teachings of the present disclosure. It is also to be understood that, when the multi-curvable body 222 is configured to curve at any location along the multi-curvable body 222, the curve may be held and/or released (or configured to uncurve, curve less, or straighten) by the surgical team (such as via the computing device/controller).

[0077] The multi-curvable body 222 may be formed in any one or more ways known in the art including. For example, the multi-curvable body 222 may include a plurality of segments, each segment linked to an adjacent segment in such a way that the segment may be controlled/configured to be pivotally positioned in a plurality of positions relative to the adjacent segment. As another example, the multi-curvable body 222 may include a plurality of wires, cables, or the like, distributed throughout the multi-curvable body 222 in such a way that a pulling/releasing, shortening/lengthening, tightening/loosening, etc. of one or a combination of cables enables the above-mentioned curving of one or more locations of the multi-curvable body 222 in one or more curvatures and in one or more directions. As another example, the multi-curvable body 222 may include a plurality of

springs, gears, motors, etc. for achieving the above-mentioned curving. It is to be understood in the present disclosure that the multi-curvable body 222 may also include a combination of one or more of the above-mentioned approaches.

[0078] One or more internal temperature control assemblies (not shown) may be provided for each image capturing assembly 220. Each internal temperature control assembly may be operable to control (such as reduce) the temperature and/or heat emission of the aforementioned camera(s) 227, illumination source(s) 229, and/or multi-curvable body 222. In an example embodiment, the one or more internal temperature control assemblies may be operable to perform such temperature control using one or more gases, liquids, and/or solids. For example, the gases and/or liquids may be fed, maintained, and/or regulated using an external source via one or more tubes, or the like. The one or more tubes used to provide, regulate, and/or discharge the gases and/or liquids may have a diameter between about 0.5 mm to 3 mm in example embodiments, but the dimensions of such tubes may also be more or less. It is to be understood in the present disclosure that the one or more tubes (if used), as well as any solids (if used), may be provided through an interior of the image capturing assembly 220 without increasing dimensions (such as diameter) of the image capturing assembly 220 and/or affecting the controllability/configurability of the multi-curvable body 222.

[0079] When the internal temperature control assembly utilizes gases, or the like, example embodiments may also be operable to provide such gases into the body cavity and/or discharge or recycle such gases outside of the body cavity via one or more tubes, or the like. The gases may comprise carbon dioxide, oxygen, and/or other gases in example embodiments. Such gases may be further operable to assist in providing and/or

maintaining insufflation of the cavity of the patient during a surgical procedure. When the internal temperature control assembly utilizes liquids, or the like, example embodiments may be operable to discharge or recycle such liquids outside of the body cavity. When the internal temperature control assembly utilizes solids, or the like, such solids may possess properties that enable the surgical team to change the temperature of the solids, such as by applying electricity or other form of energy, so as to control (such as reduce) the temperature and/or heat emission of one or more components of the image capturing assembly 220. In example embodiments, the internal temperature control assembly may utilize a combination of gases, liquids, solids, and/or the like without departing from the teachings of the present disclosure.

[0080] The image capturing assembly 220 may be secured to the port assembly 210 in one or more of a plurality of ways, including those described above and in the present disclosure for the instrument arm assemblies 230 or 240 and/or the assistant arm assemblies 250 or 260. For example, the image capturing assembly 220 may also comprise an anchoring portion 220a (e.g., similar to the securing portion 231a of the instrument arm assembly 220) operable to attach (or secure) the image capturing assembly 220 to one or more anchor ports 216 of the port assembly 210.

[0081] In an example embodiment, the image capturing body 224 and the multi-curvable body 222 may each be substantially cylindrical in shape. The image capturing body 224 and the multi-curvable body 222 may also be formed in any one of a plurality of other shapes, sizes, and/or dimensions without departing from the teachings of the present disclosure.

[0082] In an example embodiment, the length of the multi-curvable body 222 may be between about 50 to 150 mm. In example embodiments, a length of multi-curvable body 222 may also be adjustable by the surgical team 904 before, during, and/or after insertion of the camera arm assembly into the cavity of the patient. The outer diameter of the multi-curvable body 222 may be between about 5 to 7 mm. It is to be understood in the present disclosure that the above dimensions are merely an illustration of example embodiments, and as such the dimensions may be smaller or larger than those recited above without departing from the teachings of the present disclosure.

[0083] The multi-curvable body 222 may be formed using any one or more of a plurality of materials, such as stainless steel, etc. It is to be understood in the present disclosure that other materials may also be used without departing from the teachings of the present disclosure. It is to be understood in the present disclosure that the above materials are merely an illustration of example embodiments, and these and other materials and compositions may be used without departing from the teachings of the present disclosure.

[0084] As illustrated in **FIGURE 6B** and **FIGURE 6C**, the image capturing assembly 220 may further comprise a gas shield 228 located nearby one or more lenses of the camera 227. The image capturing assembly 220 may further comprise a gas shield 228 located nearby one or more of the illumination sources 229 and/or any other sensors (such as temperature sensors, pressure sensors, humidity sensors, etc.) provided by the image capturing assembly 220. The gas shield 228 may comprise one or more openings or the like, one or more external gas sources 228, and one or more tubes, channels, or the like, between the one or more external gas sources and the one or more openings of the

gas shield 228. In operation, the gas shield 228 may be operable to provide pressurized gases (and/or liquids), such as carbon dioxide, oxygen, other gases or liquids, or combinations thereof, via the one or more openings of the gas shield 228 to an area in front of the camera 227 (as well as in front of the illumination sources 229 and/or other sensors).

[0085] The overall system may also include one or more separate image capturing assemblies, such as the separate image capturing assembly 320 illustrated in **FIGURE 6D**. The separate image capturing assembly 320 may be magnetically anchored by a magnetic anchor 310 to an internal wall of the cavity of the patient, such as via a permanent magnet, electromagnet, or the like. In some example embodiments, the magnetic anchor 310 may also be secured/held in position via an external anchor (not shown). The separate image capturing assembly 320 may include one or more cameras 327, and may also include one or more illumination sources 329.

[0086] The separate image capturing assembly 320 may be operable to provide one or more of a variety of views, including, but not limited to, a normal view, zoomed view, wide-angled view, and/or panoramic view of the cavity of the patient. The separate image capturing assembly 320 may be positioned in such a way as to provide the surgical team 904 with an unobstructed view of areas of interest within the cavity of the patient. In respect to positioning and securing the separate image capturing assembly 320 in place, as illustrated in Figure 6D, the separate image capturing assembly 320 may be inserted through the central access channel 210a of the port assembly 210 and to the desired location of the interior wall of the cavity of the patient in one or more of a plurality of ways, including using a surgical tool (not shown), attaching the separate image capturing

assembly 320 to a multi-curvable body (not shown) similar to that of the image capturing assembly 220 (as illustrated in Figures 2A, 2B, 3A, 3B, and 6D), etc.

[0087] The instrument arm assembly (e.g., instrument arm assembly 230, 240)

[0088] In an example embodiment, the surgical device 200 may comprise one or more instrument arm assemblies (e.g., first instrument arm assembly 230, second instrument arm assembly 240, third instrument arm assembly (not shown), fourth instrument arm assembly (not shown), etc.), each configurable to attach to the port assembly 210.

[0089] One or more of the instrument arm assemblies (such as 230, 240) may comprise a configurable serial (or linear) arrangement of a plurality of instrument arm segments and joint portions, and at least one end instrument (or end effector) 239 integrated into and/or connected to one or more of the instrument arm segments and/or joint portions. The end effector 239 may be any instrument suitable for use in surgical procedures, such as a cutting and/or gripping instrument. One or more of the instrument arm assemblies (such as 230, 240) may also comprise one or more illumination sources (not shown), such as an LED, or the like, operable to illuminate one or more parts of the end effector 239, instrument arm assemblies, and/or parts, sections, and/or quadrants of the abdominal cavity of the patient.

[0090] One or more of the instrument arm assemblies (such as 230, 240) may also comprise one or more integrated motors operable to provide at least one degree of freedom for the instrument arm assembly. One or more of the instrument arm assemblies may also include an integrated haptic and/or force feedback subsystem (not shown) in communication with one or more of the integrated motors and/or other sensors and/or

instruments operable to provide to the surgical team (such as via computing device/controller) with one or more of a plurality of feedback responses and/or measurements, including those pertaining to position (including orientation), applied force, proximity, temperature, pressure, humidity, etc., of, by, and/or nearby to the instrument arm assembly. For example, the surgical team 904 may be provided with a master input device having manipulators, or the like, having haptic and/or force feedback and designed to map and sense the surgical team's 904 delicate finger-twisting, wrist-bending, and/or other arm/shoulder movements into movements of the instrument arm (such as 230, 240) with high precision, high dexterity, and minimum burden, while also providing feedback of contact resistance (such as tissue resistance).

[0091] When an instrument arm assembly (such as 230, 240) comprises one or more illumination sources, cameras, haptic and/or force feedback instruments, and/or other sensors and/or instruments, as described above and in the present disclosure, the instrument arm assembly may also comprise a gas shield, such as the gas shield described above for the image capturing assembly 220. One or more of the instrument arm assemblies (such as 230, 240) may further comprise one or more internal temperature control assemblies operable to control (such as reduce or increase) the temperature of one or more components of the instrument arm assembly.

[0092] As illustrated in the example embodiment of Figures 2A, 2B, 3A, 3B, **FIGURE 5A**, and **FIGURE 5B**, each of the instrument arm assemblies, including the first instrument arm assembly 230, may comprise a first instrument arm segment (or shoulder section) 231, a second instrument arm segment (or first arm section) 233, a third instrument arm segment (or second arm section) 235, and a fourth instrument arm

segment (or hand section) 237. The instrument arm assembly 230 may also comprise a first joint portion (or shoulder joint section) 232, a second joint portion (or elbow section) 234, a third joint portion (or wrist section) 236, and an end effector joint portion 238. Each of the aforementioned joint portions may be configurable, either manually and/or via the computing device (or system), to provide an attached instrument arm segment (and the end effector 239) with one or more *in vivo* degrees of freedom when the instrument arm assembly is provided in the abdominal cavity of the patient. For example, the first joint portion (or shoulder joint section) 232 may be operable to provide the second instrument arm segment (or first arm section) 233 with one or two degrees of freedom resembling the one or two degrees of freedom of the human shoulder. As another example, the second joint portion (or elbow section) 234 may be operable to provide the third instrument arm segment (or second arm section) 235 with one or two degrees of freedom resembling the one or two degrees of freedom of the human elbow. As another example, the third joint portion (or wrist section) 236 may be operable to provide the fourth instrument arm segment (or hand section) 237 with one or two degrees of freedom resembling the one or two degrees of freedom of the human wrist. As another example, the end effector joint portion 238 may be operable to provide the end effector 239 with one or more degrees of freedom. Accordingly, one or more of the instrument arm assemblies may be configurable, either manually and/or via the computing device/controller, to provide seven or more *in vivo* degrees of freedom and, together with the at least one to three or more *in vitro* degree of freedom provided by the port assembly 210 and the controllable swivel assembly 1000 (see Figures 10A and 10B), the one or more of the instrument arm assemblies may be configurable, either manually and/or via

the computing device/controller, to provide a total of eight to ten or more degrees of freedom. It is recognized herein that the aforementioned at least seven *in vivo* degrees of freedom for the instrument arm assembly enables at least the full range of natural movements by a surgeon's arm (via a controller/computer-human interface/manipulator/master input device, such as the example illustrated in Figures 9A and 9B) to be substantially directly mapped and/or translated to the instrument arm assembly.

[0093] Each joint portion, including joint portions 232, 234, and 236 and instrument joint portion 238 may comprise any one or more configurations of gears and/or gear assemblies, including straight gear configurations, planetary gear configurations, beveled gear configurations, spiral beveled gear configurations, hypoid gear configurations, helical gear configurations, worm gear configurations, and/or any other gear configuration without departing from the teachings of the present disclosure. In example embodiments, each instrument arm assembly may also comprise one or more internal integrated motors, or the like, operable to actuate the gears of each joint portion, including joint portions 232, 234, and 236 and/or the instrument arm segments 231, 233, 235, and 237. In this regard, each of the abovementioned integrated motors, joint portions, and/or instrument arm segments may be operable to communicate, such as receive control commands and/or transmit information, from and/or to the computing device/controller of one or more nearby and/or remotely located surgical teams 904 via wired and/or wireless communication in example embodiments. Furthermore, each of the abovementioned integrated motors, joint portions, and/or instrument arm segments

may be operable to receive power from an external power source and/or the computing device/controller via wired and/or wireless transmissions in example embodiments.

[0094] Each of the instrument arm assemblies may be securable to (and unsecured from) the anchor ports 216 of the port assembly 210 via a securing portion 231a of the shoulder section 231. It is recognized in the present disclosure that the instrument arm assembly 230, 240 may be secured to the anchor port 216 of the port assembly 210 in the forward-directed position (e.g., as illustrated in Figures 2B and 3B) and/or the reverse-directed position (e.g., as illustrated in Figures 2A and 3A). Furthermore, in example embodiments, the instrument arm assembly 230, 240 may or may not be transitioned between the forward-directed position and the reverse-directed position. In example embodiments where the instrument arm assembly 230, 240 is transitionable between the forward-directed position and the reverse-directed position, such transition may be performable before, during, and/or after the securing of the shoulder section 231 to the anchor port 216 of the port assembly 210. For example, in such embodiments, the securing portion 231a may be adjustably changed in position relative to the shoulder section 231, such as from the forward-directed position illustrated in Figure 5A to the reverse-directed position illustrated in Figure 5B, and vice versa.

[0095] One or more internal temperature control assemblies (not shown) may be provided for each of the one or more instrument arm assemblies 230, 240. Each internal temperature control assembly may be operable to control (such as reduce) the temperature and/or heat emission of the aforementioned gears and/or gear assemblies, motors, instrument joint portions (such as 232, 234, and 236), and/or instrument arm segments (such as 231, 233, 235, and 237). The one or more internal temperature control

assemblies may also be operable to control (such as increase or decrease) the temperature of the end effector 239 (which may be desirable when the end effector 239 is a cutting tool, or the like). In an example embodiment, the one or more internal temperature control assemblies may be operable to perform such temperature control using one or more gases, liquids, and/or solids. For example, the gases and/or liquids may be fed, maintained, and/or regulated using an external source via one or more tubes, or the like. The one or more tubes used to provide, regulate, and/or discharge the gases and/or liquids may have a diameter between about 0.5 mm to 3 mm in example embodiments, but the dimensions of such tubes may also be more or less. It is to be understood in the present disclosure that the one or more tubes (if used), as well any solids (if used), may be provided through an interior of the instrument arm assembly without increasing dimensions (such as diameter) of the instrument arm assembly.

[0096] When the internal temperature control assembly utilizes gases, or the like, example embodiments may also be operable to provide such gases into the body cavity and/or discharge or recycle such gases outside of the body cavity via one or more tubes, or the like. The gases may comprise carbon dioxide, oxygen, and/or other gases in example embodiments. Such gases may be further operable to assist in providing and/or maintaining insufflation of the body cavity, such as via an opening (not shown). When the internal temperature control assembly utilizes liquids, or the like, example embodiments may be operable to discharge or recycle such liquids outside of the body cavity. When the internal temperature control assembly utilizes solids, or the like, such solids may possess properties that enable the surgical team to change the temperature of the solids, such as by applying electricity or other form of energy, so as to control (such

as reduce) the temperature and/or heat emission of one or more components of the instrument arm assembly 230, 240.

[0097] In example embodiments, the internal temperature control assembly may utilize a combination of gases, liquids, solids, and/or the like without departing from the teachings of the present disclosure.

[0098] After the instrument arm assembly 230, 240 has been inserted and attached (or secured) to the port assembly 210, the end effector 239 may be configurable, either manually and/or via the computing device (or system), to apply between about 0 to 20 N of force when performing surgical actions and procedures, such as clipping and/or grasping actions. Furthermore, the end effector 239 may be configurable, either manually and/or via the computing device/controller, to apply between about 0 to 10 N of force when performing other surgical actions and procedures, such as translational, twisting, pulling, and/or pushing actions. It is to be understood in the present disclosure that the above range of applicable force are merely an illustration of example embodiments, and as such the range of applicable force may be smaller or larger than those recited above without departing from the teachings of the present disclosure.

[0099] In an example embodiment, the instrument arm segments, including the first instrument arm segment 231, the second instrument arm segment 233, the third instrument arm segment 235, and/or the fourth instrument arm segment 237, may be substantially cylindrical in shape. The instrument arm segments, including the first instrument arm segment 231, the second instrument arm segment 233, the third instrument arm segment 235, and/or the fourth instrument arm segment 237, may also be

formed in any one of a plurality of other shapes, sizes, and/or dimensions without departing from the teachings of the present disclosure.

[00100] As described above, the instrument arm assembly 230, 240 may also include one or more securing portions 231a. The securing portion 231a may be attachable or attached to the first instrument arm segment 231, a part of the first instrument arm segment 231, and/or formed as a unitary article with the first instrument arm segment 231. Such securing portions 231a may be for use in securing the instrument arm assembly 230, 240 to the anchor ports 216. Such securing portions 231a may also be for use in performing or assisting in performing the process of inserting the instrument arm assembly 230, 240 into and securing onto the port assembly 210 in example embodiments.

[00101] After the instrument arm assembly 230 is inserted through the port assembly 210 and into the cavity of a patient (such as a vagina or rectum), the securing portion 231a of the first instrument arm segment (or shoulder section) 231 may be securely received by the anchor port 216 of the port assembly 210.

[00102] In an example embodiment, the length of the securing portion 231a may be between about 350 to 450 mm, the length of the first instrument arm segment 231 may be between about 15 to 40 mm, the length of the second instrument arm segment 233 may be between about 80 to 105 mm, the length of the third instrument arm segment 235 may be between about 65 to 90 mm, the length of the fourth instrument arm segment 237 may be between about 5 to 30 mm, and the overall length of the collective instrument arm may be between about 165 to 265 mm. In example embodiments, the length of the securing portion 231a may be between about 340 to 400 mm, the length of the first instrument arm segment 231 may be between about 15 to 25 mm, the length of the

second instrument arm segment 233 may be between about 90 to 100 mm, the length of the third instrument arm segment 235 may be between about 75 to 85 mm, the length of the fourth instrument arm segment 237 may be between about 15 to 25 mm, and the overall length of the collective instrument arm may be between about 195 to 235 mm. In example embodiments, a length of one or more of the instrument arm segments, the securing portion 231a, and/or the end effector 239 may also be adjustable by the computing device (or system) of one or more nearby and/or remotely located surgical teams 904 before, during, and/or after insertion of the instrument arm assembly into the cavity of the patient. The outer diameter of one or more of the instrument arm segments may be about 10 to 16 mm. In an example embodiment, the outer diameter of one or more of the instrument arm segments may be about 16 mm.

[00103] Each of the instrument arm assemblies, including the securing portion 231a, the first instrument arm segment 231, the second instrument arm segment 233, the third instrument arm segment 235, the fourth instrument arm segment 237, the end effector 239, the first joint portion 232, the second joint portion 234, the third joint portion 236, and/or the instrument joint 238, may be formed using any one or more of a plurality of materials, such as surgical-grade metals, high-strength aluminum alloys, stainless steel (such as 304/304L, 316/316L, and 420), pure titanium, titanium alloys (such as Ti6Al4V, NiTi), and cobalt-chromium alloys. It is to be understood in the present disclosure that other materials may also be used without departing from the teachings of the present disclosure.

[00104] **The assistant arm assemblies (e.g., assistant arm assembly 250, 260)**

[00105] In an example embodiment, the surgical device 200 may comprise one or more assistant arm assemblies (e.g., assistant arm assembly 250 or 260) configurable to be inserted into and attach to the port assembly 210. As illustrated in Figures 2A, 2B, 3A, and 3B, one or more of the assistant arm assemblies may be a suction/irrigation assembly 250 or an assistant instrument arm assembly such as a retractor arm assembly 260, and each of them may include a multi-curvable body 252 or 262, respectively, and an anchoring portion, respectively (e.g., similar to the multi-curvable body 222 and anchoring portion 220a of the image capturing assembly 220).

[00106] As illustrated in Figures 2A, 2B, 3A, and 3B, the suction/irrigation assembly 250 may include an end having a suction port 259 for applying a suction or negative pressure, which may be for use in removing liquids (e.g., blood, etc.) from the cavity of the patient. In respect to the assistant instrument arm assembly 260, the assistant instrument arm assembly 260 may include an end having an instrument 269, such as a gripper, retractor, cutter, needle, or the like, which may be for use in assisting the one or more instrument arm assemblies 230 and/or 240 in performing the surgical action.

[00107] As illustrated in the example embodiment of Figures 2A, 2B, 3A, and 3B, the assistant arm assemblies 250 and/or 260 may comprise a multi-curvable body 252 and/or 262, respectively, attached to their ends (suction port or instrument, respectively). The multi-curvable body 252 or 262 may be any elongated multi-curvable body similar to that of the image capturing assembly 220 described above and in the present disclosure that can be controlled/configured by the surgical team 904 (such as via the computing device/controller/manipulator/master input device) to, among other things, straighten and/or curve (and hold such a straightness and/or curvature) at one or more of a plurality

of locations along the multi-curvable body 252 or 262, curve (and hold such a curvature) in one or more of a plurality of curvatures, and/or straighten and/or curve (and hold such a straightness and/or curvature) in one or more of a plurality of directions. It is to be understood that, when the multi-curvable body 252 or 262 is configured to curve at any location along the multi-curvable body 252 or 262, the curve may be held and/or released (or configured to uncurve, curve less, or straighten) by the surgical team 904 (such as via the computing device/controller/manipulator/master input device).

[00108] The multi-curvable body 252 or 262 may be formed in any one or more ways known in the art. For example, the multi-curvable body 252 or 262 may be a unitary or substantially unitary elongated body having a plurality of wires, cables, or the like, distributed/run throughout the multi-curvable body 252 or 262 in such a way that a manipulating, such as a pulling/releasing, shortening/lengthening, tightening/loosening, etc., of one or a combination of such wires, cables, or the like enables the above-mentioned curving of one or more locations of the multi-curvable body 252 or 262 in one or more curvatures and in one or more directions. As another example, the multi-curvable body 252 or 262 may include a plurality of segments, each segment linked to an adjacent segment in such a way that the segment may be controlled/configured to be pivotly positioned in a plurality of positions relative to the adjacent segment. As another example, the multi-curvable body 252 or 262 may include a plurality of springs, gears, motors, etc. for achieving the above-mentioned curving of one or more locations of the multi-curvable body 252 or 262 in one or more curvatures and in one or more directions. It is to be understood in the present disclosure that the multi-curvable body 252 or 262 may also include a combination of one or more of the above-mentioned approaches.

[00109] The assistant arm assembly 250 or 260 may be secured to the port assembly 210 in one or more of a plurality of ways, including those described above and in the present disclosure for the instrument arm assemblies 230, 240 and/or the image capturing assembly 220. For example, the assistant arm assembly 250 or 260 may also comprise an anchoring portion (e.g., similar to the anchoring portion 220a of the image capturing assembly 220 and/or the securing portion 231a of the instrument arm assembly 220), respectively, operable to attach (or secure) the assistant arm assembly 250 or 260 to one or more anchor ports 216 of the port assembly 210.

[00110] In an example embodiment, the multi-curvable body 252 or 262 may each be substantially cylindrical in shape. The multi-curvable body 252 or 262 may also be formed in any one of a plurality of other shapes, sizes, and/or dimensions without departing from the teachings of the present disclosure.

[00111] In an example embodiment, the length of the multi-curvable body 252 or 262 may be between about 170 to 270 mm. In example embodiments, a length of multi-curvable body 252 or 262 may also be adjustable by the surgical team 904 before, during, and/or after insertion of the camera arm assembly into the cavity of the patient. The outer diameter of the multi-curvable body 252 or 262 may be between about 5 to 7 mm. It is to be understood in the present disclosure that the above dimensions are merely an illustration of example embodiments, and as such the dimensions may be smaller or larger than those recited above without departing from the teachings of the present disclosure.

[00112] **Controller**

[00113] In example embodiments, the surgical system may include a controller (or computing device, manipulator, and/or master input device). The controller may be configurable to perform one or more of a plurality of operations in and on the surgical system 200. For example, the controller may be configurable to communicate with and/or control one or more elements of the surgical system 200, such as the external anchor 1 or 1000, the port assembly 210, the instrument arm assemblies 230 or 240, the image capturing assembly 220, and/or the assistant arm assemblies 250 or 260. The controller may be accessible and/or controllable by the surgical team 904, and the surgical team may be able to communicate with and/or control the configuring and/or operation of the one or more elements of the surgical system 200. For example, the controller may be configurable to control a movement and action of some or all parts of the instrument arm assemblies 230 or 240, the first gate assembly 212b, the second gate assembly 214b, the movement and action of some or all parts of the image capturing assembly 220 (including the image capturing, temperature control, etc.), the movement and action of some or all parts of the multi-curable body 222 of the image capturing assembly 220, the movement and action of some or all parts of the multi-curable body 252 or 262 of the assistant arm assemblies, the movement and action of some or all parts of the assistant arm assemblies 250 or 260, and the like.

[00114] **Method of setting up the surgical device 200 in a forward-directed position (e.g., method 700)**

[00115] As illustrated in **FIGURE 7** and Figures 8A-8E, example embodiments of the surgical device 200 may be configurable to perform a forward-directed surgical action or procedure in one of a plurality of ways. In an example embodiment, the external anchor

1 may be provided and installed/anchored to the stationary object. The port assembly 210 may be provided (e.g., action 702), and the instrument arm assembly may be provided (e.g., action 704). A second instrument arm assembly may be provided, as well as the image capturing assembly 220 and/or 320 and any of the assistant arm assemblies 250 and/or 260 required. The port assembly 210 may be inserted (e.g., action 706) into the opening (and cavity) of the patient and anchored in position using the external anchor 1 (e.g., action 708), and a workable volume/space in the cavity may be formed, such as via insufflation using CO₂ and/or other gases, vacuum suction tools, and/or retractable hook tools. The controllable swivel assembly 1000 may also be used in example embodiments. For example, a workable abdominal cavity of about 10-12 cm in height may be provided for the patient. Thereafter, one or more image capturing assemblies 220, one or more assistant arm assemblies (e.g., action 710), and one or more assistant arm assemblies 250 or 260 (if needed) may be inserted into the port assembly 210 via the central access channel 210a, secured to the anchor ports 216, and configured in the cavity of the patient. A surgical action or procedure may then be performed in any part, area, and/or quadrant of the cavity of the patient using the surgical device 200. These processes will now be described below with references to at least Figures 7, 8A-8E, 9B, and 10B.

[00116] (1) Providing the external anchor and installing the port assembly.

[00117] In an example embodiment, the external anchor 1 may be provided and installed/anchored to one or more stationary objects, such as a side rail 300 of a surgical table/bed, as illustrated in Figures 1A and 1B. One or more segments 2, 6, 10, and 14 of the external anchor 1 may cooperate using one or more joints 4, 8, 12, and 16 of the

external anchor 1 to fix the position (including orientation) of the port assembly 210 in or about the opening of the patient.

[00118] In an example embodiment, as illustrated in Figures 10A and 10B, the external anchor 1 may comprise a controllable swivel assembly 1000 operable to provide one or more additional *in vitro* degrees of freedom, such as via a first swivel portion 1002, second swivel portion 1004, and/or third swivel portion 1006. The controllable swivel assembly 1000 may further comprise a motor 1002a for the first swivel portion 1002, a motor 1004a for the second swivel portion 1004, a motor 1006a for the third swivel portion 1006, one or more supporting arms 1008, and one or more locks 1010.

[00119] The first swivel portion 1002 may be operable to provide, as one of the *in vitro* degrees of freedom, a translational movement of the port assembly 210 along an axis defined by the elongated length of the port assembly 210, as illustrated by the arrow A. In example embodiments, the translational movement, as illustrated by arrow A, provided by the first swivel portion 1002 may be between about 0 to 50 mm.

[00120] The controllable swivel assembly 1000 may further comprise a second swivel portion 1004 operable to provide, as another one of the *in vitro* degrees of freedom, a torsional or rotational movement of the port assembly 210 about an axis depicted by axis Y. In example embodiments, the torsional or rotational movement, as illustrated by the arrow B, provided by the second swivel portion 1004 may be between about +/- 180 degrees.

[00121] The controllable swivel assembly 1000 may further comprise a third swivel portion 1006 operable to provide, as another one of the *in vitro* degrees of freedom, a pivotal or rotational movement of the port assembly 210 about an axis perpendicular to

the Y-axis, such as the axis depicted by axis Z (which comes out of the page). In example embodiments, the Z-axis or the center of rotation may be located at about opening of the patient, such as at the mid-point of the abdominal wall. In example embodiments, the pivotal or rotational movement, as illustrated by the arrow C, provided by the third swivel portion 1006 may be between about +/- 80 degrees.

[00122] It is recognized in the present disclosure that the controllable swivel assembly 1000 may comprise the first swivel portion 1002, second swivel portion 1004, and/or third swivel portion 1006 in example embodiments. The controllable swivel assembly 1000 may further comprise other swivel portions (not shown) when more than three *in vitro* degrees of freedom and/or movements/rotations other than those providable by the first swivel portion 1002, second swivel portion 1004, and third swivel portion 1006 are desired and/or required.

[00123] The controllable swivel assembly 1000, including the first swivel portion 1002, the second swivel portion 1004, and/or the third swivel portion 1006, may be controllable either locally or remotely by the surgical team.

[00124] In an example embodiment, the port assembly 210 may be installed and secured to the external anchor 1 or 1000. As illustrated in Figures 8A-8E, the second end 214 of the port assembly 210 may be inserted into the opening of the patient and into the cavity of the patient and the first end 212 of the port assembly 210 may be secured to the external anchor 1 or 1000. Thereafter, a workable volume/space in the cavity may be formed in the cavity of the patient, such as via insufflation using CO₂ and/or other gases, vacuum suction tools, and/or retractable hook tools. Before doing so, the first gate assembly 212b and the second gate assembly 214b may be expanded to the closed

position. Insufflation of the cavity may be achieved in one or more of a plurality of ways. For example, the insufflation port of the port assembly 210 may be used to provide the required insufflation.

[00125] (2) Inserting and attaching the image capturing assembly.

[00126] After the workable volume/space in the cavity has been formed and the port assembly 210 is secured in position, as illustrated in **FIGURE 8A**, the image capturing assembly 220 may be inserted through the central access channel 210a and secured to the anchor port 216 of the port assembly 210. To do so while maintaining the workable volume/space, the first gate assembly 212b may be configured to the open position while the second gate assembly 214b is configured to the closed position. Once the first gate assembly 212b is in the open position, the image capturing assembly 220 may be inserted into the mid section 213. The first gate assembly 212b may then be configured to the closed position after the image capturing assembly 220 passes through the first gate assembly 212b. The second gate assembly 214b may then be configured to the open position. It is recognized in the present disclosure that the workable volume/space in the cavity is maintained via the insufflation since the first gate assembly 212b is configured to the closed position. Once the second gate assembly 214b is in the open position, the image capturing assembly 220 may be inserted into the cavity of the patient and the anchor portion 220a secured to an anchor port 216. The second gate assembly 214b may then be configured to the closed position after the image capturing assembly 220 passes through the second gate assembly 214b. The multi-curvable body 222 of the image capturing assembly 220 may then be configured/controlled to curve in one or more

locations along the multi-curvable body 222 so that the image capturing assembly 220 can be directed in a forward-directed position (as illustrated in Figures 2B and 3B).

[00127] The separate image capturing assembly 320 may also be inserted through the port assembly 210 in a similar manner as described above. Once inserted through the port assembly 210 and into the cavity of the patient, the separate image capturing assembly 320 may then be attached/secured to the interior wall of the cavity of the patient via the magnetic anchor 310.

[00128] (3) Inserting and attaching a first instrument arm assembly.

[00129] The instrument arm assembly 230 may be inserted through the central access channel 210a and secured to the anchor port 216 of the port assembly 210. To do so while maintaining the workable volume/space, the first gate assembly 212b may again be configured to the open position while the second gate assembly 214b is configured to the closed position. Once the first gate assembly 212b is in the open position, the instrument arm assembly 230 may be inserted into the mid section 213, as illustrated in **FIGURE 8B**. The first gate assembly 212b may then be configured to the closed position after the instrument arm assembly 230 passes through the first gate assembly 212b and into the mid section 213, as illustrated in **FIGURE 8C**. The second gate assembly 214b may then be configured to the open position, as illustrated in **FIGURE 8D**. Once the second gate assembly 214b is in the open position, the instrument arm assembly 230 may be inserted into the cavity of the patient and the securing portion 231a secured to an anchor port 216, as illustrated in **FIGURE 8E**. The second gate assembly 214b may then be configured to the closed position after the instrument arm assembly 230 passes through the second gate assembly 214b.

[00130] (5) Inserting and attaching one or more additional instrument arm assemblies, one or more assistant arm assemblies, and/or one or more additional camera arm assemblies.

[00131] One or more additional instrument arm assemblies 240, one or more assistant arm assemblies 250 or 260, and/or one or more additional image capturing assemblies (not shown) may also be inserted into the port assembly 210 via the central access channel 210a in the same manner as described above for the image capturing assembly 220 and the instrument arm assembly 230.

[00132] (6) Unattaching and removing the instrument arm assembly, image capturing assembly, and assistant arm assemblies.

[00133] The instrument arm assembly 230, image capturing assembly 220, other instrument arm assembly 240 (if provided), other image capturing assembly (if provided), and the one or more other assistant arm assemblies 250 or 260 (if provided) may be unattached (or unsecured) from the anchor ports 216 and removed from the cavity of the patient via the central access channel 210a of the port assembly 210 in a substantially reverse manner as described above for the inserting and attaching.

[00134] Method of setting up the surgical device 200 in a reverse-directed position (e.g., method 700)

[00135] As illustrated in Figures 7 and 8F-8K, example embodiments of the surgical device 200 may be configurable to perform a reverse-directed surgical action or procedure in one of a plurality of ways. In an example embodiment, the external anchor 1 may be provided and installed/anchored to the stationary object in a similar manner as described above and in the present disclosure. The port assembly 210 may be provided

(e.g., action 702), and the instrument arm assembly may be provided (e.g., action 704). A second instrument arm assembly may be provided, as well as the image capturing assembly 220 and/or 320 and any of the assistant arm assemblies 250 and/or 260 required. The port assembly 210 may be inserted (e.g., action 706) into the opening (and cavity) of the patient and anchored in position using the external anchor 1 (e.g., action 708), and a workable volume/space in the cavity may be formed, such as via insufflation using CO₂ and/or other gases, vacuum suction tools, and/or retractable hook tools. The controllable swivel assembly 1000 may also be used in example embodiments. For example, a workable abdominal cavity of about 10-12 cm in height may be provided for the patient. Thereafter, one or more image capturing assemblies 220, one or more assistant arm assemblies (e.g., action 710), and one or more assistant arm assemblies 250 or 260 (if needed) may be inserted into the port assembly 210 via the central access channel 210a, secured to the anchor ports 216, and configured in the cavity of the patient. For the inserting, each of the image capturing assemblies 220, instrument arm assemblies 230 and/or 240, and assistant arm assemblies 250 and/or 260 are inserted in reverse orientation as compared to the forward-directed position described above and in the present disclosure. A surgical action or procedure may then be performed in any part, area, and/or quadrant of the cavity of the patient using the surgical device 200. These processes will now be described below with references to at least Figures 7, 8F-8K, 9B, and 10B.

[00136] (1) Providing the external anchor and installing the port assembly.

[00137] In an example embodiment, the port assembly 210 may be installed and secured to the external anchor 1 or 1000. As illustrated in Figures 8A-8E, the second end

214 of the port assembly 210 is inserted into the opening of the patient and into the cavity of the patient and the first end 212 of the port assembly 210 is secured to the external anchor 1 or 1000. Thereafter, a workable volume/space in the cavity may be formed in the cavity of the patient, such as via insufflation using CO₂ and/or other gases, vacuum suction tools, and/or retractable hook tools. Before doing so, the first gate assembly 212b and the second gate assembly 214b may be expanded to the closed position. Insufflation of the cavity may be achieved in one or more of a plurality of ways. For example, the insufflation port of the port assembly 210 may be used to provide the required insufflation.

[00138] (2) Inserting and attaching the image capturing assembly.

[00139] After the workable volume/space in the cavity has been formed and the port assembly 210 is secured in position, as illustrated in **FIGURE 8F**, the image capturing assembly 220 may be inserted with the image capturing body 224 inserted last through the central access channel 210a and secured to the anchor port 216 of the port assembly 210. To do so while maintaining the workable volume/space, the first gate assembly 212b may be configured to the open position while the second gate assembly 214b is configured to the closed position. Once the first gate assembly 212b is in the open position, the image capturing assembly 220 may be inserted into the mid section 213. The first gate assembly 212b may then be configured to the closed position after the image capturing assembly 220 passes through the first gate assembly 212b. The second gate assembly 214b may then be configured to the open position. It is recognized in the present disclosure that the workable volume/space in the cavity is maintained via the insufflation since the first gate assembly 212b is configured to the closed position. Once

the second gate assembly 214b is in the open position, the image capturing assembly 220 may be inserted completely into the cavity of the patient with the image capturing body 224 being closest to the anchor port 216. The multi-curvable body 222 of the image capturing assembly 220 may then be configured/controlled to curve in one or more locations along the multi-curvable body 222 so that the image capturing assembly 220 can be directed in a reverse-directed position next to the outer surface of the port assembly 210 (as illustrated in Figures 2A and 3A). The image capturing assembly 220 may then be provided adjacent to the outer surface of the port assembly 210 so that the anchoring portion 220a of the image capturing assembly 220 is adjacent to the anchor port 216. The anchoring portion 220a of the image capturing assembly 220 may then be secured to the anchor port 216. The second gate assembly 214b may be configured to the closed position after the image capturing assembly 220 passes through the second gate assembly 214b.

[00140] The separate image capturing assembly 320 may also be inserted through the port assembly 210 in a similar manner as described above. Once inserted through the port assembly 210 and into the cavity of the patient, the separate image capturing assembly 320 may then be attached/secured to the interior wall of the cavity of the patient via the magnetic anchor 310.

[00141] (3) Inserting and attaching a first instrument arm assembly.

[00142] To insert the instrument arm assembly 230 through the central access channel 210a and secure it to the anchor port 216 of the port assembly 210 while maintaining the workable volume/space, the first gate assembly 212b may again be configured to the open position while the second gate assembly 214b is configured to the closed position.

Once the first gate assembly 212b is in the open position, the instrument arm assembly 230 may be inserted with the end effector 239 inserted last into the mid section 213, as illustrated in **FIGURE 8G**. The first gate assembly 212b may then be configured to the closed position after the instrument arm assembly 230 passes through the first gate assembly 212b and into the mid section 213, as illustrated in **FIGURE 8H**. The second gate assembly 214b may then be configured to the open position, as illustrated in **FIGURE 8I**. Once the second gate assembly 214b is in the open position, the instrument arm assembly 230 may be inserted completely into the cavity of the patient with the end effector 239 being closest to the anchor port 216, as illustrated in **FIGURE 8J**. The instrument arm assembly 230 may then be turned 180 degrees (if needed) and/or moved so that the instrument arm assembly 230 can be brought next to the outer surface of the port assembly 210. The instrument arm assembly 230 may then be pulled adjacent to the outer surface of the port assembly 210 so that the securing portion 231a of the shoulder section 231 of the instrument arm assembly 230 is adjacent to the anchor port 216. The securing portion 231a of the instrument arm assembly 230 may then be secured to the anchor port 216, as illustrated in **FIGURE 8K**. The second gate assembly 214b may be configured to the closed position at any time after at least the end effector 230 of the instrument arm assembly 230 passes through the second gate assembly 214b.

[00143] (5) Inserting and attaching one or more additional instrument arm assemblies, one or more assistant arm assemblies, and/or one or more additional camera arm assemblies.

[00144] One or more additional instrument arm assemblies 240, one or more assistant arm assemblies 250 or 260, and/or one or more additional image capturing assemblies

(not shown) may also be inserted and installed in a reverse-directed manner via the central access channel 210a of the port assembly 210 in the same manner as described above for the image capturing assembly 220 and the instrument arm assembly 230.

[00145] (6) Unattaching and removing the instrument arm assembly, image capturing assembly, and assistant arm assemblies.

[00146] The instrument arm assembly 230, image capturing assembly 220, other instrument arm assembly 240 (if provided), other image capturing assembly (if provided), and the one or more other assistant arm assemblies 250 or 260 (if provided) may be unattached (or unsecured) from the anchor ports 216 and removed from the cavity of the patient via the central access channel 210a of the port assembly 210 in a substantially reverse manner as described above for the inserting and attaching in the reverse-directed manner.

[00147] While various embodiments in accordance with the disclosed principles have been described above, it should be understood that they have been presented by way of example only, and are not limiting. Thus, the breadth and scope of the example embodiments described in the present disclosure should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the claims and their equivalents issuing from this disclosure. Furthermore, the above advantages and features are provided in described embodiments, but shall not limit the application of such issued claims to processes and structures accomplishing any or all of the above advantages.

[00148] For example, "assembly," "device," "portion," "segment," "member," "body," or other similar terms should generally be construed broadly to include one part or more than one part attached or connected together.

[00149] Various terms used herein have special meanings within the present technical field. Whether a particular term should be construed as such a "term of art" depends on the context in which that term is used. "Connected," "connecting," "attached," "attaching," "anchored," "anchoring," "in communication with," "communicating with," "associated with," "associating with," or other similar terms should generally be construed broadly to include situations where attachments, connections, and anchoring are direct between referenced elements or through one or more intermediaries between the referenced elements. These and other terms are to be construed in light of the context in which they are used in the present disclosure and as one of ordinary skill in the art would understand those terms in the disclosed context. The above definitions are not exclusive of other meanings that might be imparted to those terms based on the disclosed context.

[00150] As referred to in the present disclosure, a computing device, controller, manipulator, master input device, a processor, and/or a system may be a virtual machine, computer, node, instance, host, and/or device in a networked or non-networked computing environment. A networked computing environment may be a collection of devices connected by communication channels that facilitate communications between devices and allow devices to share resources. Also as referred to in the present disclosure, a computing device may be a device deployed to execute a program operating as a socket listener and may include software instances.

[00151] Resources may encompass any type of resource for running instances including hardware (such as servers, clients, mainframe computers, networks, network storage, data sources, memory, central processing unit time, scientific instruments, and other computing devices), as well as software, software licenses, available network services, and other non-hardware resources, or a combination thereof.

[00152] A networked computing environment may include, but is not limited to, computing grid systems, distributed computing environments, cloud computing environment, etc. Such networked computing environments include hardware and software infrastructures configured to form a virtual organization comprised of multiple resources that may be in geographically disperse locations.

[00153] Furthermore, the coverage of the present application and any patents issuing from the present application may extend to one or more communications protocols, including TCP/IP.

[00154] Words of comparison, measurement, and timing such as "at the time," "equivalent," "during," "complete," and the like should be understood to mean "substantially at the time," "substantially equivalent," "substantially during," "substantially complete," etc., where "substantially" means that such comparisons, measurements, and timings are practicable to accomplish the implicitly or expressly stated desired result.

[00155] Additionally, the section headings herein are provided for consistency with the suggestions under 37 C.F.R. 1.77 or otherwise to provide organizational cues. These headings shall not limit or characterize the invention(s) set out in any claims that may issue from this disclosure. Specifically, a description of a technology in the

"Background" is not to be construed as an admission that technology is prior art to any invention(s) in this disclosure. Furthermore, any reference in this disclosure to "invention" in the singular should not be used to argue that there is only a single point of novelty in this disclosure. Multiple inventions may be set forth according to the limitations of the multiple claims issuing from this disclosure, and such claims accordingly define the invention(s), and their equivalents, that are protected thereby. In all instances, the scope of such claims shall be considered on their own merits in light of this disclosure, but should not be constrained by the headings herein.

Claims

What is claimed is:

1. A surgical system comprising:

a port assembly, the port assembly being an elongated structure and having:

a first end section, the first end section having a first end channel and a first gate assembly, the first gate assembly configurable to transition between an open position to allow access through the first end channel and a closed position to prevent access through the first end channel; and

a second end section, the second end section having:

a second end channel, the second end channel being substantially aligned with the first end channel;

a second gate assembly, the second gate assembly configurable to transition between an open position to allow access through the second end channel and a closed position to prevent access through the second end channel; and

an anchor port; and

an instrument arm assembly, the instrument arm assembly having:

a shoulder section securable to the anchor port of the second end section;

a first arm section secured to the shoulder section;

an elbow section secured to the first arm section;

a second arm section secured to the elbow section;

a wrist section secured to the second arm section; and

an end effector section secured to the wrist section, the end effector section having an end effector.

2. The surgical system of claim 1,

wherein the first gate assembly includes a first expandable portion, the first expandable portion configurable to expand when the first gate assembly is configured to the closed position; and

wherein, when the first gate assembly is configured to the closed position, the first expandable portion is operable to substantially block a gas medium from passing through the first end channel.

3. The surgical system of claim 2,

wherein the first expandable portion comprises a plurality of first expandable members arranged around a portion of the first end channel; and

wherein the plurality of first expandable members are operable to cooperate to substantially block the gas medium from passing through the first end channel when the first gate assembly is configured to the closed position.

4. The surgical system of claim 1,

wherein the second gate assembly includes a second expandable portion, the second expandable portion configurable to expand when the second gate assembly is configured to the closed position; and

wherein, when the second gate assembly is configured to the closed position, the second expandable portion is operable to substantially block a gas medium from passing through the second end channel.

5. The surgical system of claim 4,

wherein the second expandable portion comprises a plurality of second expandable members arranged around a portion of the second end channel; and

wherein the plurality of second expandable members are operable to cooperate to substantially block the gas medium from passing through the second end channel when the second gate assembly is configured to the closed position.

6. The surgical system of claim 1,

wherein the port assembly further comprises a mid section between the first end section and the second end section, the mid section having a mid section channel substantially aligned with the first end channel and the second end channel; and

wherein the mid section channel is operable to cooperate with the first gate assembly and the second gate assembly to function as an isolation chamber for instruments when the instruments are transported through the port assembly.

7. The surgical system of claim 1, wherein the port assembly further comprises an insufflation port operable to maintain a positive pressure within a cavity of a patient when at least a portion of the port assembly is inserted into the cavity of the patient.

8. The surgical system of claim 1, wherein the instrument arm assembly is configurable to provide at least 7 degrees of freedom.

9. The surgical system of claim 8, wherein the instrument arm assembly includes at least one integrated motor to achieve each degree of freedom.

10. The surgical system of claim 9, wherein the instrument arm assembly includes an integrated force and/or haptic feedback subsystem in communication with the at least one integrated motor.

11. The surgical system of claim 1,

wherein the shoulder section is configurable to provide at least two degrees of freedom; and

wherein, when the shoulder section is secured to the anchor port of the second end section, the shoulder section is configurable to move in such a way as to transition the instrument arm assembly between a forward-directed position and a reverse-directed position.

12. The surgical system of claim 1,

further comprising an image capturing assembly, the image capturing assembly including a multi-curvable body;

wherein the multi-curvable body is configurable to curve at one or more of a plurality of locations along the multi-curvable body, in one or more of a plurality of curvatures, and/or in one or more of a plurality of directions; and

wherein the multi-curvable body is securable to a second anchor port of the second end section.

13. The surgical system of claim 12,

wherein the multi-curvable body includes a plurality of embedded wires;

wherein the multi-curvable body is configured to curve at one or more of a plurality of locations, in one or more of a plurality of curvatures, and/or in one or more of a plurality of directions by controlling a length of one or a combination of the embedded wires.

14. The surgical system of claim 12, wherein the image capturing assembly includes a high definition (HD) 3-dimensional (3-D) video camera.

15. The surgical system of claim 1,
further comprising a suction assembly, the suction assembly including a multi-curvable body and a suction port at an end of the multi-curvable body operable to apply a negative pressure;

wherein the multi-curvable body is configurable to curve at one or more of a plurality of locations along the multi-curvable body, in one or more of a plurality of curvatures, and/or in one or more of a plurality of directions; and

wherein the multi-curvable body is securable to a second anchor port of the second end section.

16. The surgical system of claim 1, further comprising a second instrument arm assembly securable to the port assembly, the second instrument arm assembly having:

a second shoulder section securable to a second anchor port of the second end section;

a second first arm section secured to the second shoulder section;

a second elbow section secured to the second first arm section;

a second second arm section secured to the second elbow section;

a second wrist section secured to the second second arm section; and

a second end effector section secured to the second wrist section, the second end effector section having a second end effector.

17. The surgical system of claim 1, further comprising a controller, the controller operable to configure one or more of the following:

the first gate assembly to be in the closed position or open position;

the second gate assembly to be in the closed position or open position;

the shoulder section to be secured to the anchor port of the second end section;
the shoulder section to move in at least 2 degrees of freedom;
the shoulder section to move in such a way as to transition the instrument arm assembly between a forward-directed position and a reverse-directed position;
the elbow section to move in at least 1 degree of freedom;
the wrist section to move in at least 2 degrees of freedom;
the end effector section to move in at least 1 degree of freedom; and/or
the end effector to perform an action.

18. The surgical system of claim 1, further comprising an external anchor assembly securable to a fixedly positioned object, the external anchor assembly configurable to secure to the first end section of the port assembly, the external anchor assembly configurable to provide at least 3 degrees of freedom.

19. A port assembly for use in a surgical system, the surgical system having one or more instrument arm assemblies for performing a surgical action, the port assembly comprising:

a first end section, the first end section having a first end channel and a first gate assembly, the first gate assembly configurable to transition between an open position to allow access through the first end channel and a closed position to prevent access through the first end channel; and

a second end section, the second end section having:

a second end channel, the second end channel being substantially aligned with the first end channel;

a second gate assembly, the second gate assembly configurable to transition between an open position to allow access through the second end channel and a closed position to prevent access through the second end channel; and

an anchor port;

wherein the anchor port is configurable to be securable to one of the instrument arm assembly;

wherein the first end section is configurable to secure to an external anchor;

wherein the first end channel and second end channel are operable to cooperate with the first gate assembly and second gate assembly to allow and not allow access of the instrument arm assembly through the port assembly.

Abstract

A surgical system (200) includes a port assembly (210) and an instrument arm assembly (230). The port assembly (210) has a first end section (212) and a second end section (214). The first end section (212) includes a first end channel (212a) and a first gate assembly (212b). The second end section (214) includes a second end channel (214a), a second gate assembly (214b) and an anchor port (216). The first and second gate assemblies (212b, 214b) could make the transition between an open position to allow the access through the first and second end channels (212a, 214a), respectively, and a closed position to prevent the access. The instrument arm assembly (230) includes a shoulder section (231) securable to the anchor port, a first arm section (233) secured to the shoulder section (231), an elbow section (234) secured to the first arm section (233), a second arm section (235) secured to the elbow section (234), a wrist section (236) secured to the second arm section (235) and an end effector section (238) secured to the wrist section (236). A port assembly for use in a surgical system and a method of configuring a surgical system are also provided.

[Figure 2A]

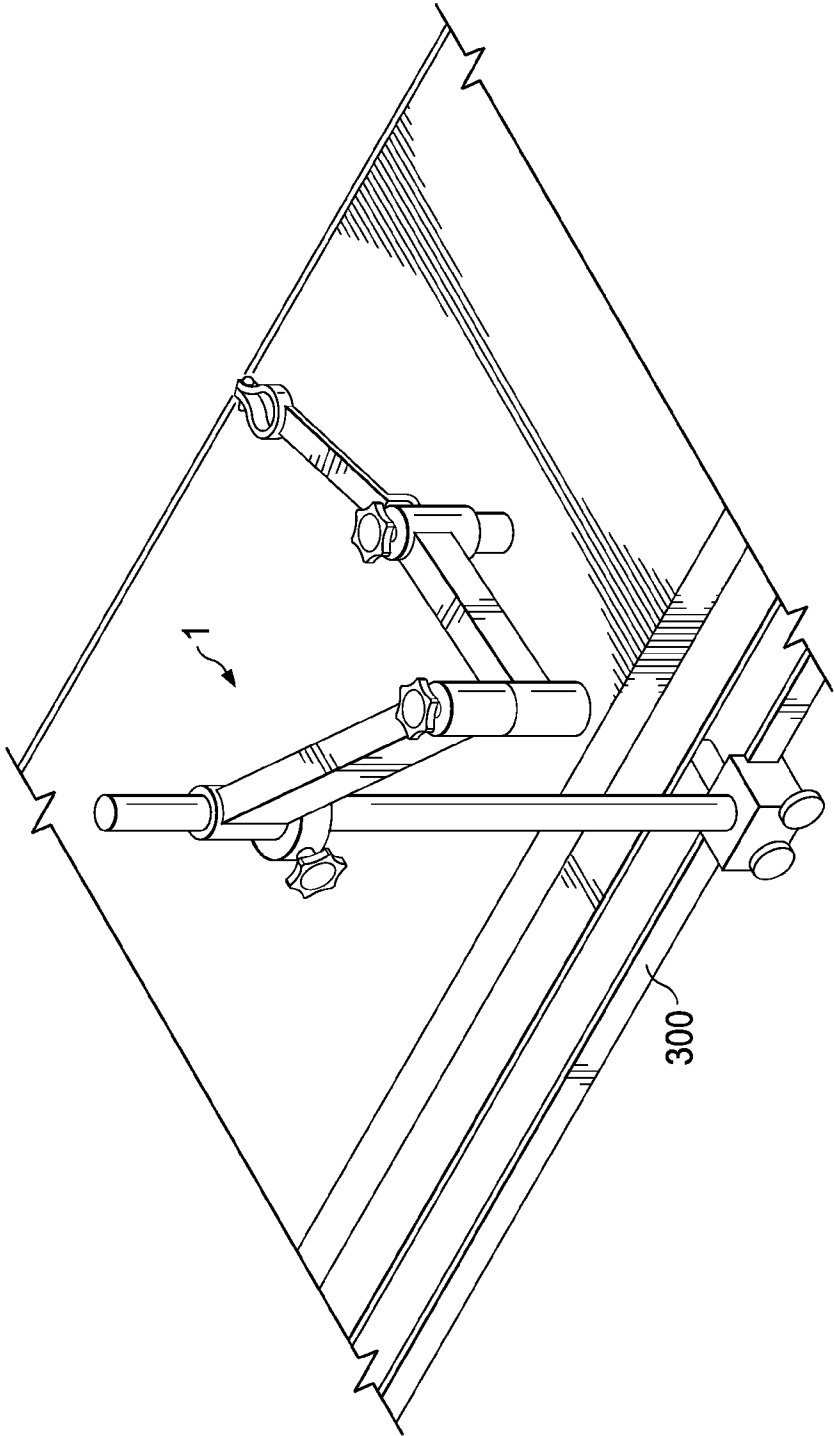


FIG. 1A

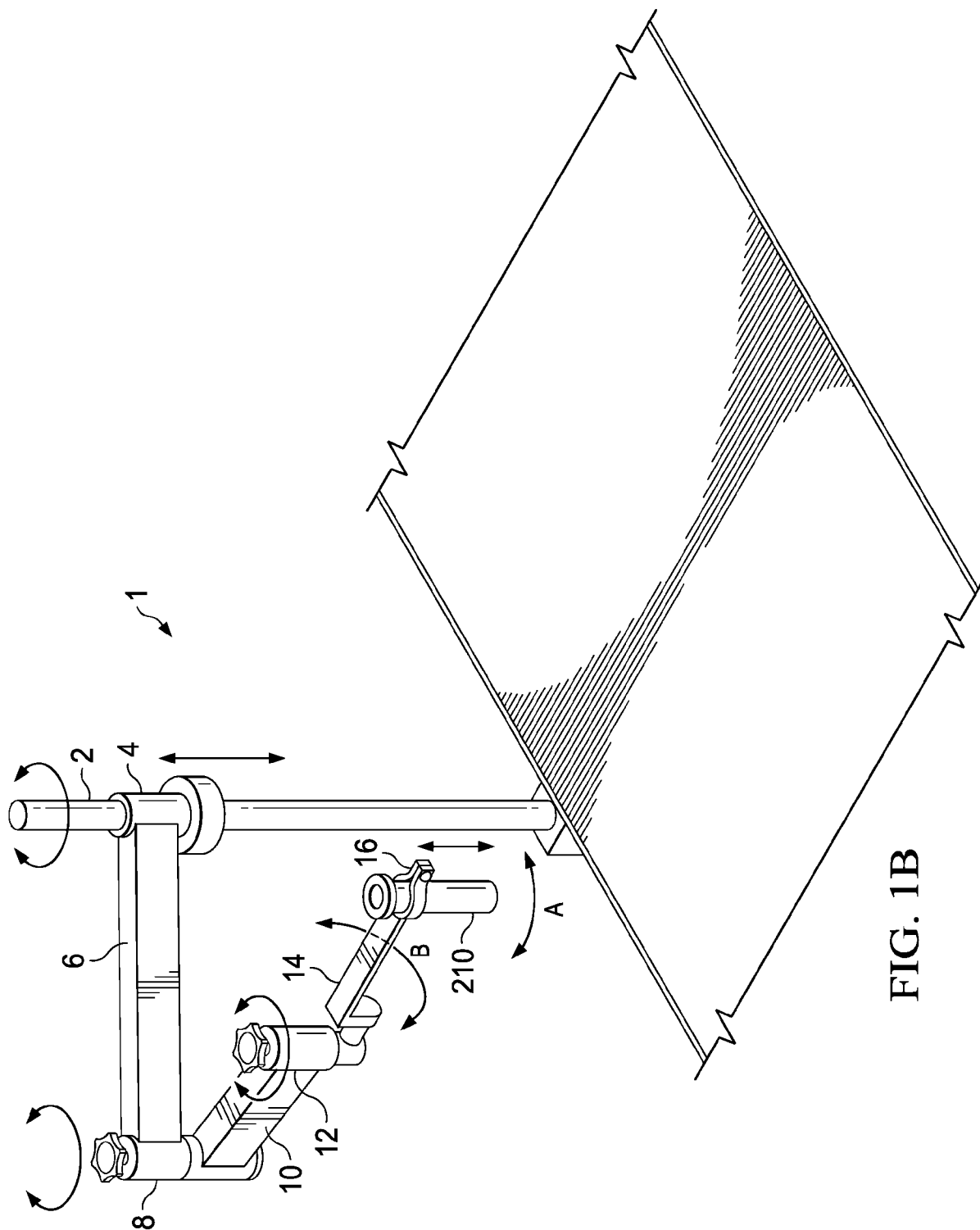


FIG. 1B

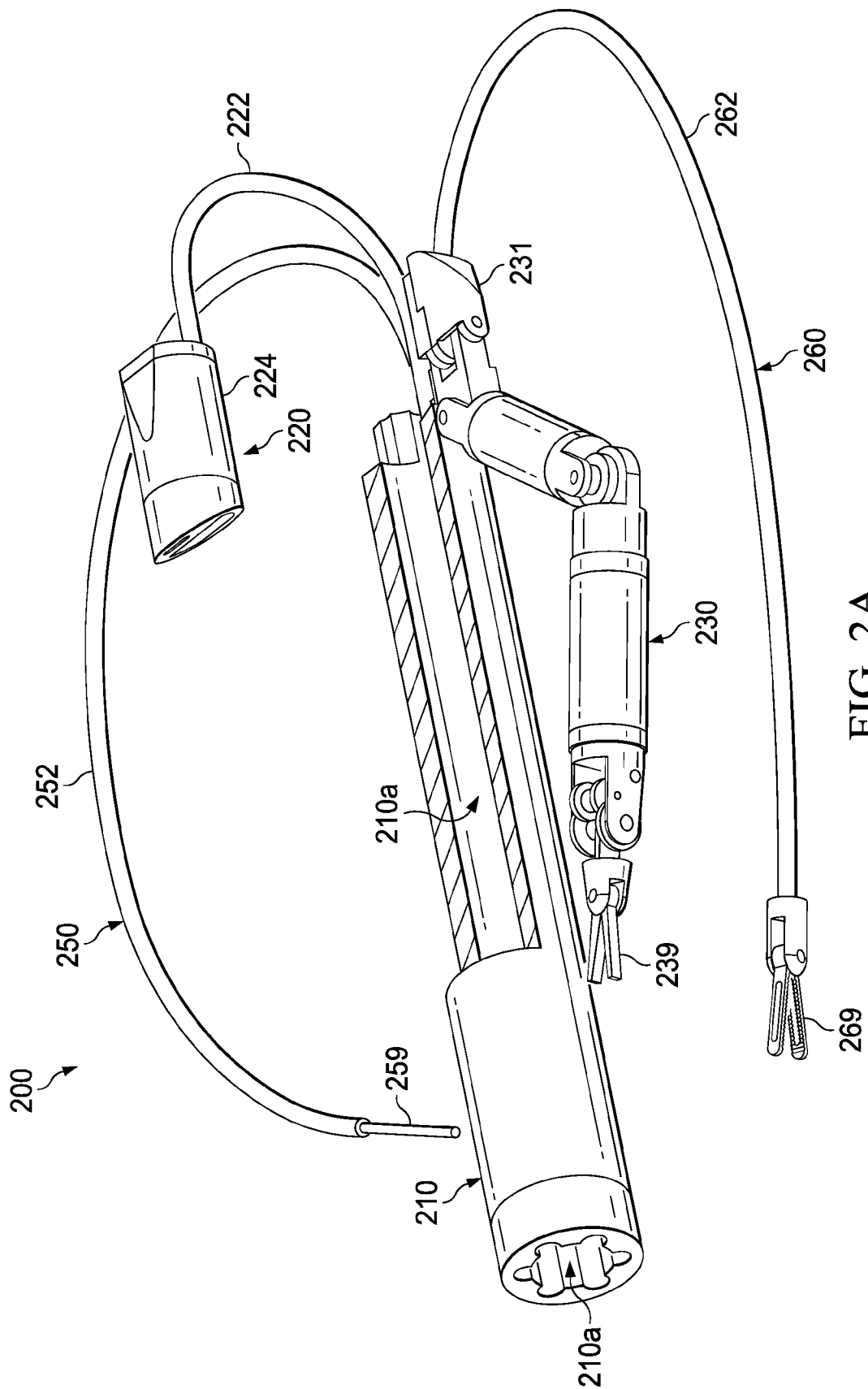


FIG. 2A

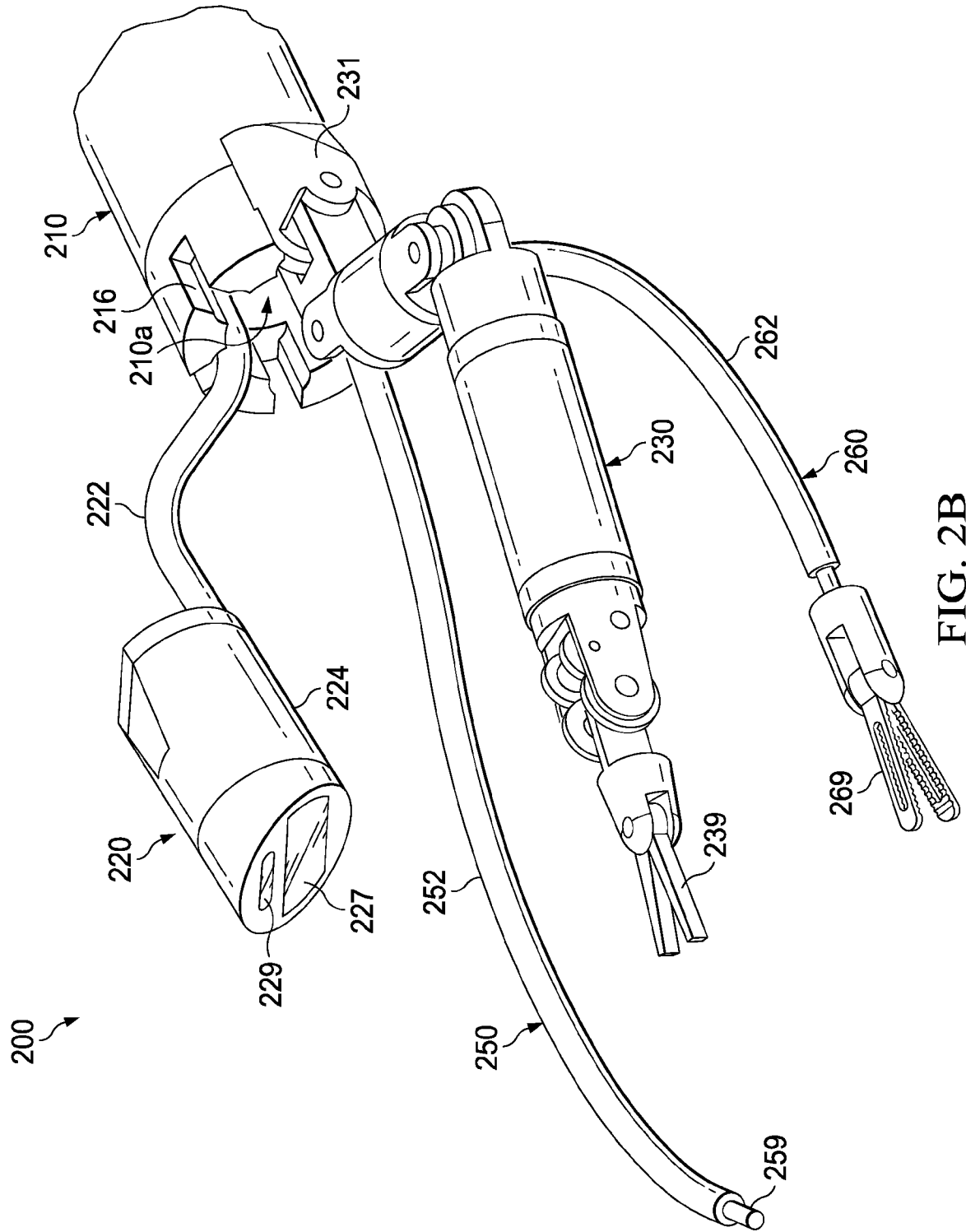


FIG. 2B

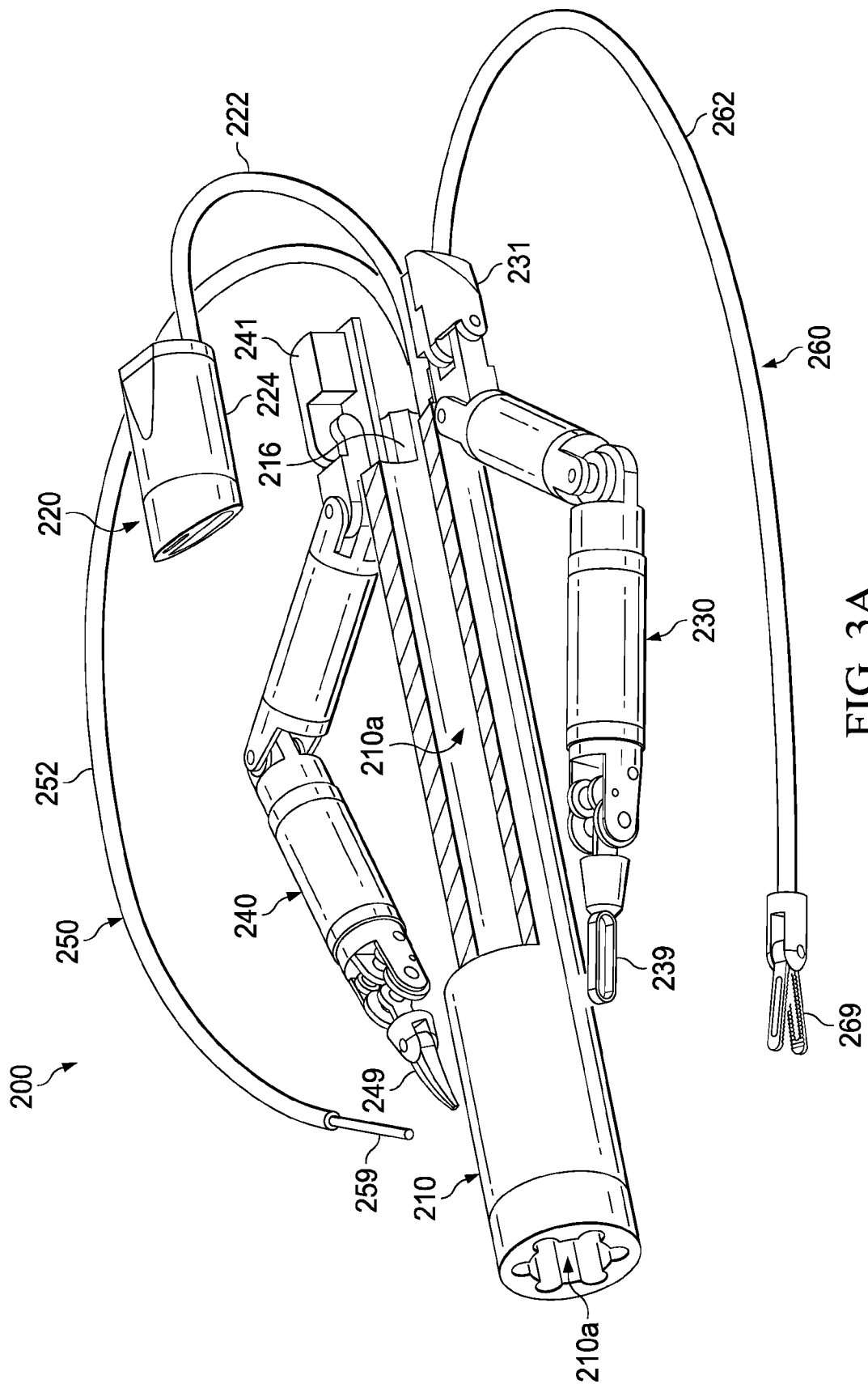


FIG. 3A

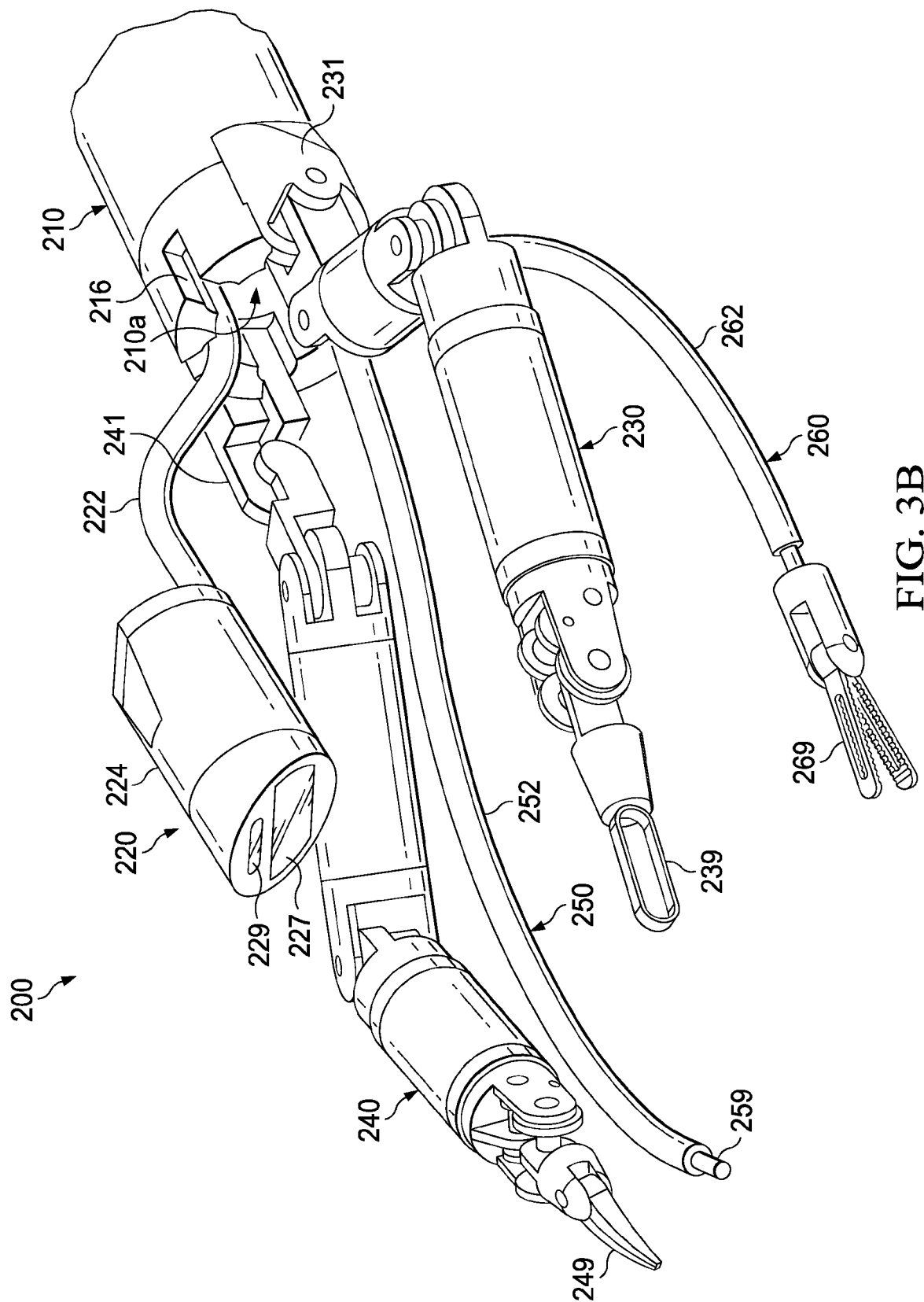
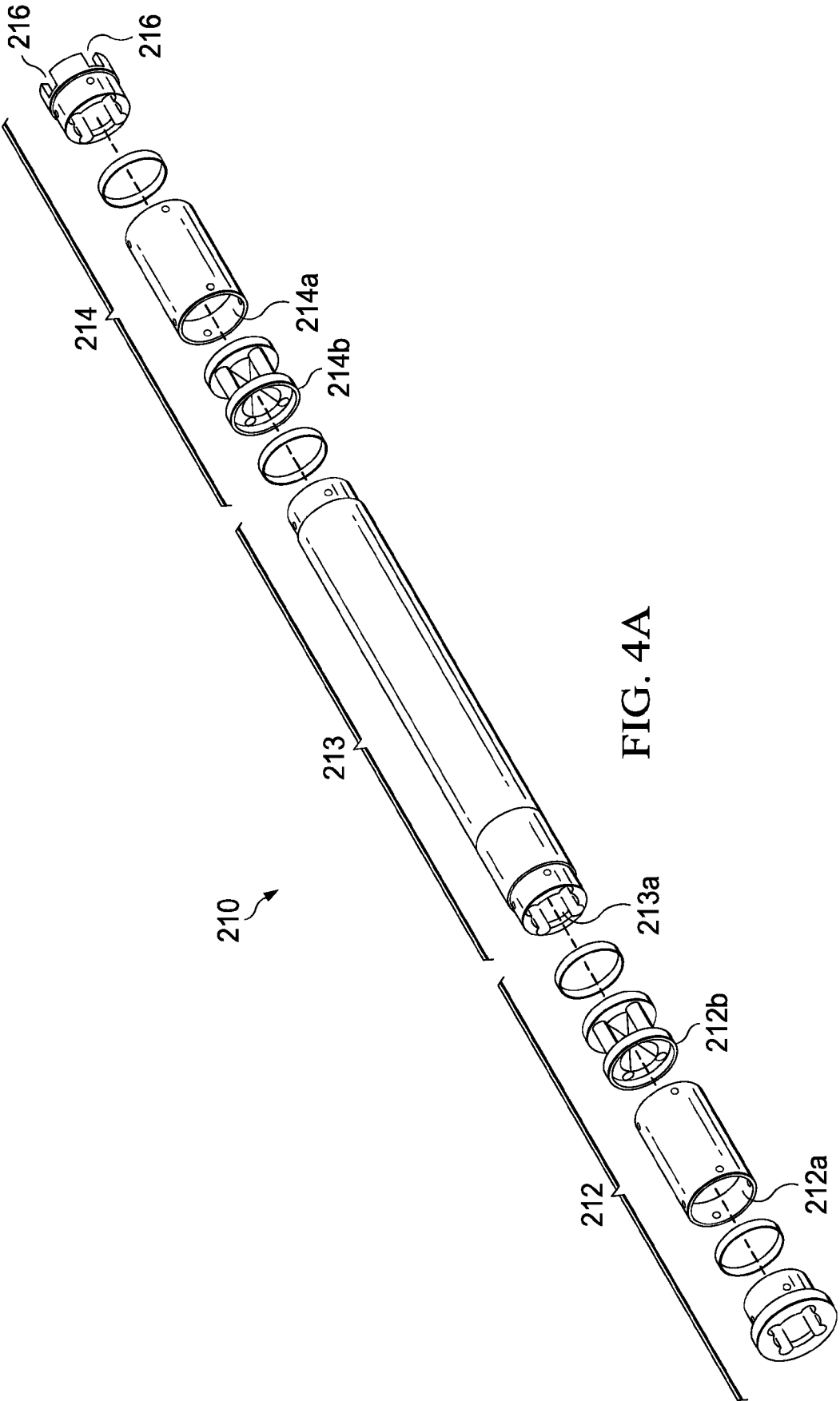


FIG. 3B



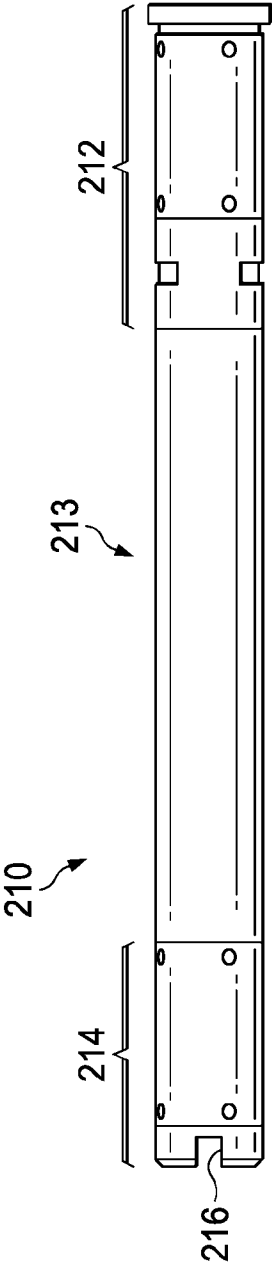


FIG. 4B

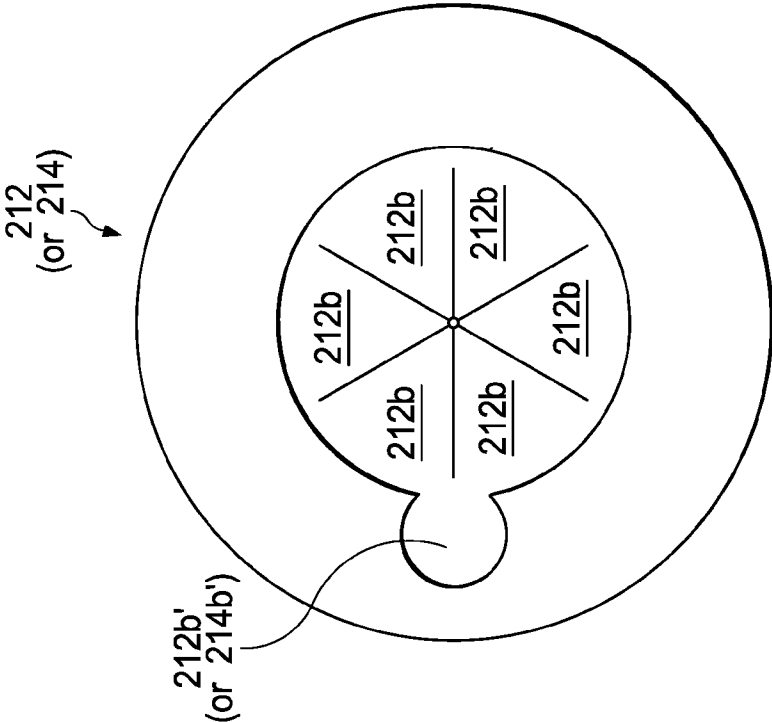


FIG. 4D

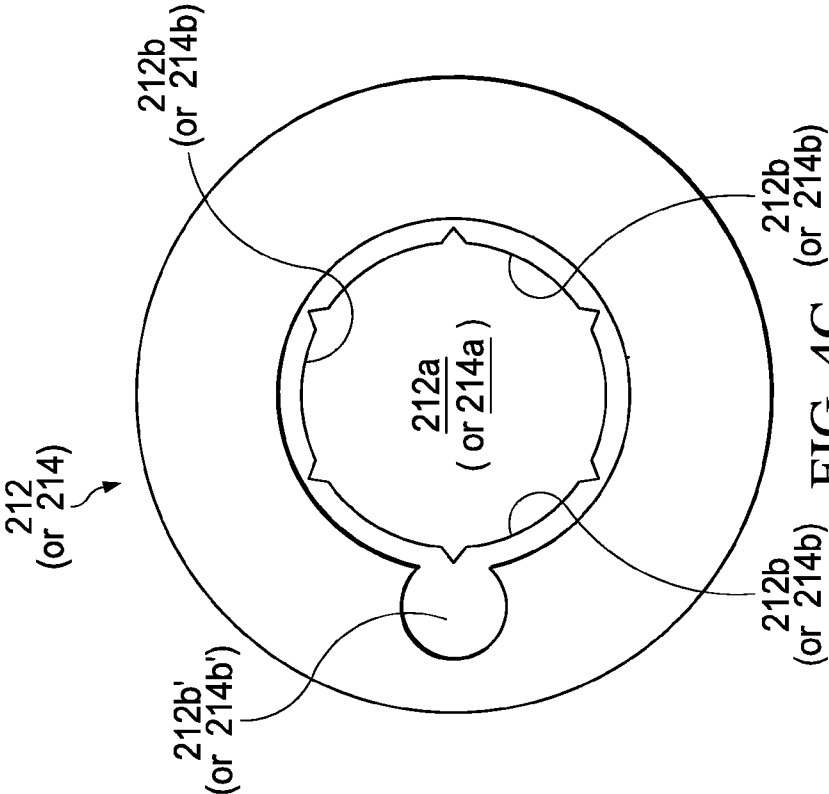
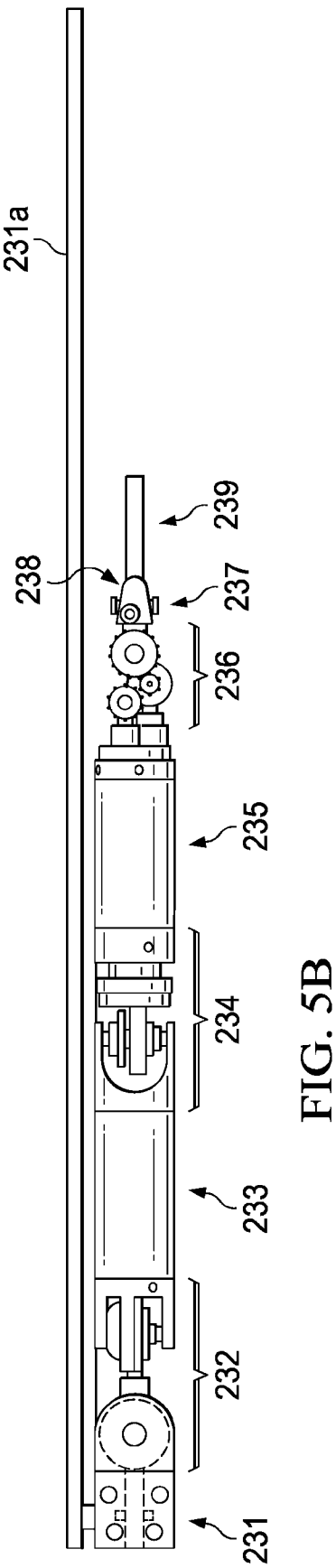
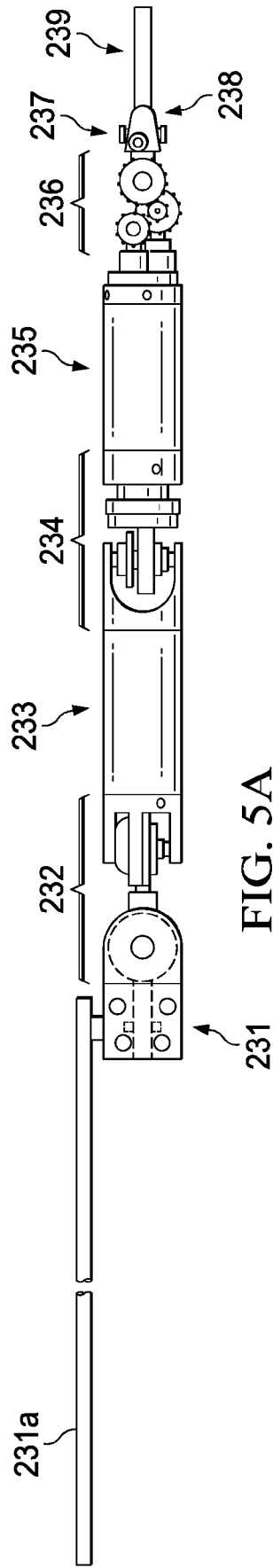


FIG. 4C



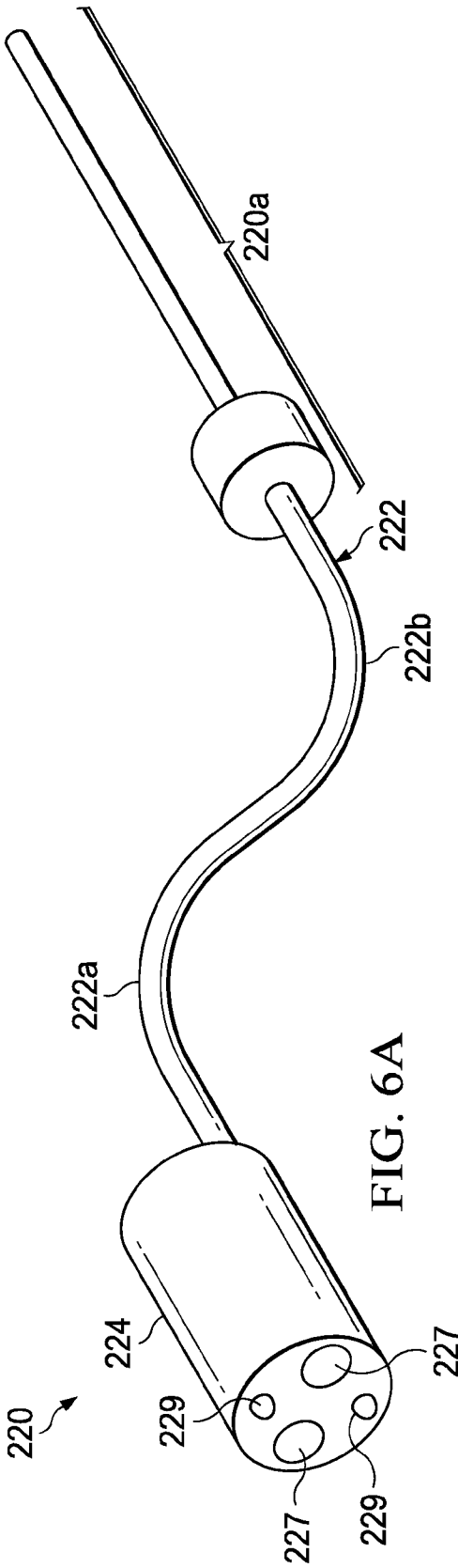


FIG. 6A

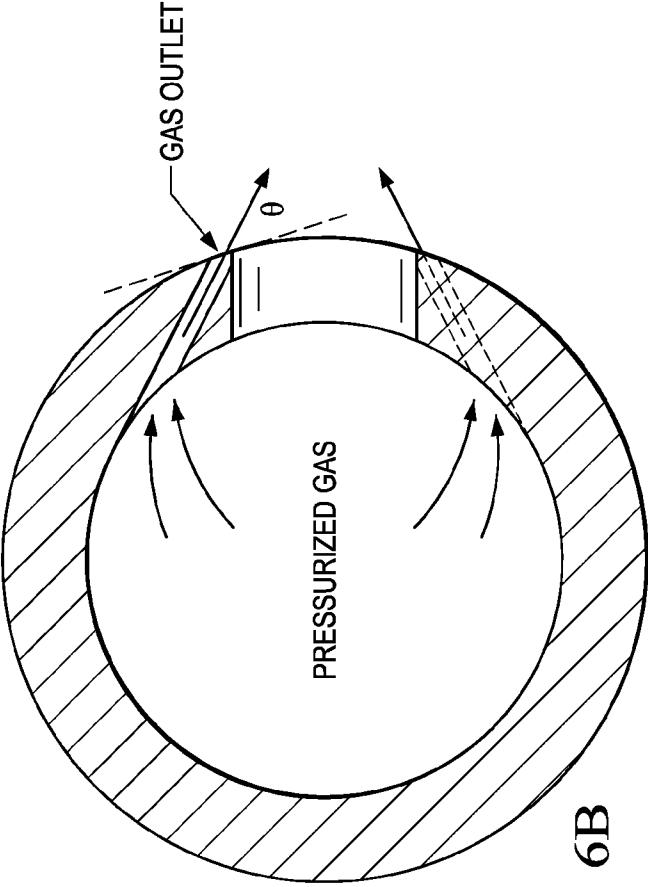
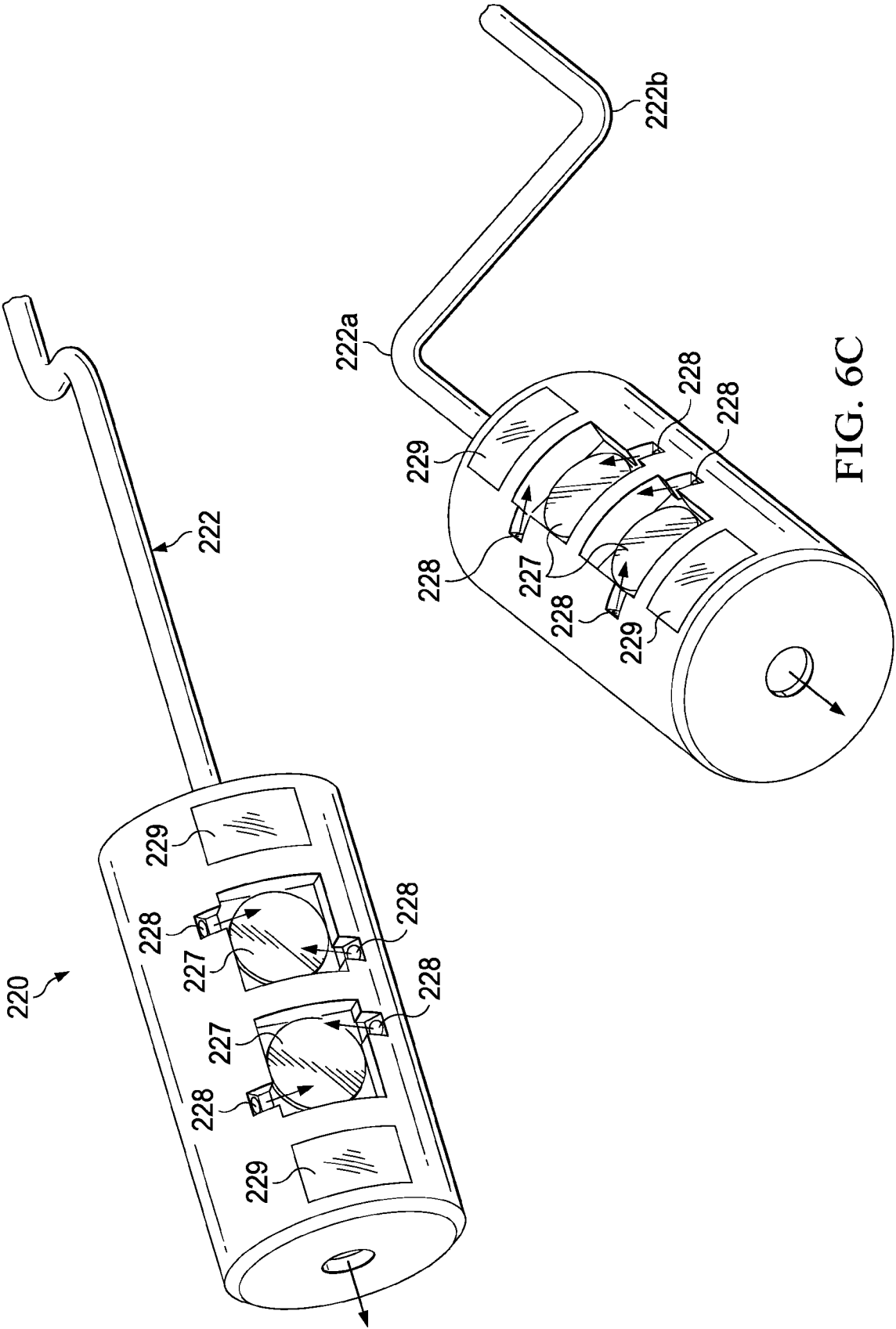


FIG. 6B



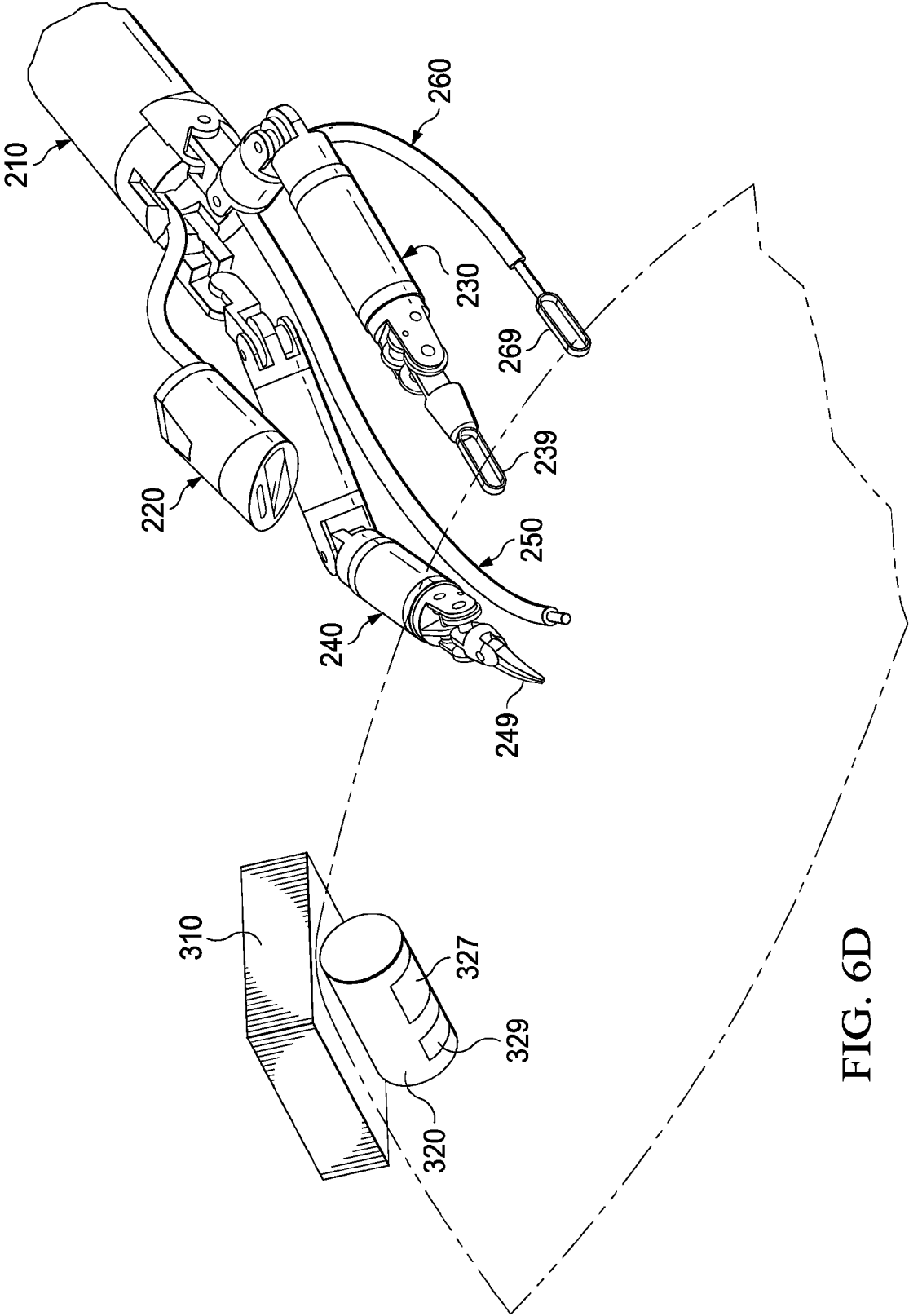


FIG. 6D

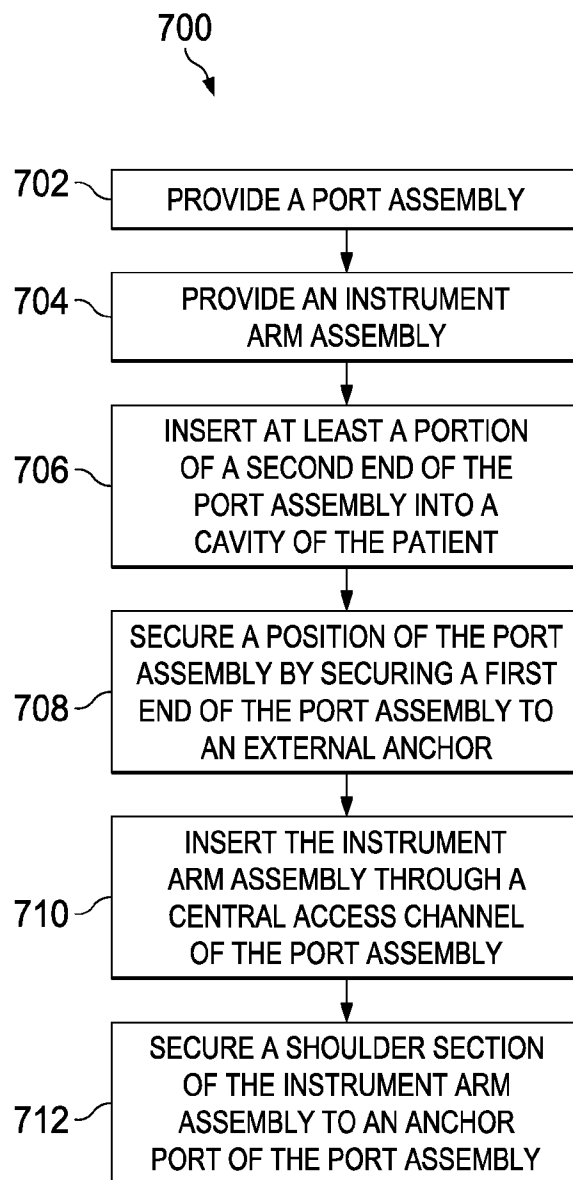
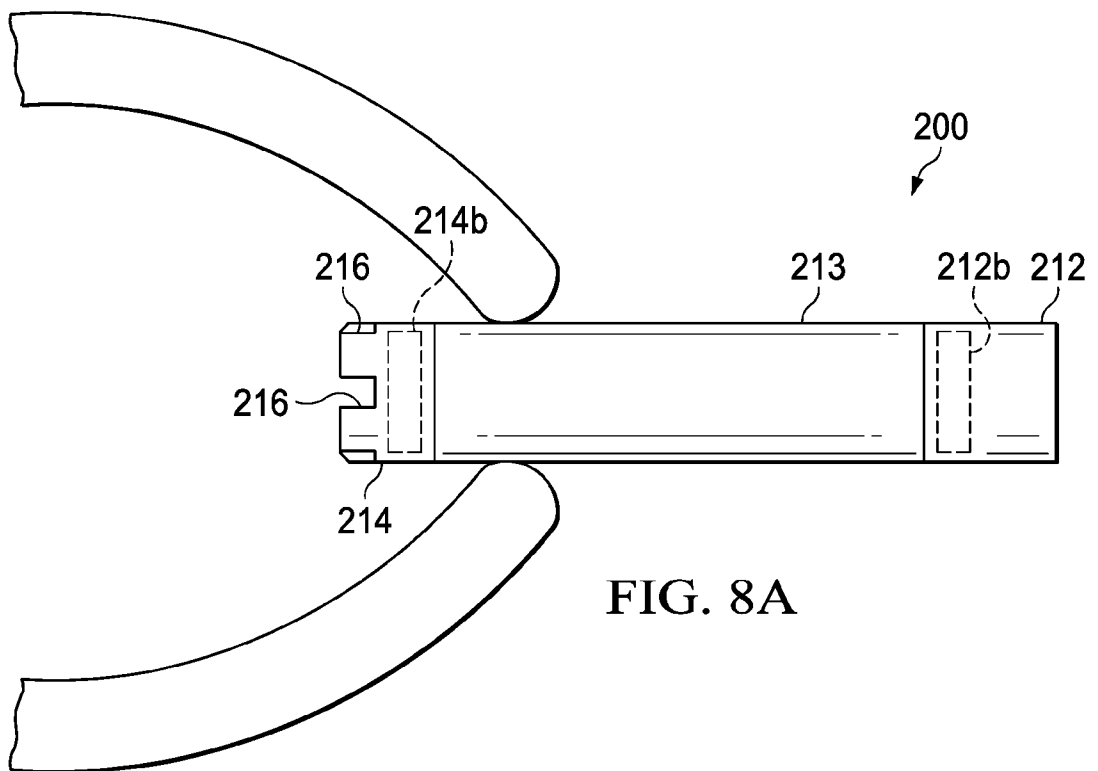


FIG. 7



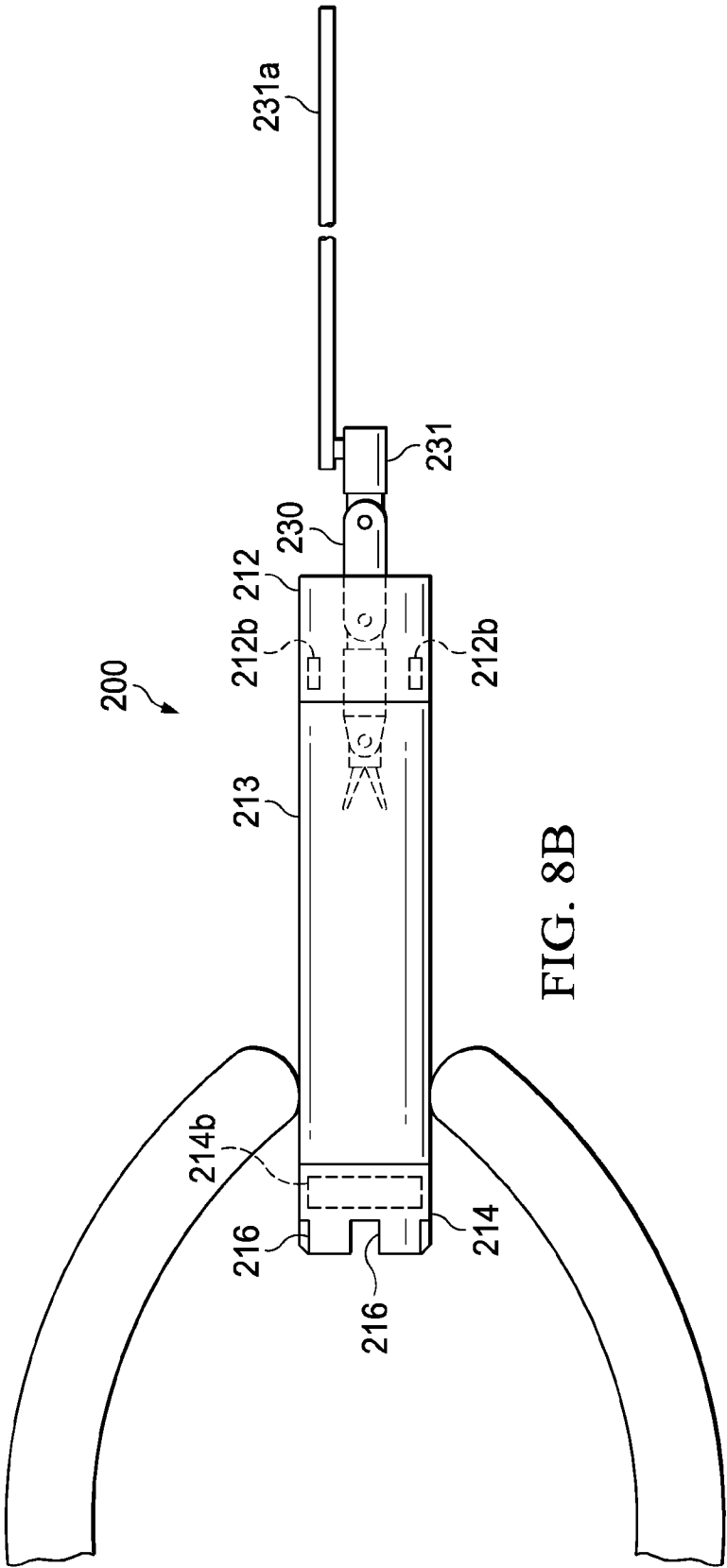
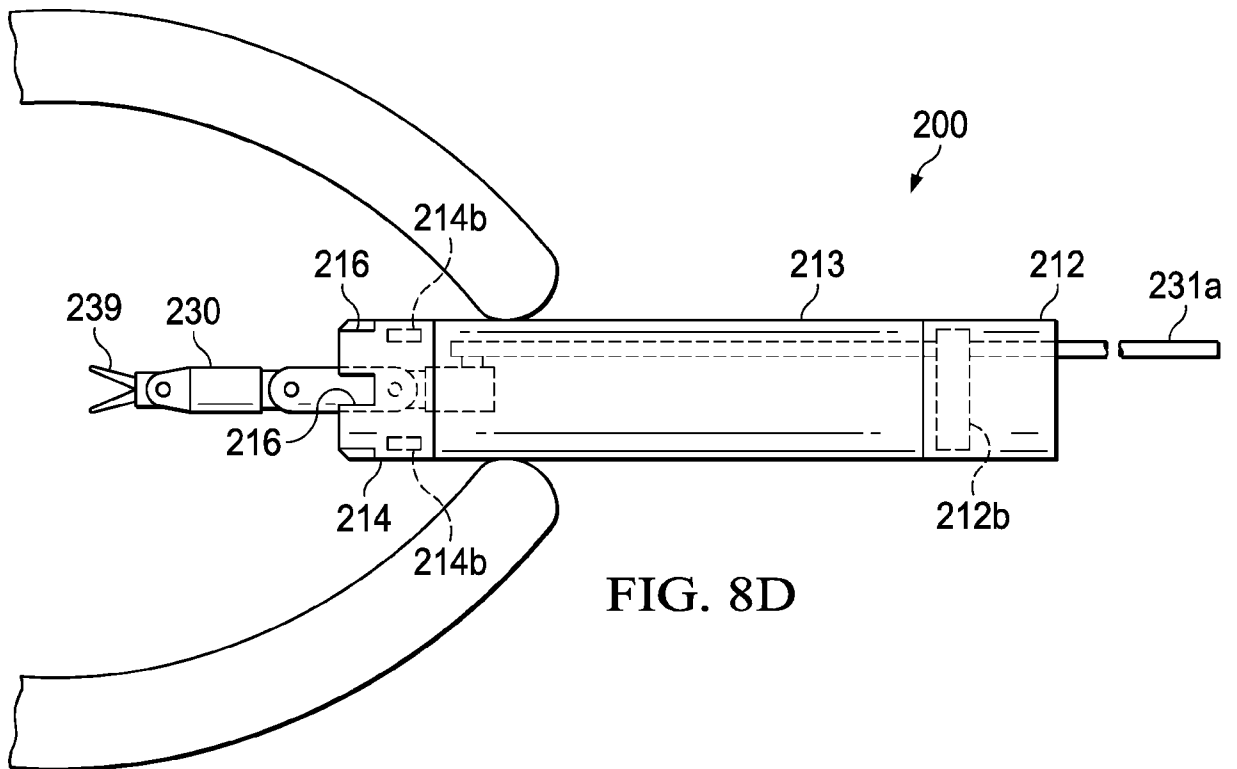
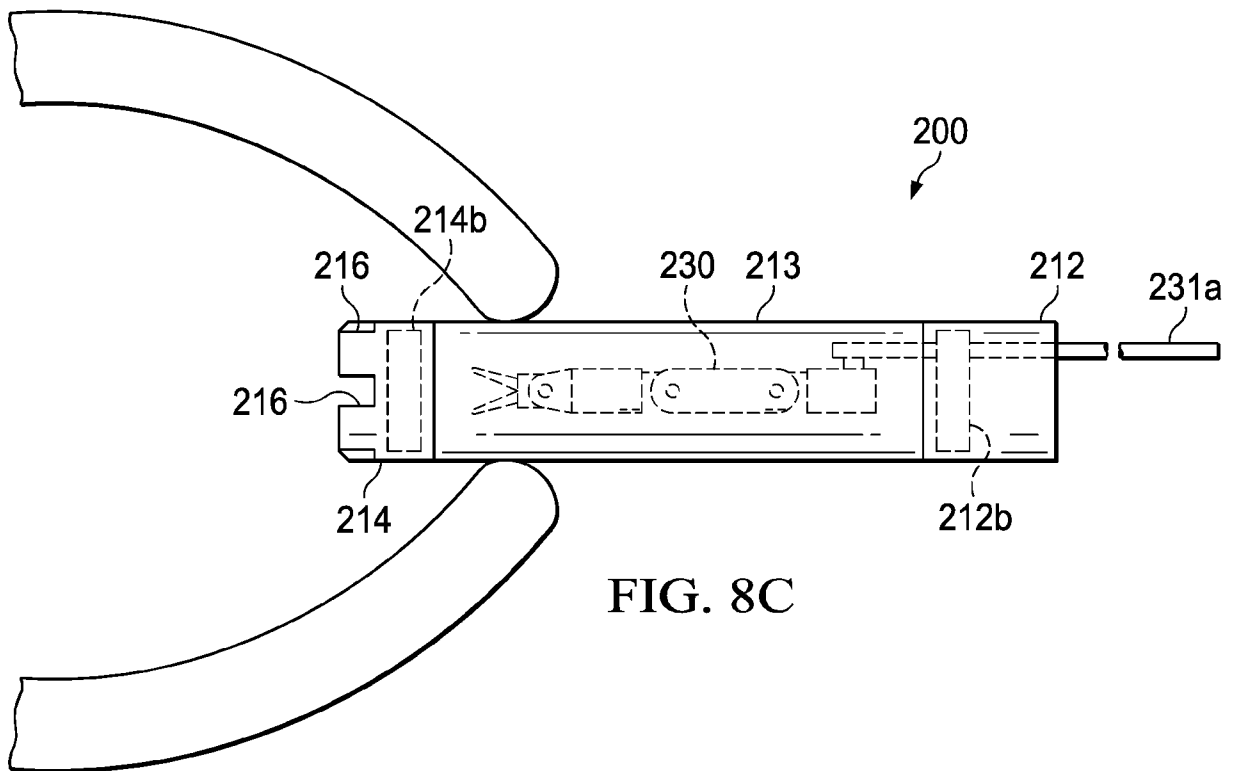
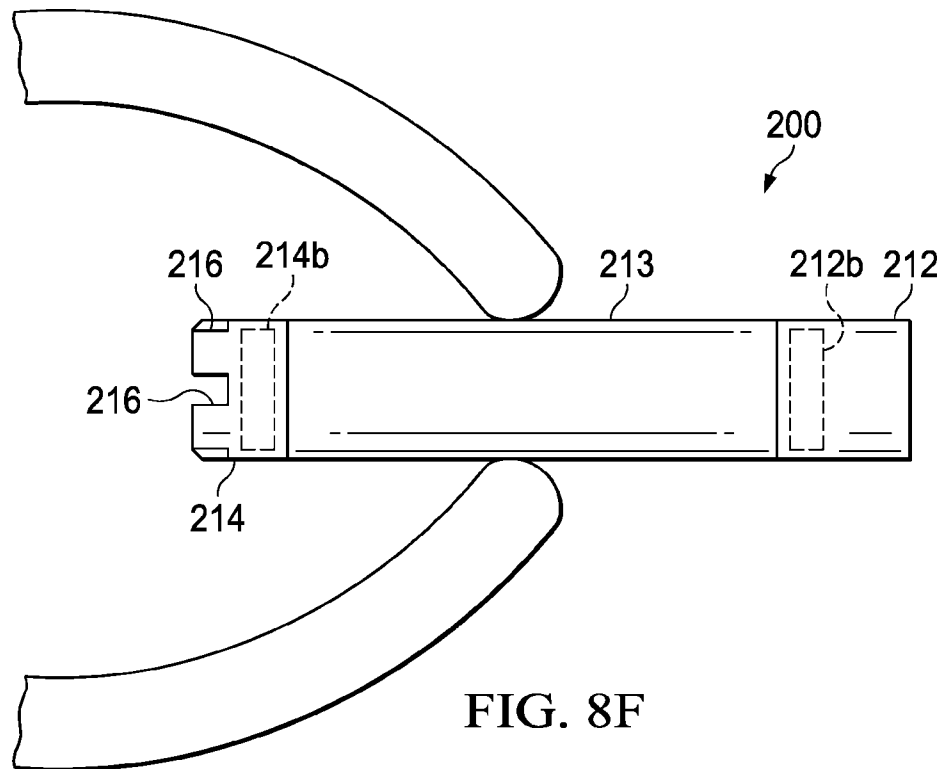
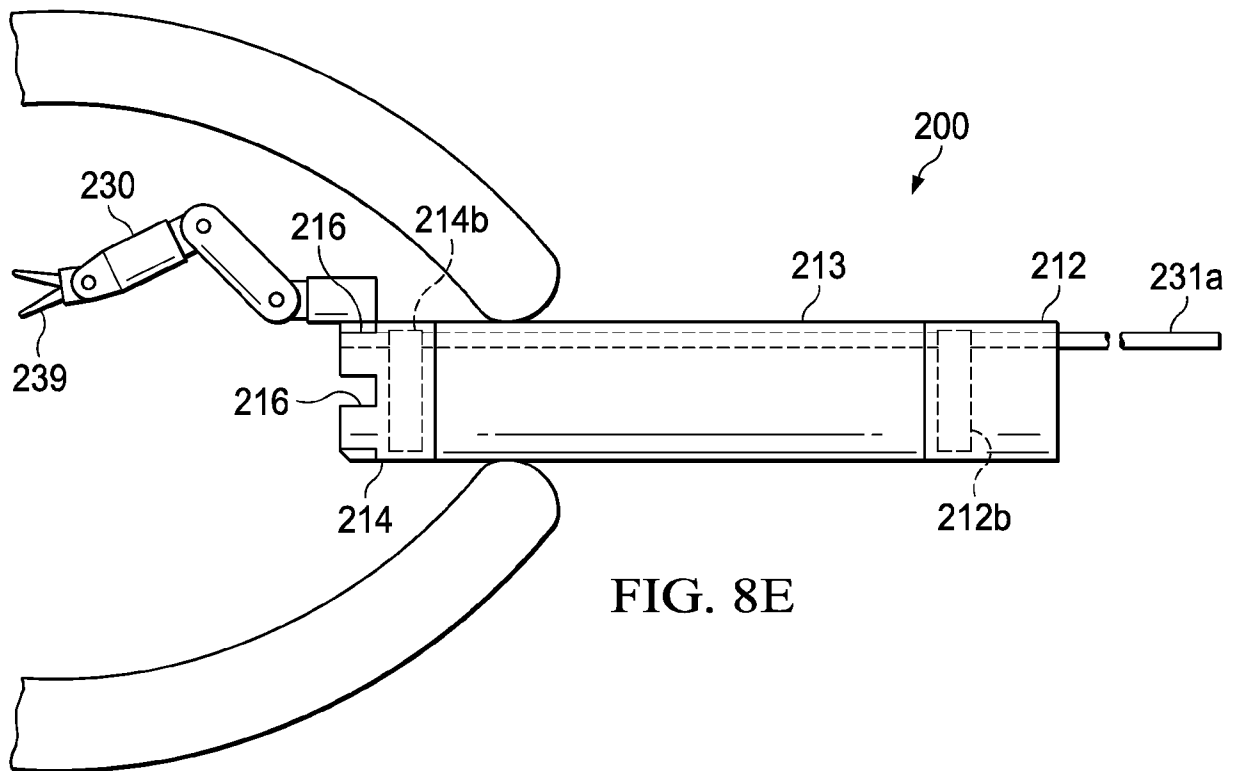


FIG. 8B





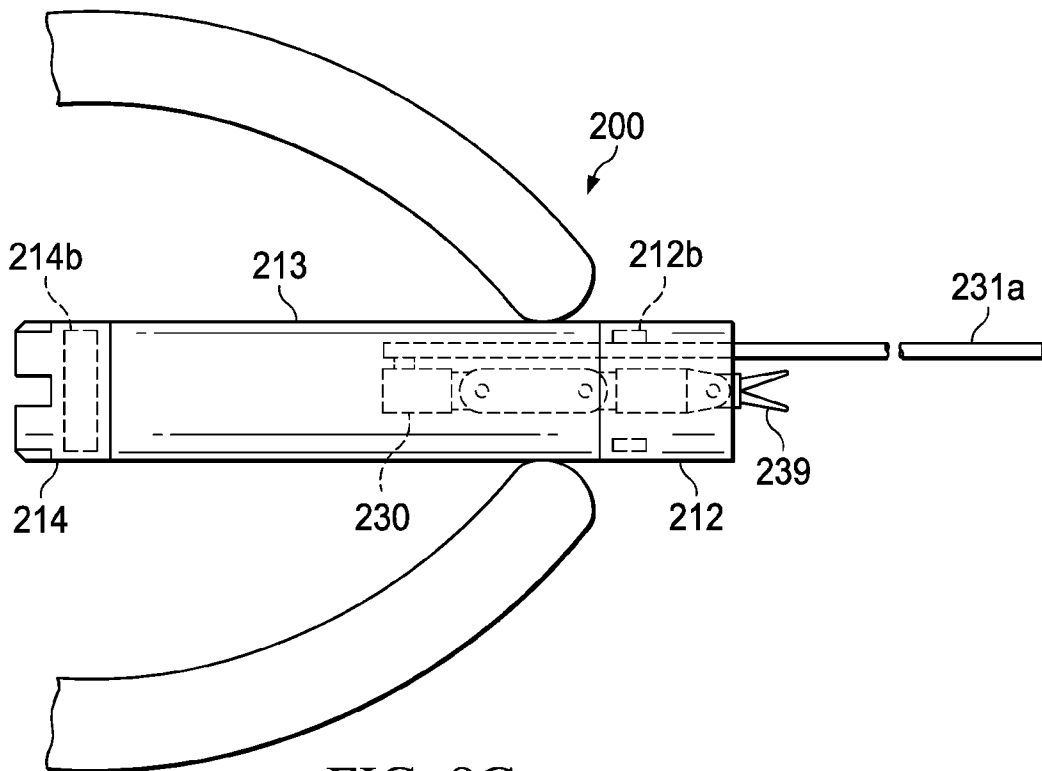


FIG. 8G

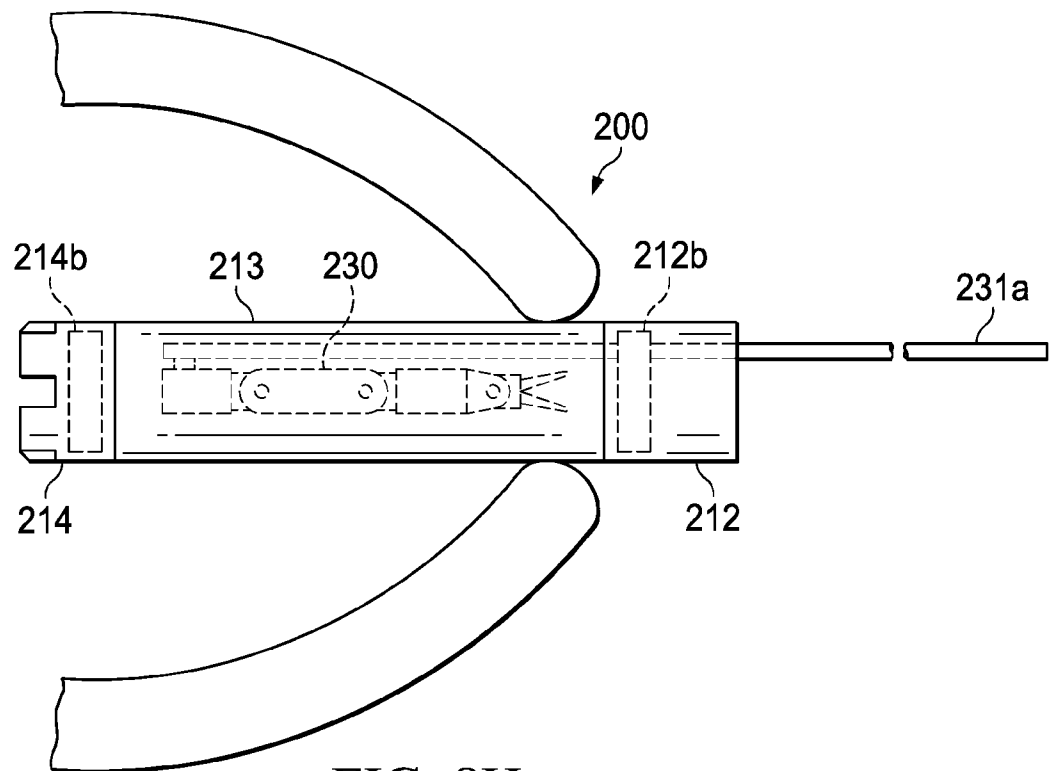


FIG. 8H

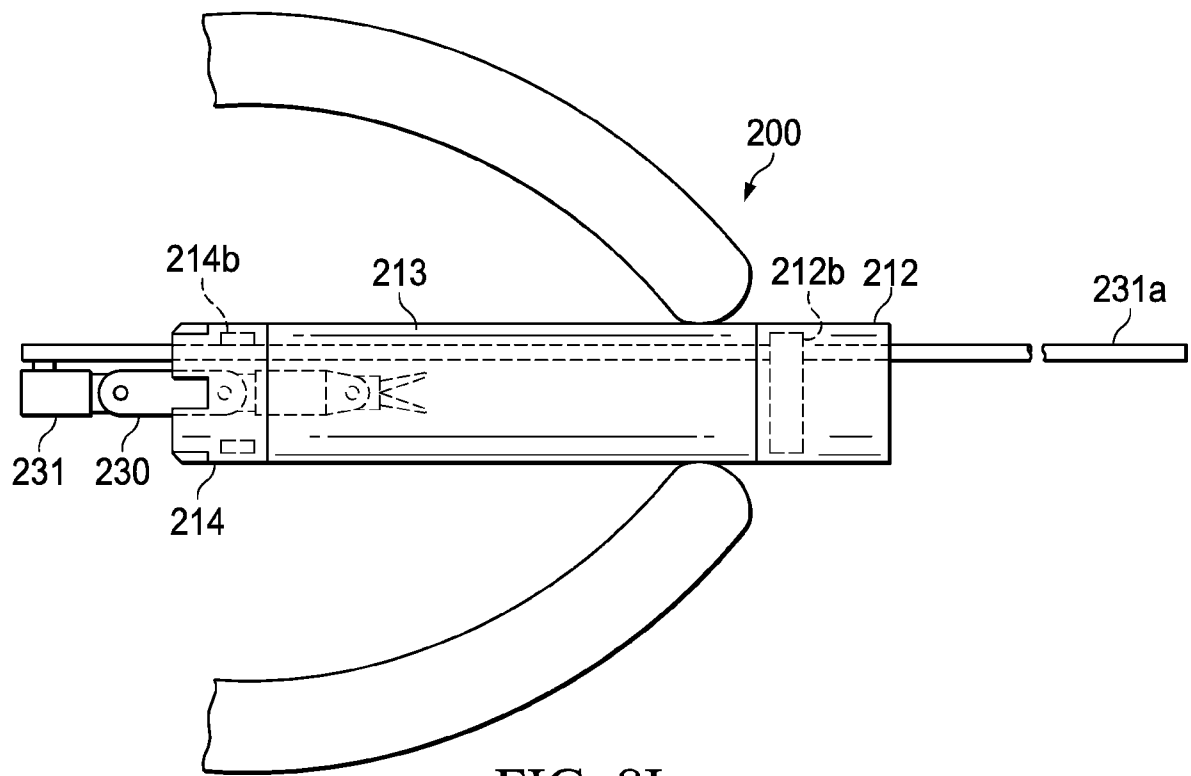


FIG. 8I

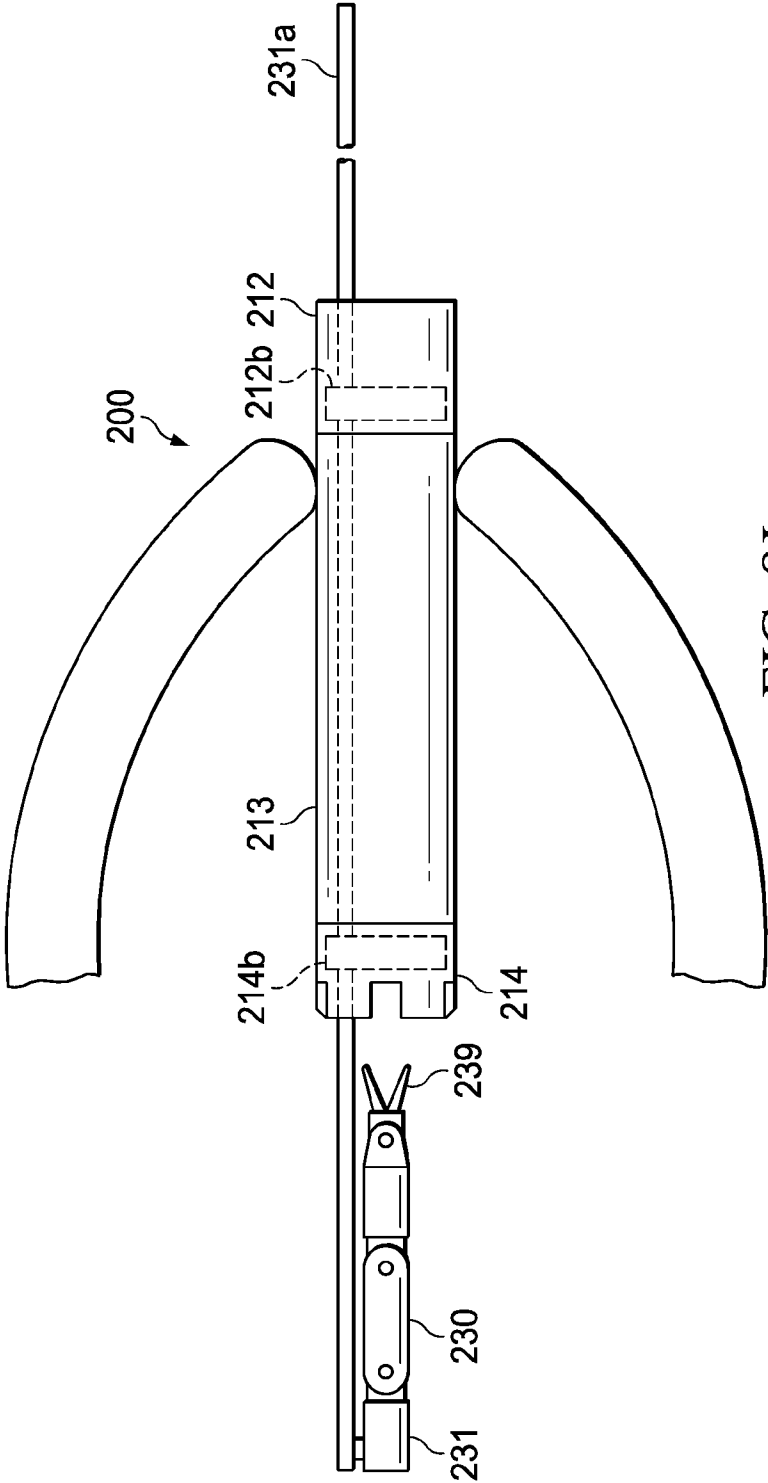


FIG. 8J

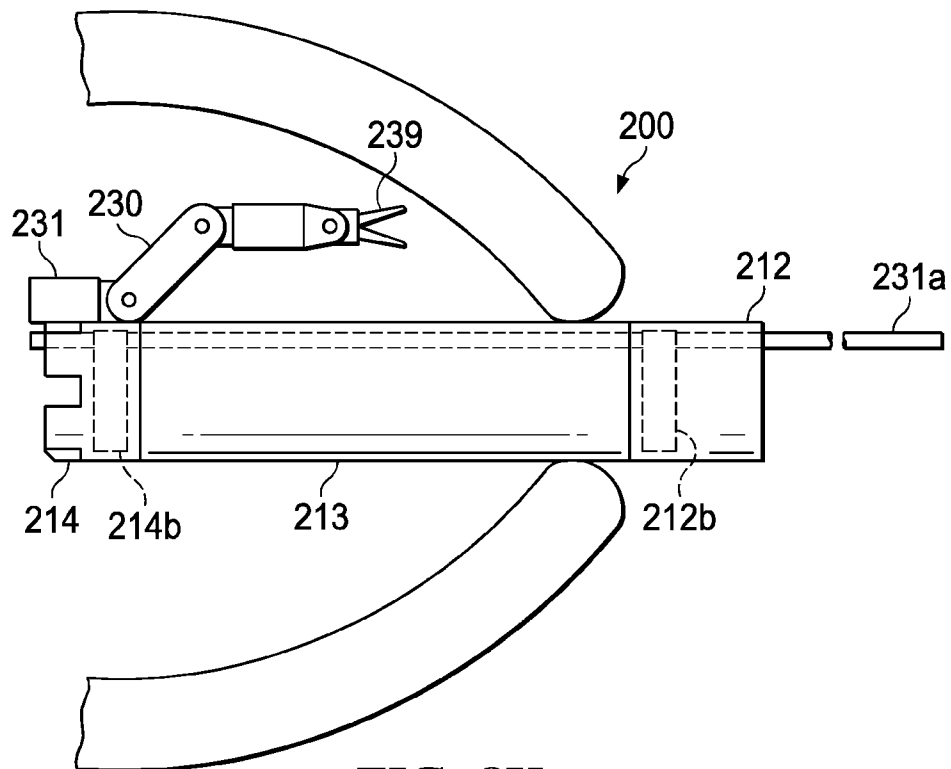


FIG. 8K

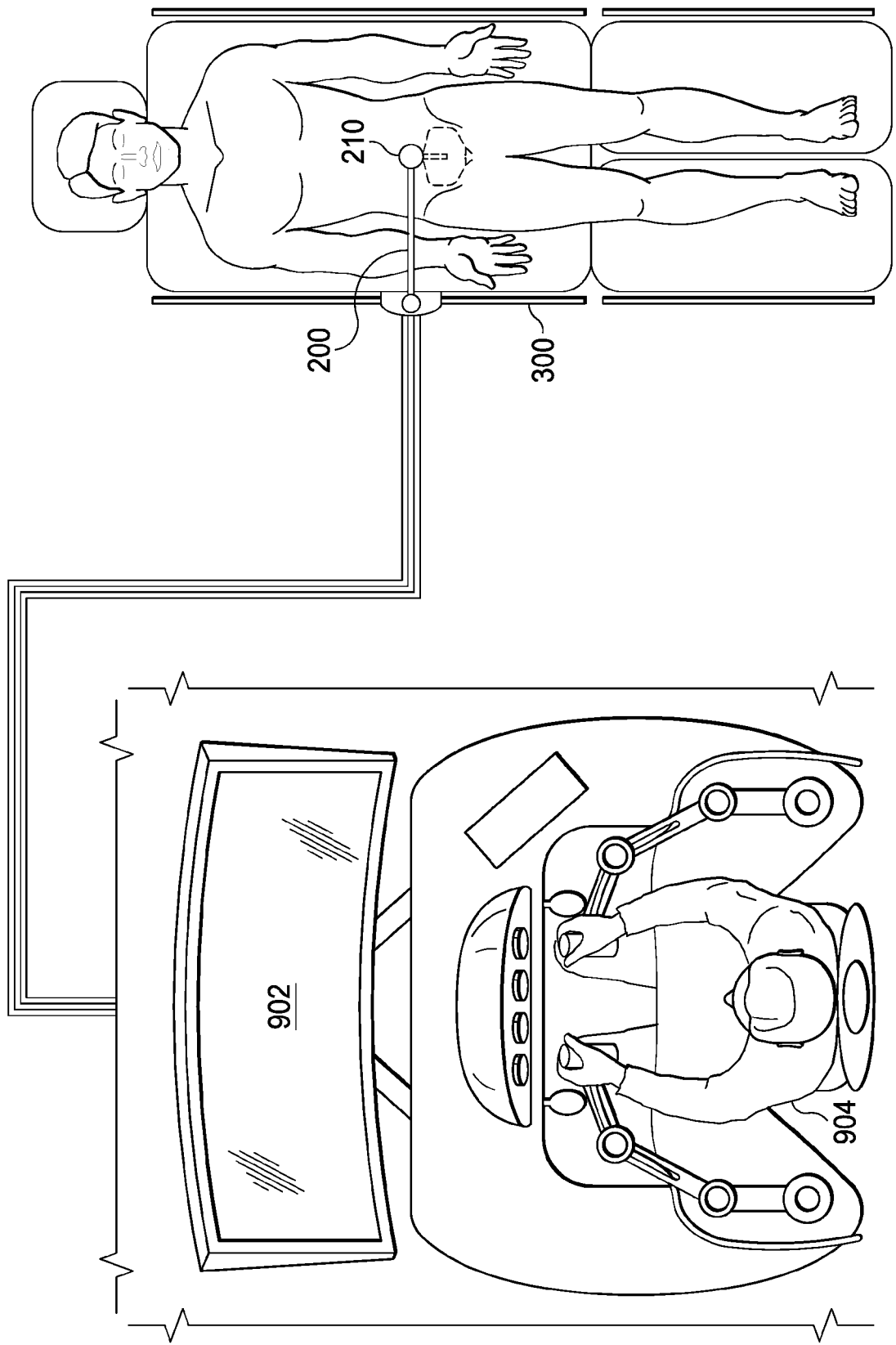


FIG. 9A

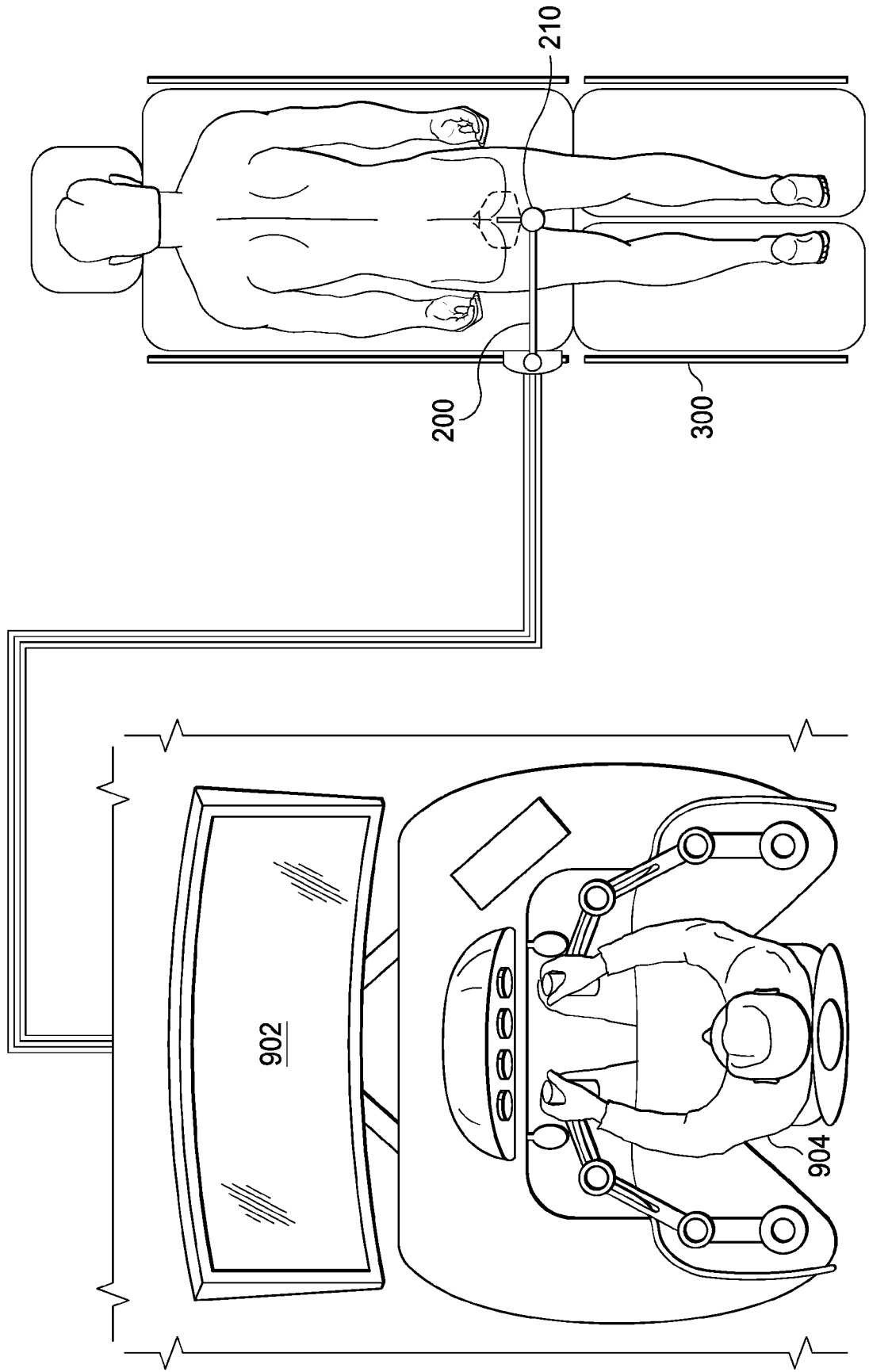


FIG. 9B

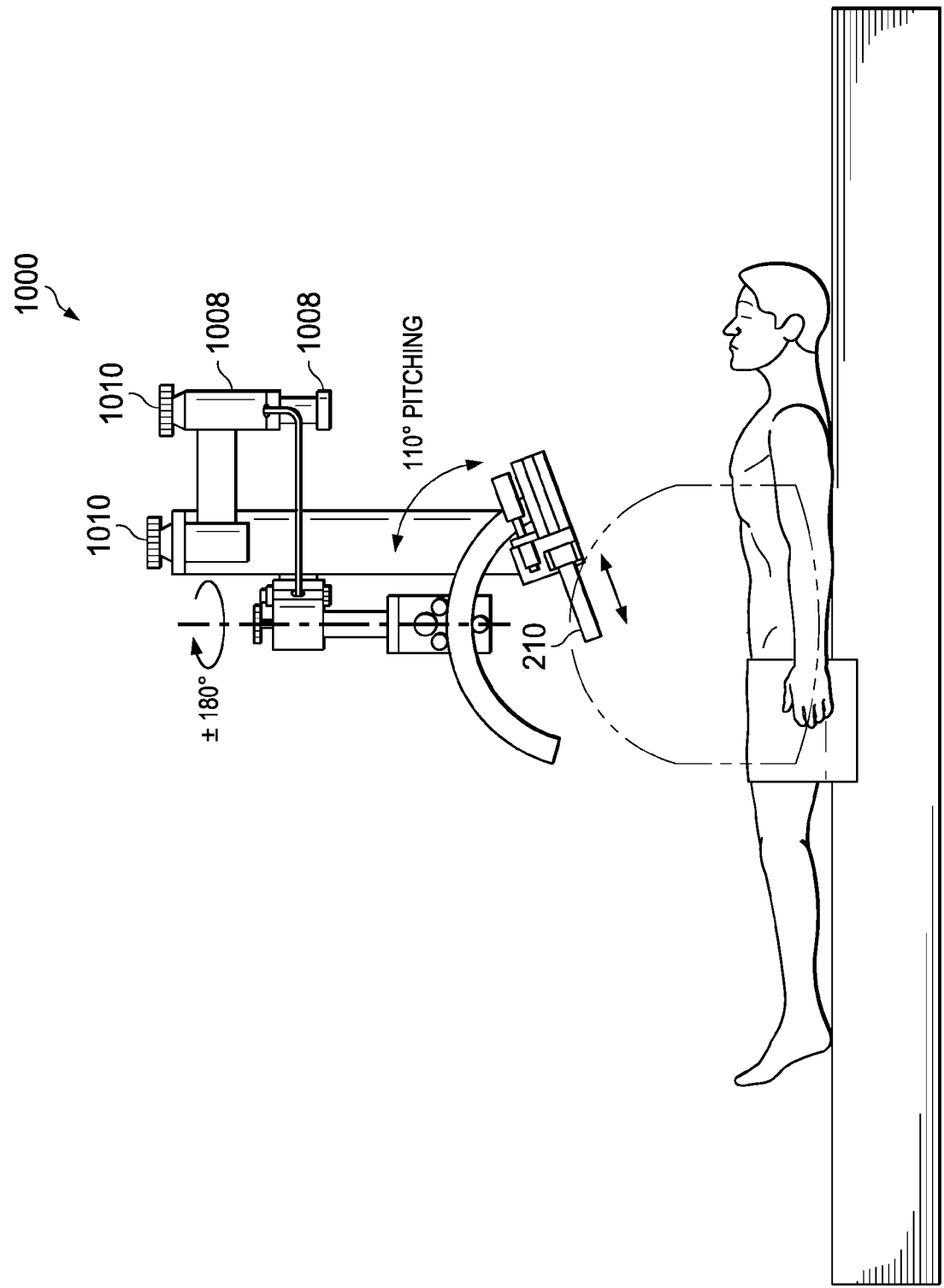


FIG. 10A

