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Naumann et al.

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(45) Date of Patent: Aug. 12, 2025

(54) **SYSTEMS AND METHODS FOR WIRELESS LOCALIZATION**

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(73) Assignee: **Elucent Medical, Inc.**, Eden Prairie, MN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **18/359,417**

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(65) **Prior Publication Data**

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Related U.S. Application Data

(60) Provisional application No. 63/424,977, filed on Nov. 14, 2022, provisional application No. 63/392,177, filed on Jul. 26, 2022.

(51) **Int. Cl.**
A61B 34/20 (2016.01)
A61B 90/00 (2016.01)

(52) **U.S. Cl.**
CPC ***A61B 34/20*** (2016.02); ***A61B 90/361*** (2016.02); *A61B 2034/2051* (2016.02)

(58) **Field of Classification Search**
CPC A61B 34/20; A61B 90/361; A61B 2034/2051; A61B 2017/07271;
(Continued)

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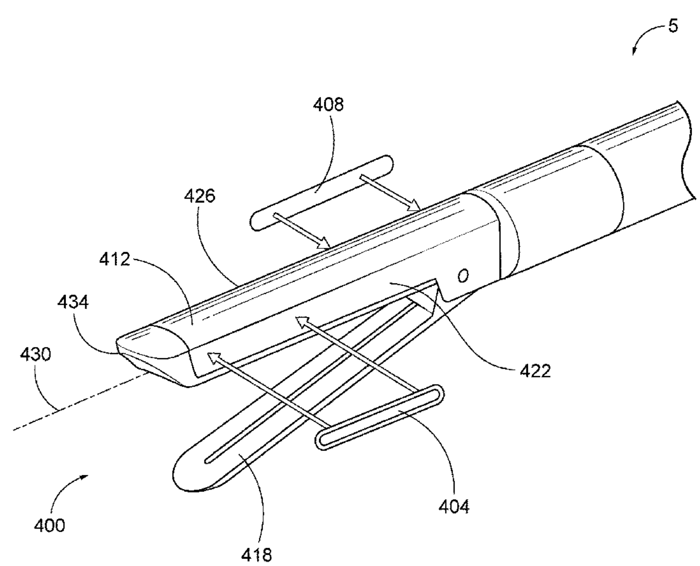
Primary Examiner — Pascal M Bui Pho
Assistant Examiner — Michael Yiming Fang
(74) *Attorney, Agent, or Firm* — CASIMIR JONES, S.C.; Brian F. Bradley

(57) **ABSTRACT**

A wireless localization system including an exciter coil, a sensor coil, a surgical tool including a head defining a longitudinal axis, and a first wireless tag coupled to the head at a first position along the longitudinal axis. The first wireless tag is configured to generate a first signal in response to a magnetic field generated by the exciter coil. The wireless localization system further includes a second wireless tag coupled to the head at a second position along the longitudinal axis, the second position is spaced from the first position. The second wireless tag is configured to generate a second signal in response to the magnetic field generated by the excited coil. The wireless localization system further includes a processor that determines the location of the head based on the first signal and the second signal detected by the sensor coil.

20 Claims, 27 Drawing Sheets



(58) **Field of Classification Search**
CPC . A61B 34/25; A61B 90/98; A61B 2017/0053; A61B 2017/00973; A61B 2090/3983; A61B 17/07207; A61B 90/39; A61B 2090/3937; A61B 17/068; A61B 17/072; A61B 17/083; A61B 17/00; A61B 2017/00
See application file for complete search history.

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2024/0041488	A1 *	2/2024	Shelton, IV	A61B 17/2841
2024/0057889	A1 *	2/2024	Ramirez	A61B 5/061

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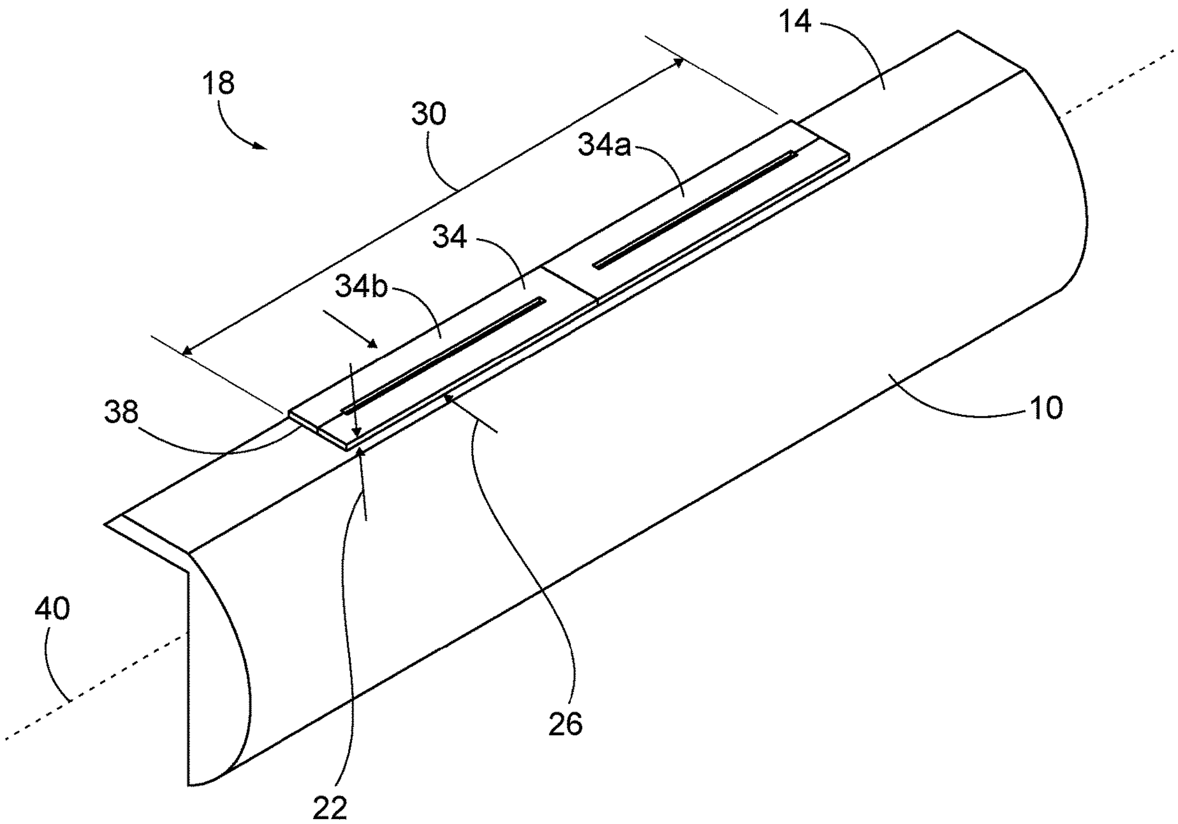


FIG. 1

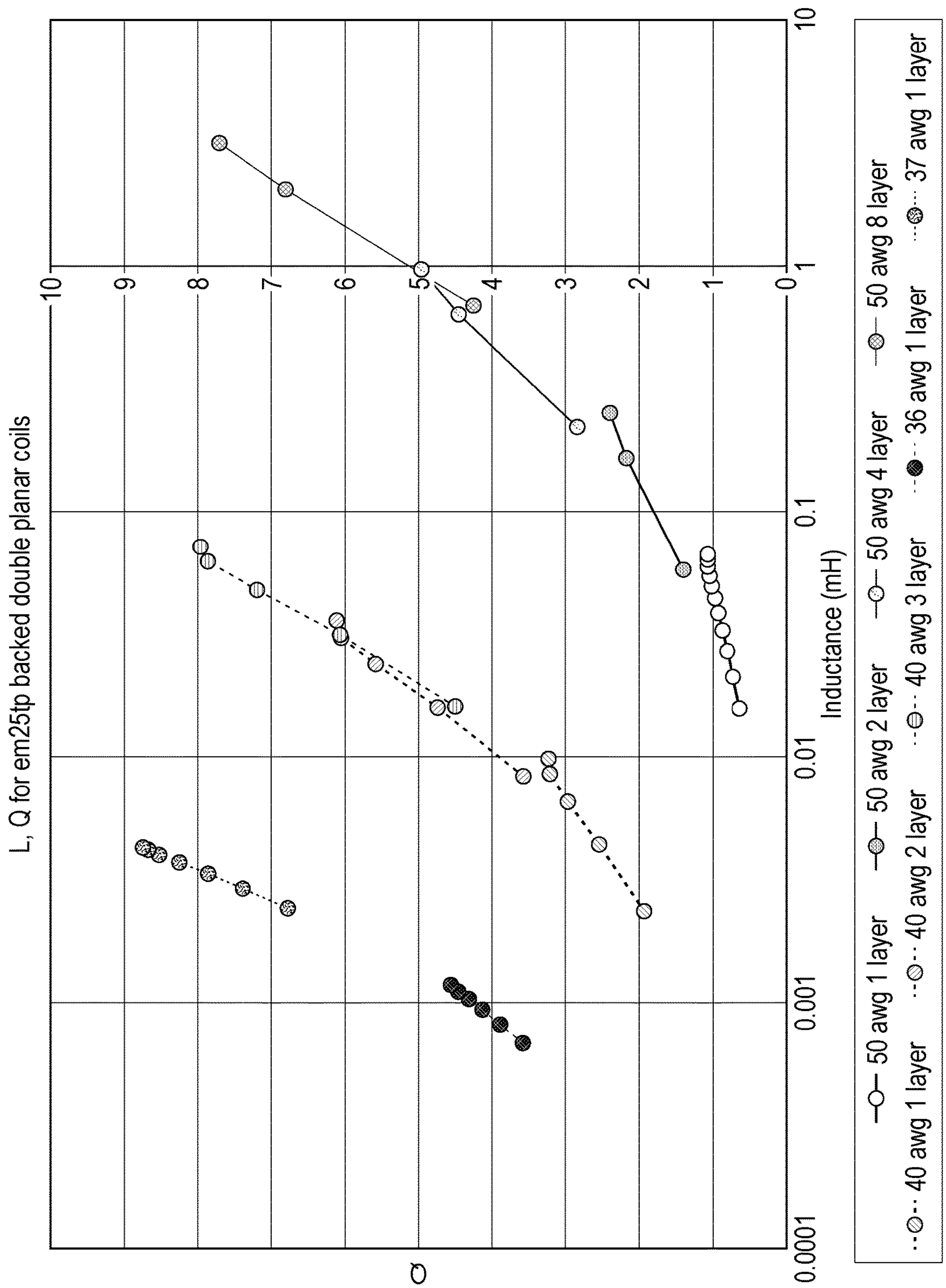

L, Q for em25tp backed double planar coils
Q
Inductance (mH)
0.0001
0.001
0.01
0.1
1
10
0
1
2
3
4
5
6
7
8
9
10
50 awg 1 layer
50 awg 2 layer
50 awg 4 layer
50 awg 8 layer
40 awg 1 layer
40 awg 2 layer
40 awg 3 layer
36 awg 1 layer
37 awg 1 layer

FIG. 2

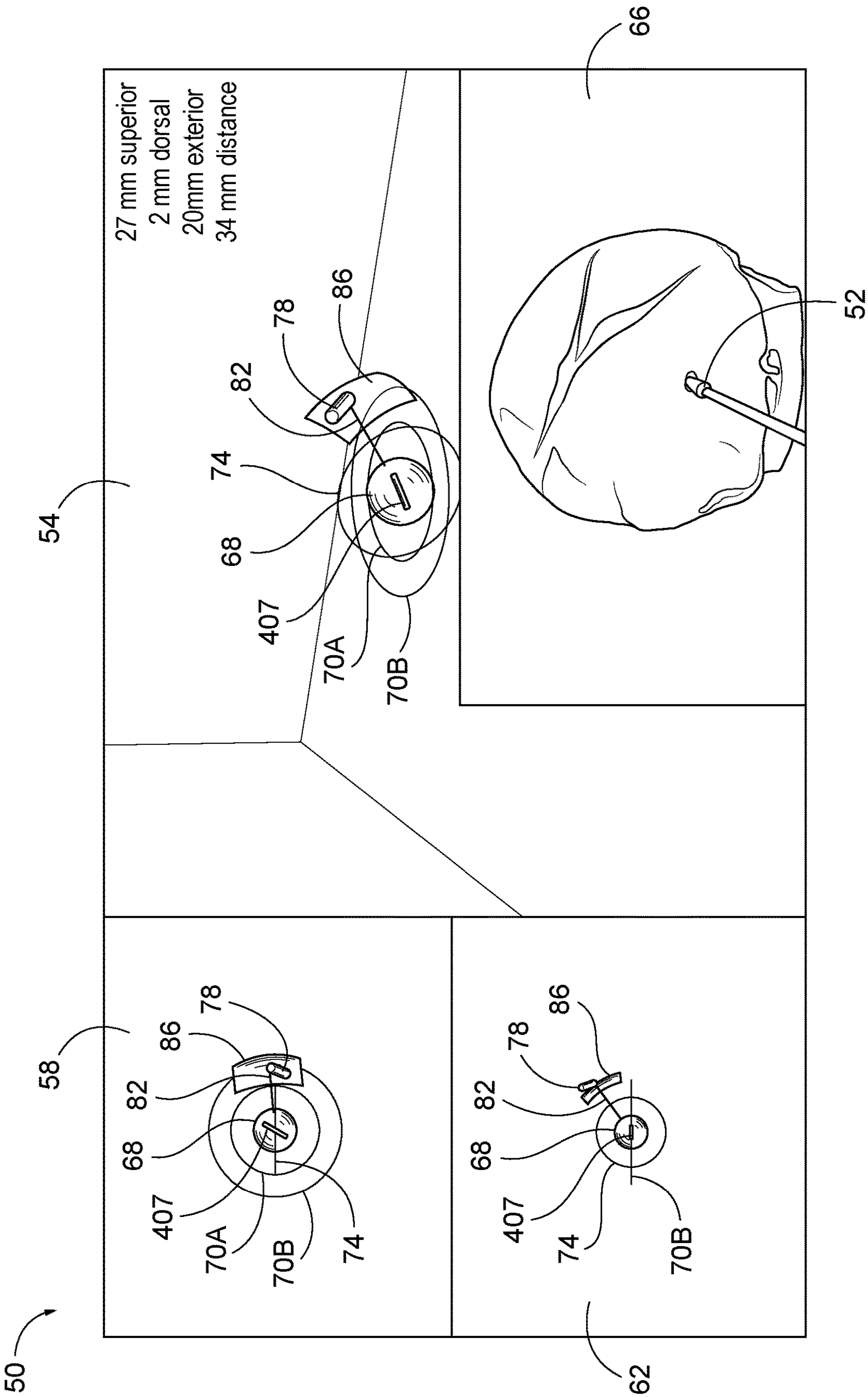

27 mm superior
2 mm dorsal
20mm exterior
34 mm distance
50
52
54
58
62
66
68
70A
70B
74
78
82
86
407

FIG. 3

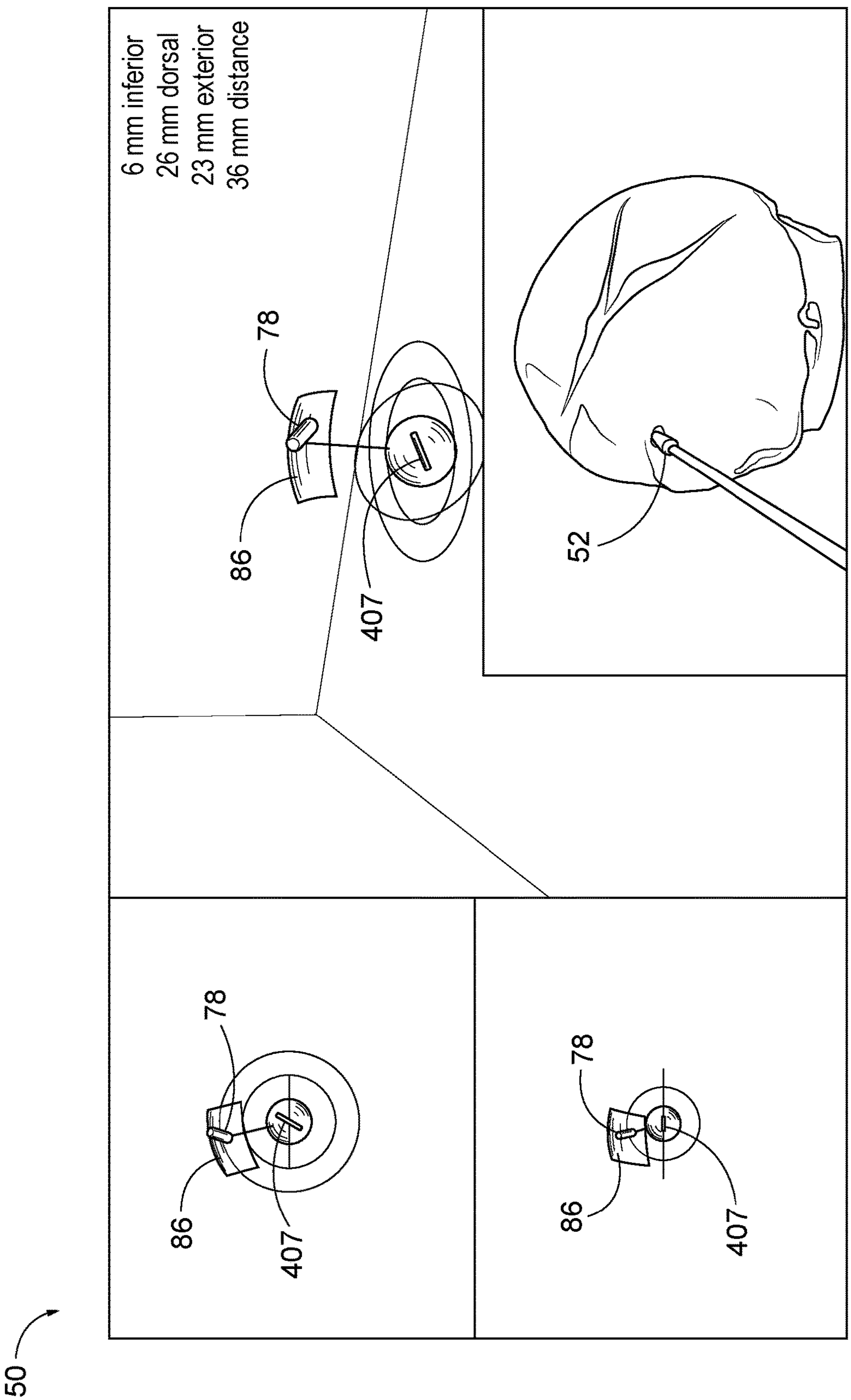

6 mm inferior
26 mm dorsal
23 mm exterior
36 mm distance
78
86
407
52
78
86
407
78
86
407
50

FIG. 4A

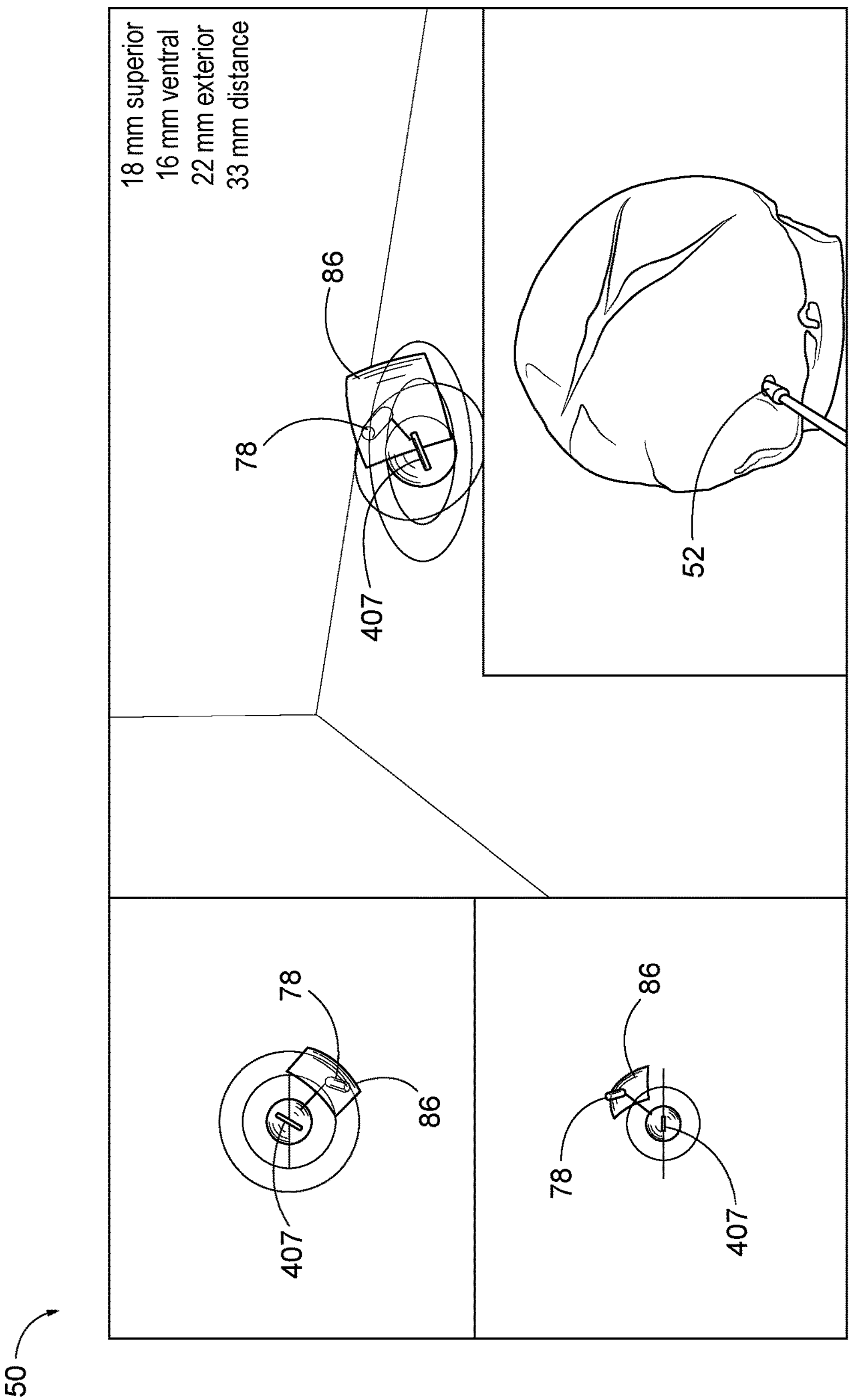

18 mm superior
16 mm ventral
22 mm exterior
33 mm distance
86
78
407
52
78
86
407
86
78
407
50

FIG. 4B

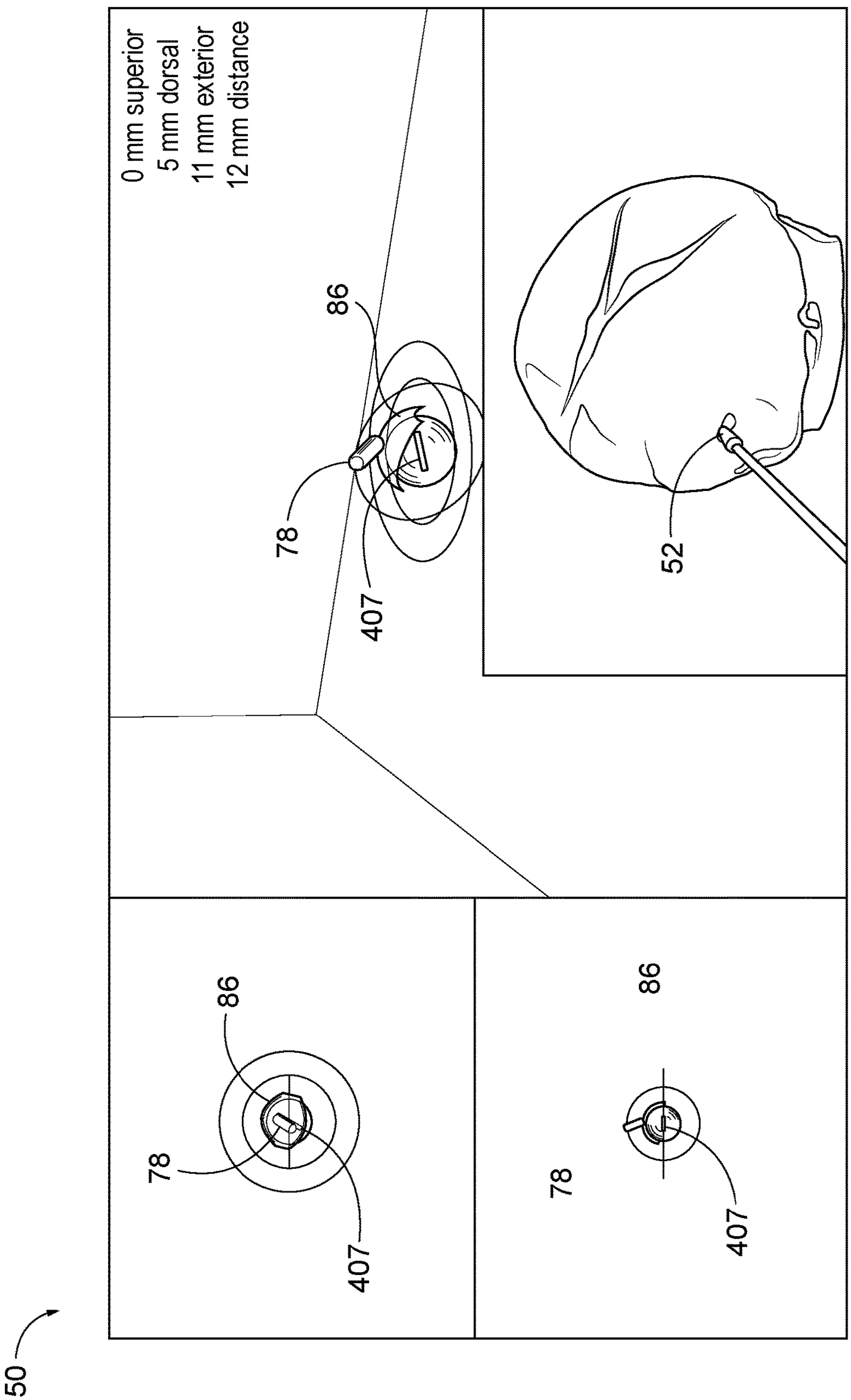

0 mm superior
5 mm dorsal
11 mm exterior
12 mm distance
86
78
407
52
86
78
407
86
78
407
50

FIG. 4C

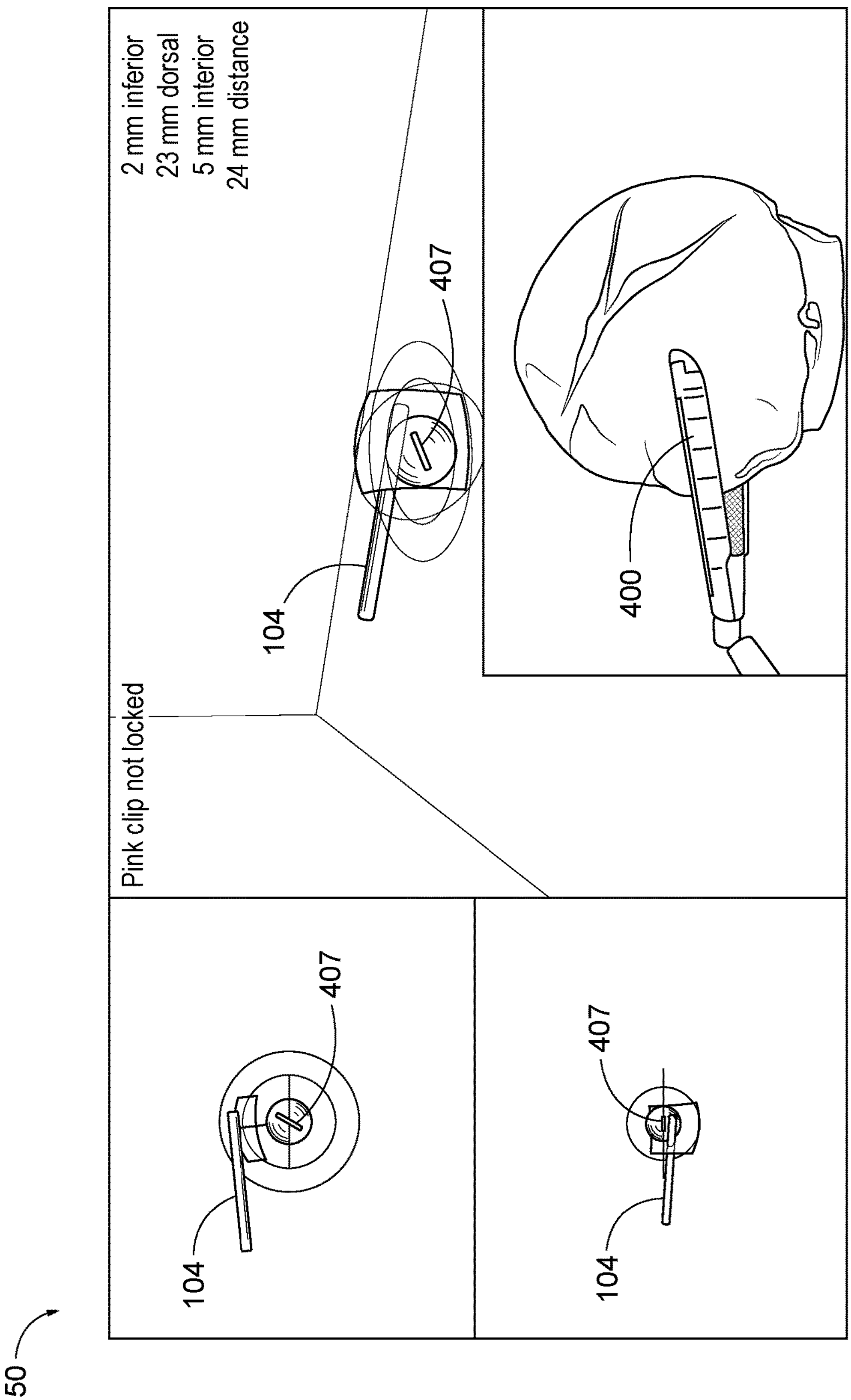

2 mm inferior
23 mm dorsal
5 mm interior
24 mm distance
Pink clip not locked
407
104
400
407
104
407
104
50

FIG. 5A

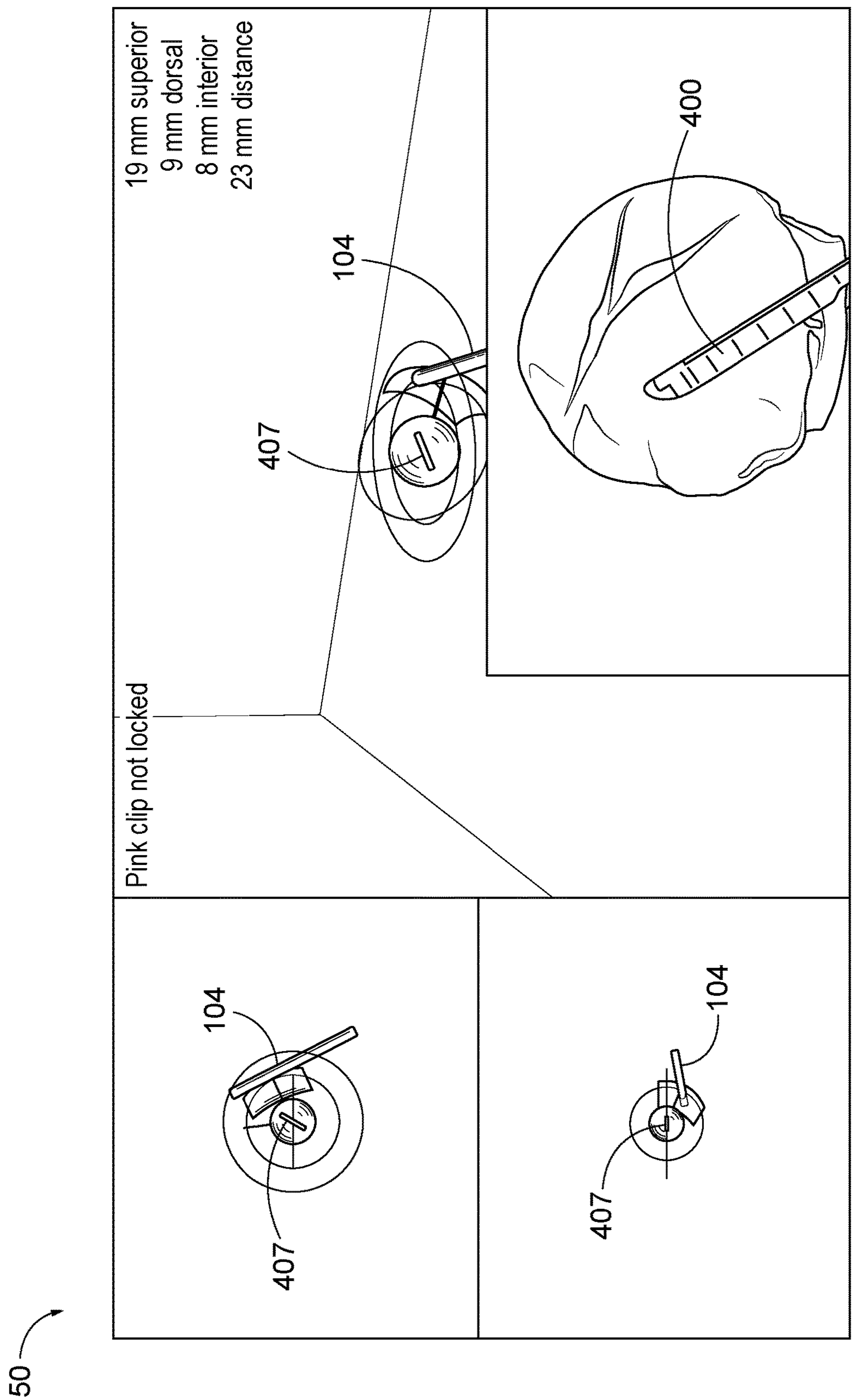

19 mm superior
9 mm dorsal
8 mm interior
23 mm distance
104
407
400
Pink clip not locked
104
407
104
407
50

FIG. 5B

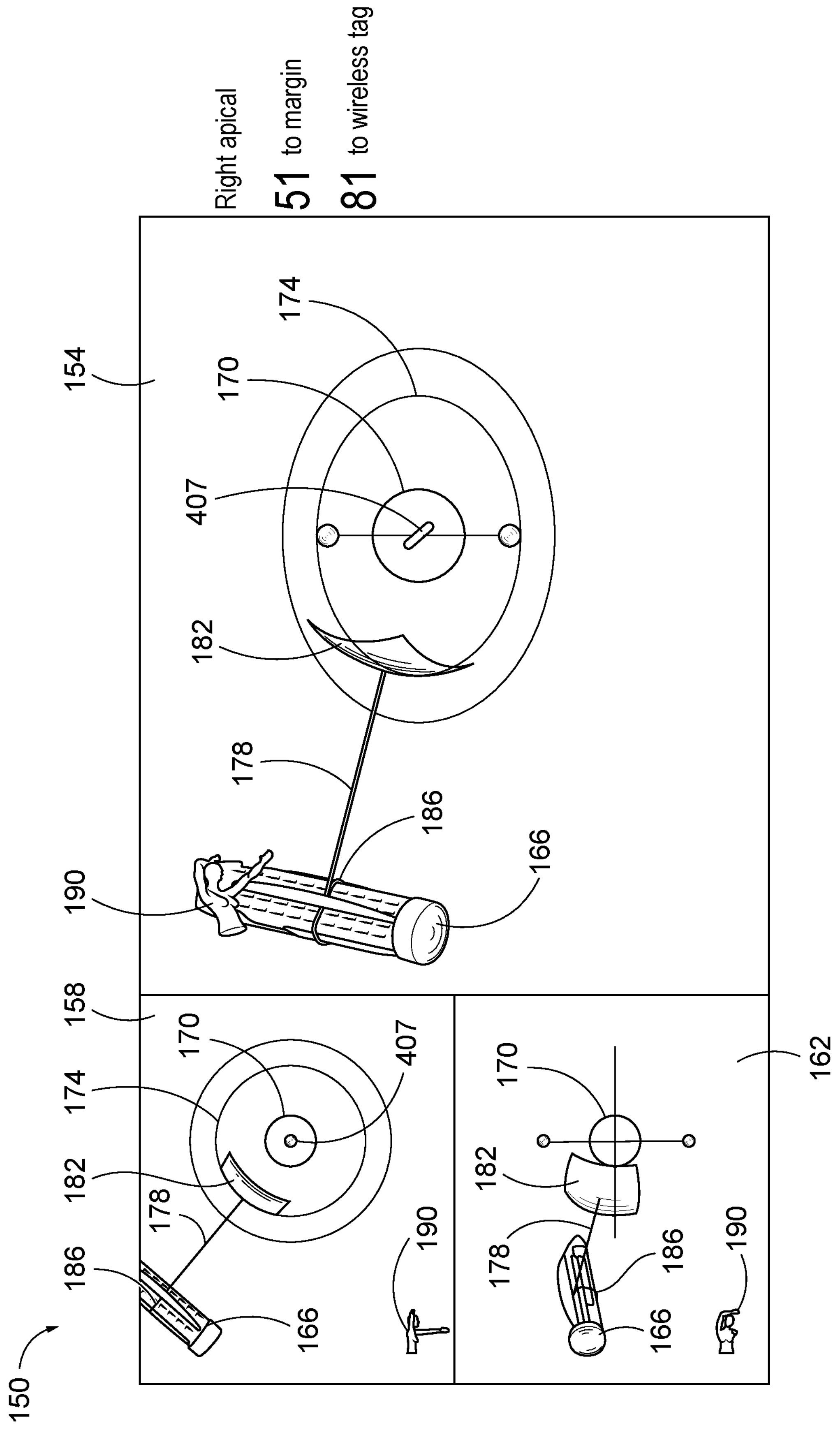

Right apical
51 to margin
81 to wireless tag
150
154
158
162
166
170
174
178
182
186
190
407

FIG. 6

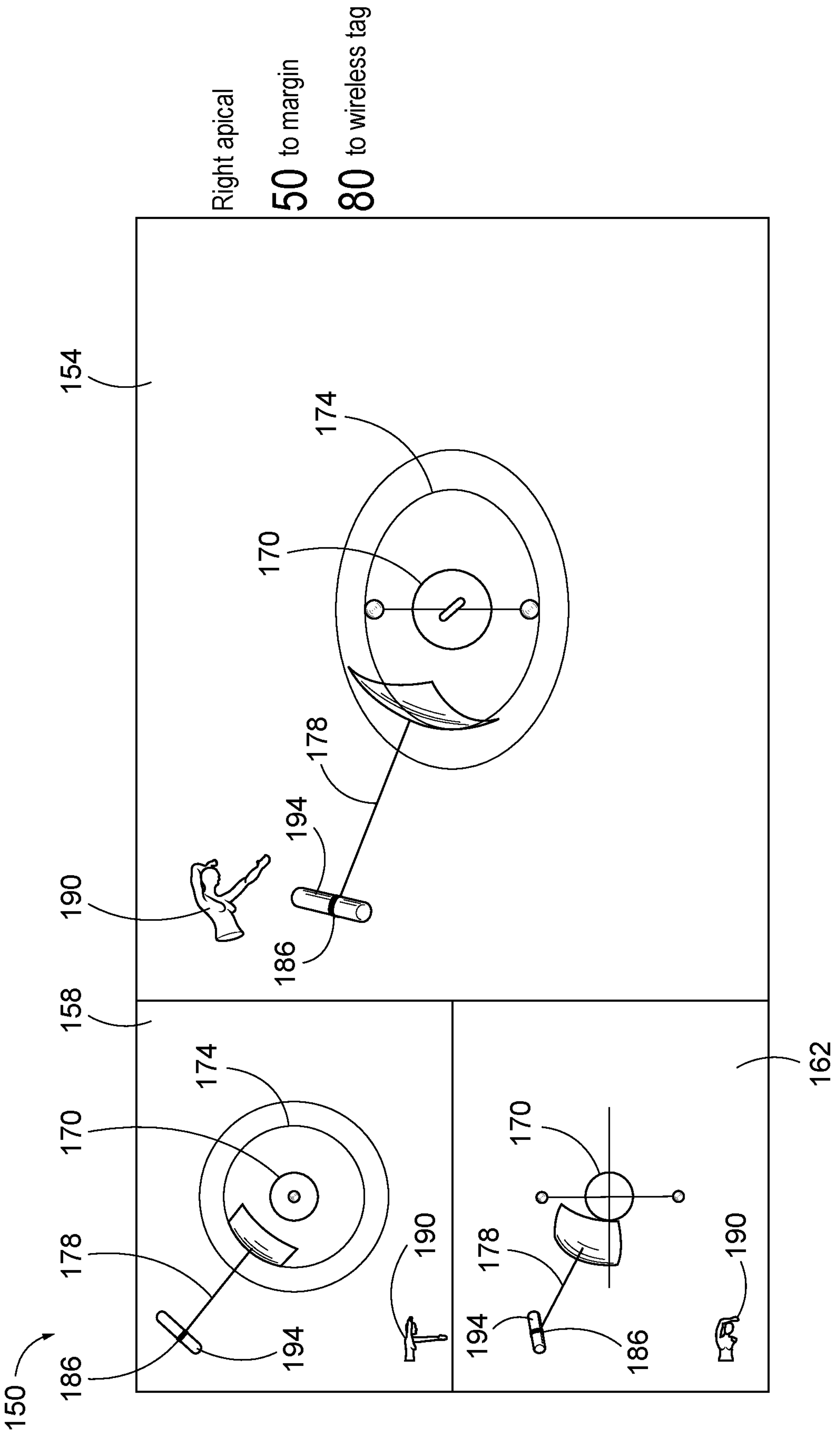

Right apical
50 to margin
80 to wireless tag
154
174
170
178
194
190
186
158
174
170
178
190
186
194
150
162
170
178
190
194
186

FIG. 7

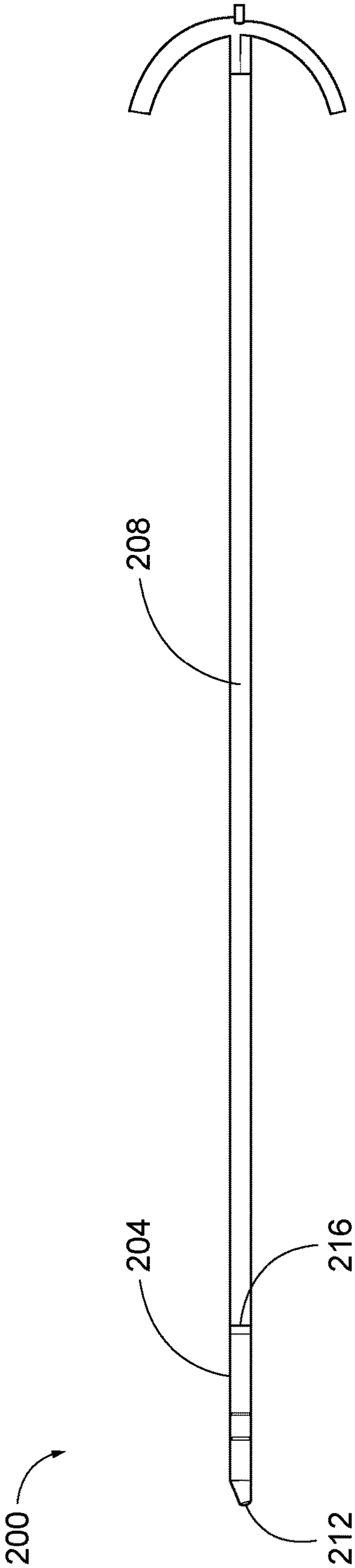


FIG. 8

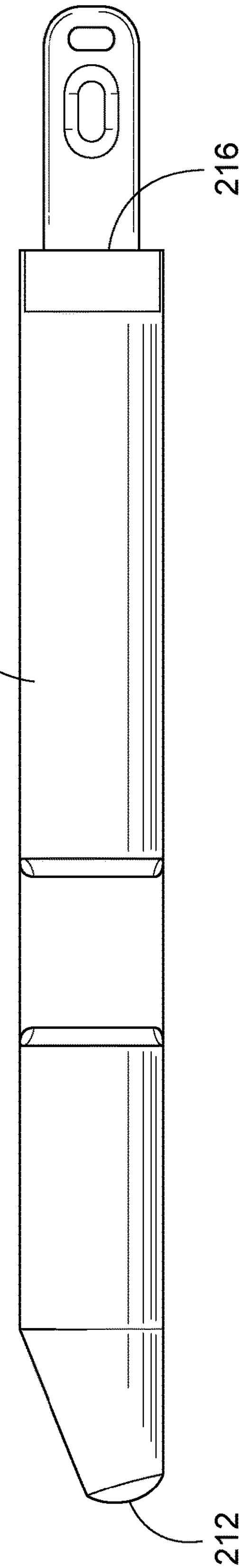


FIG. 9

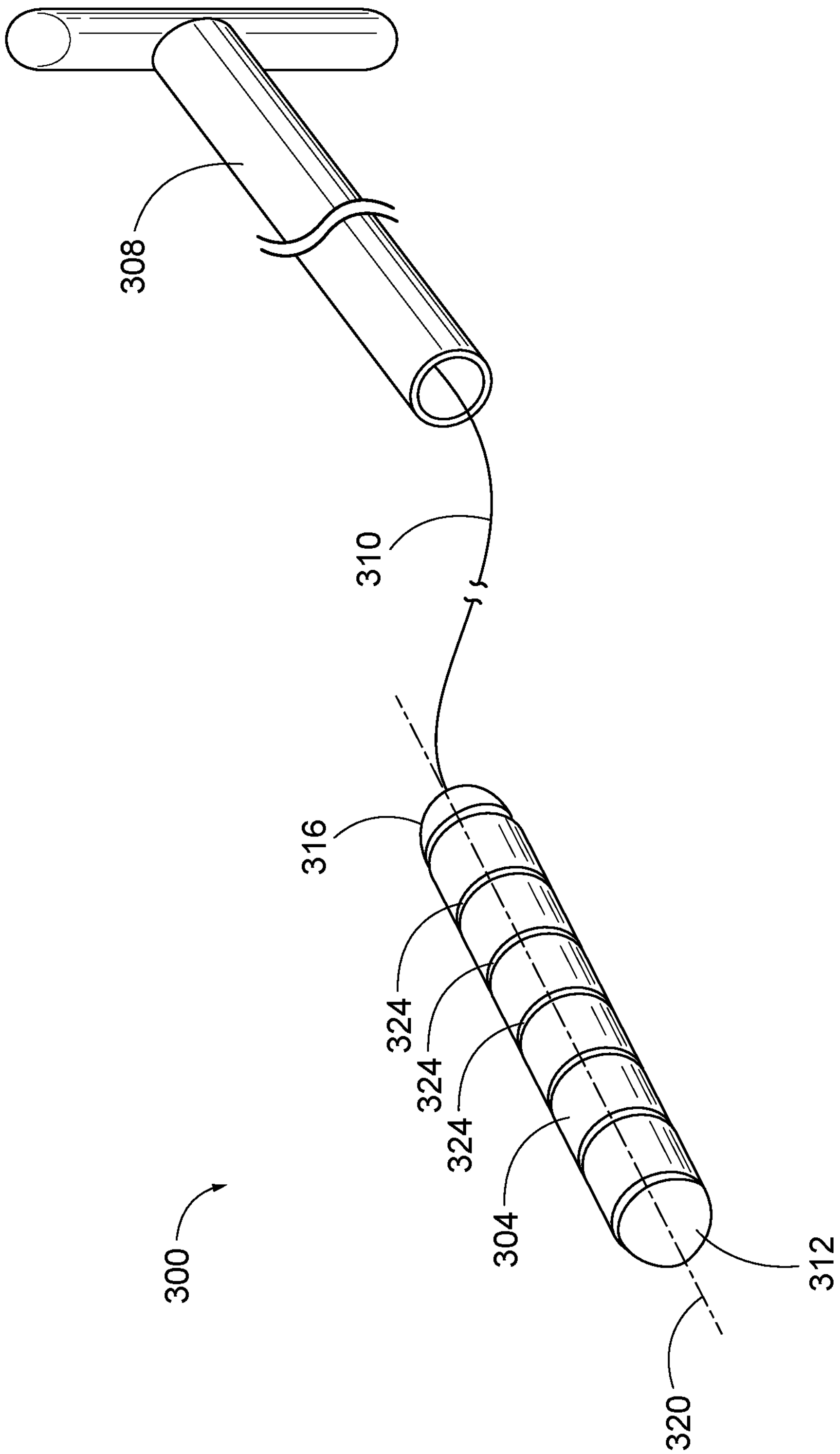


FIG. 10

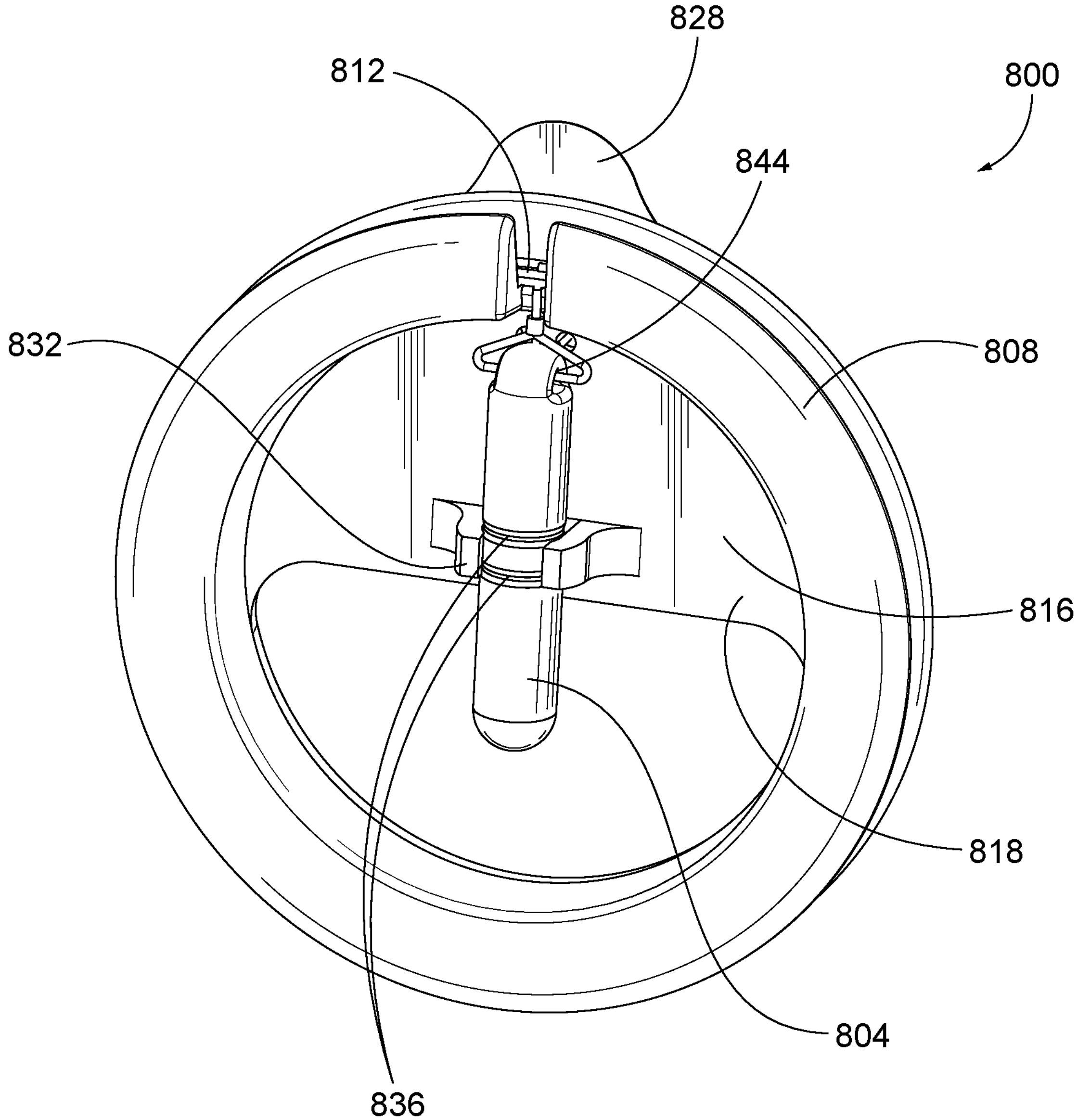


FIG. 11

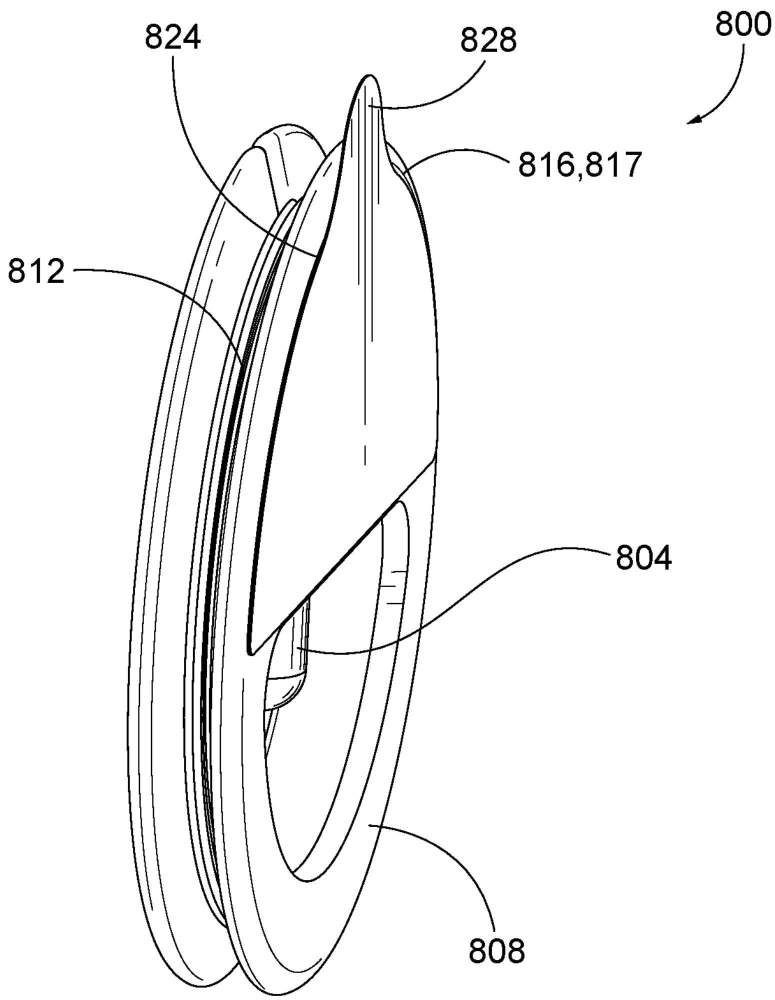


FIG. 12

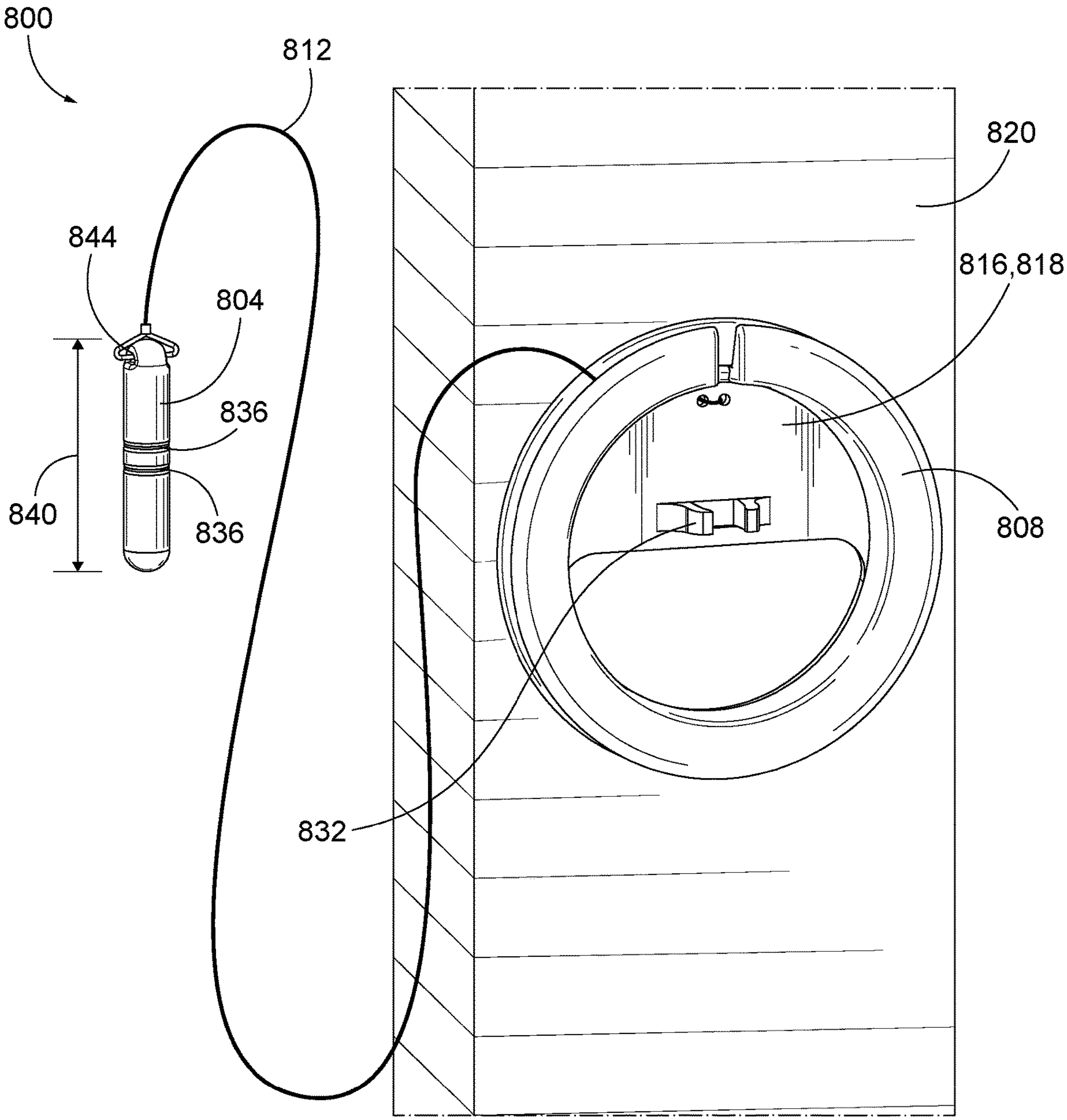


FIG. 13

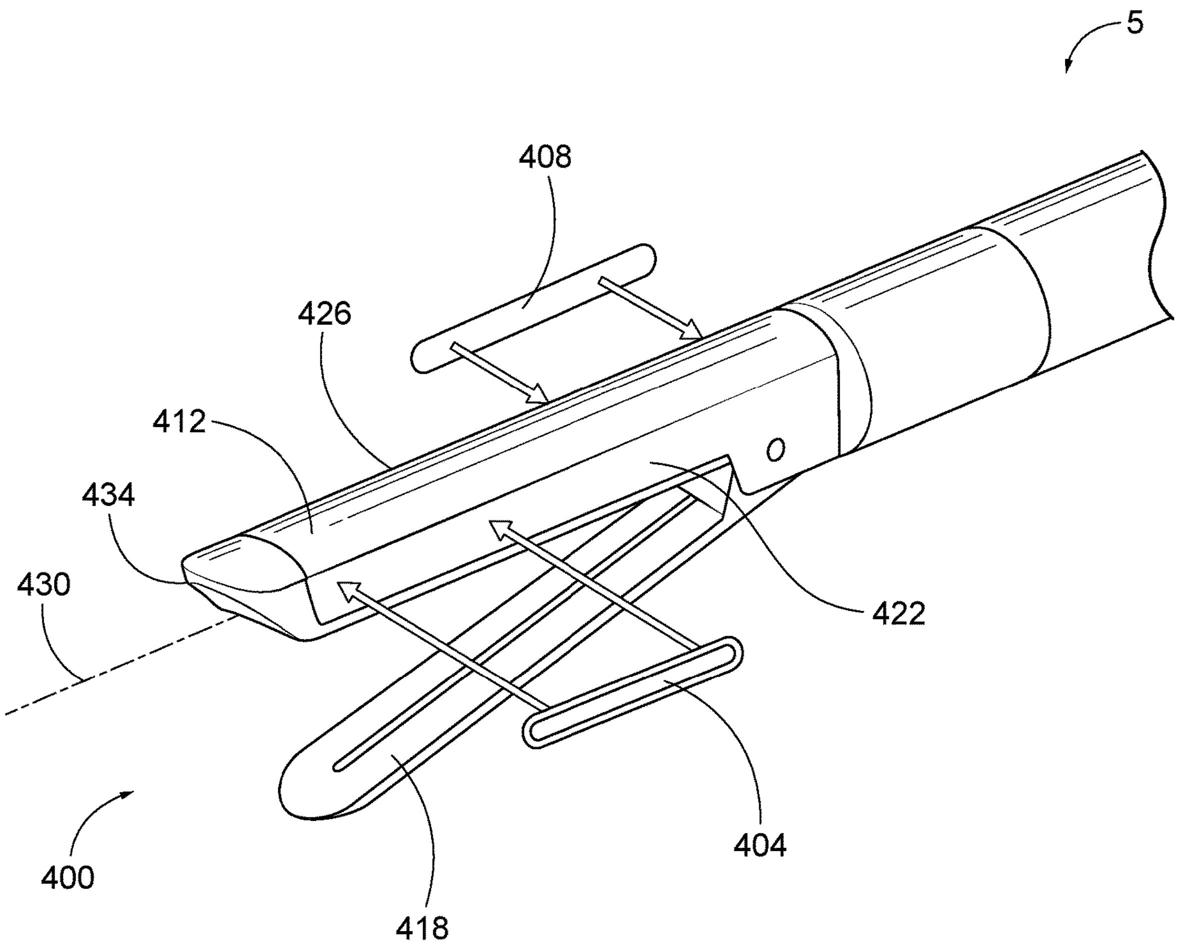


FIG. 14

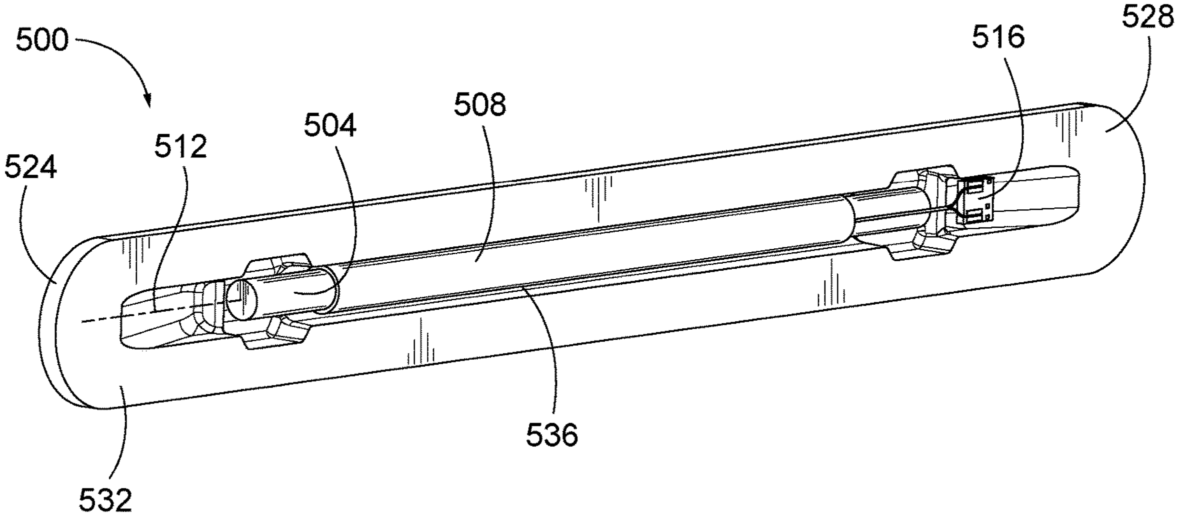

500
528
516
508
504
512
524
536
532

FIG. 15

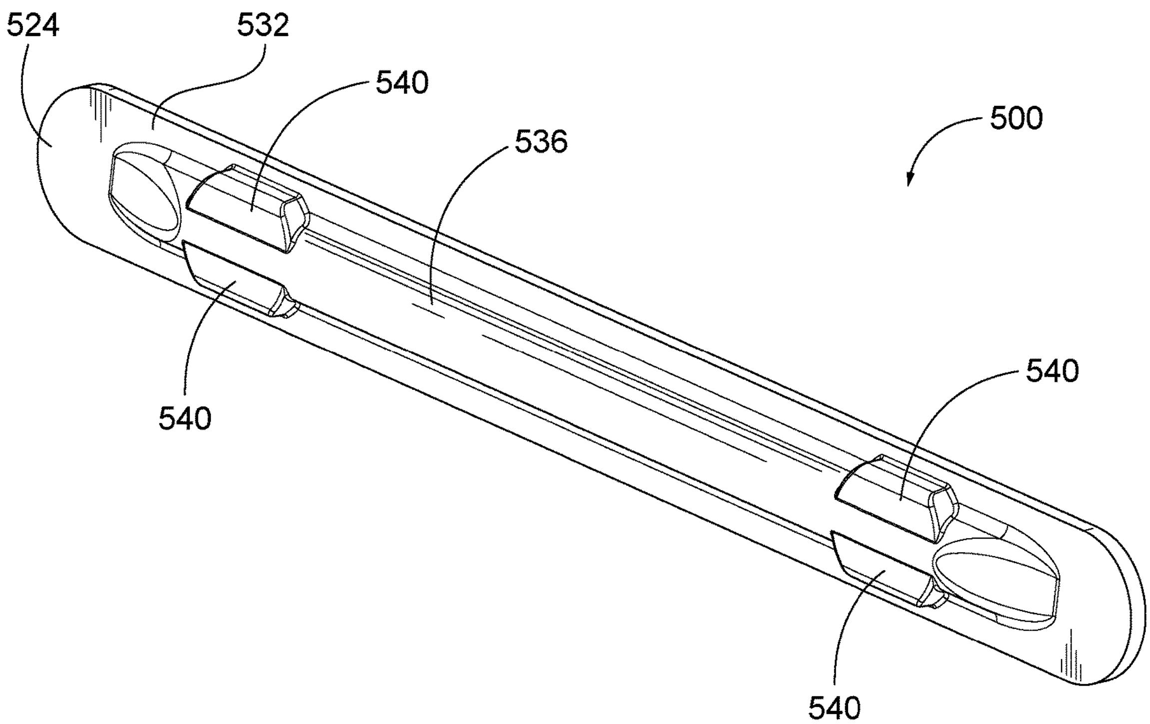

524
532
540
536
500
540
540
540

FIG. 16

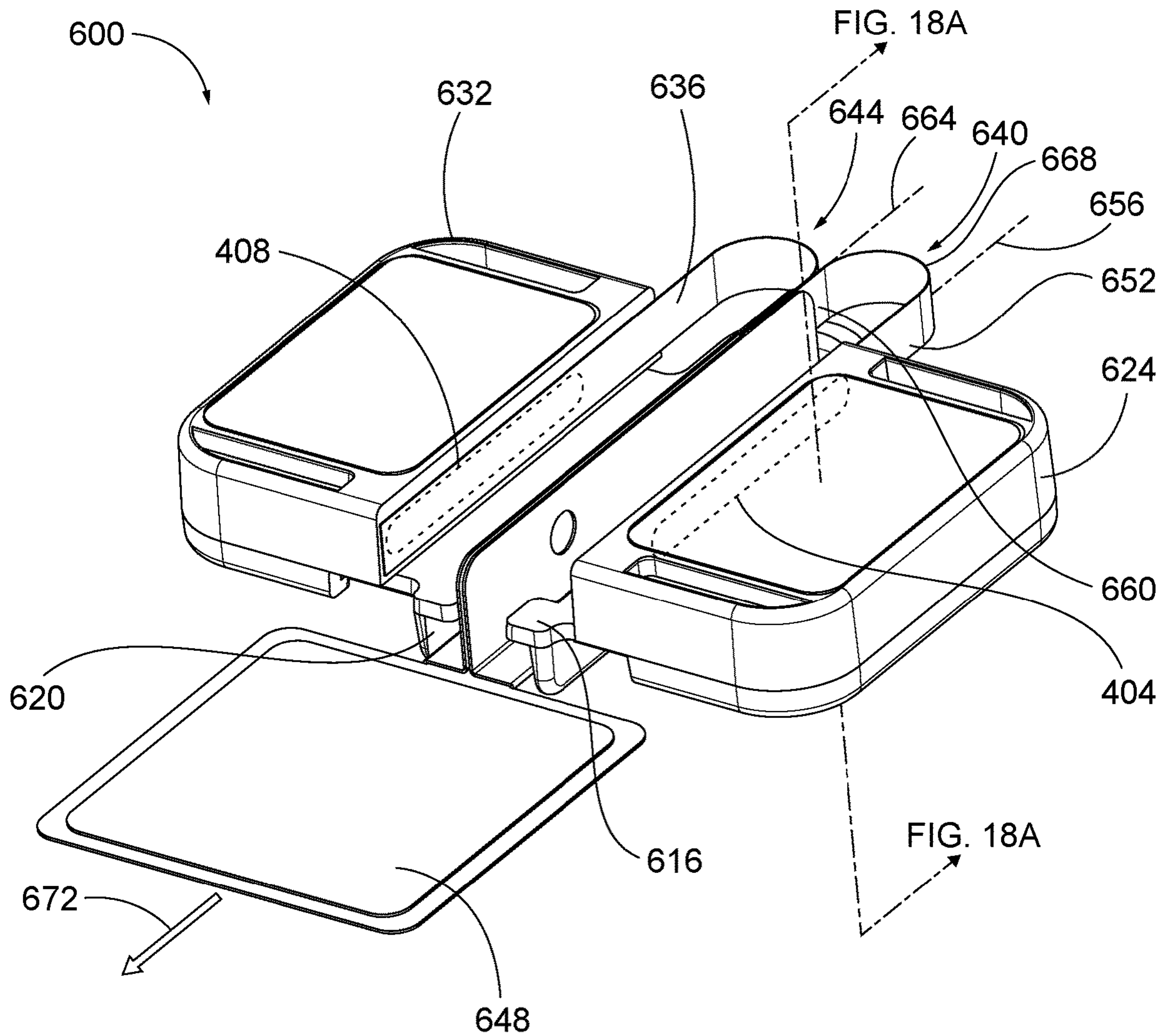

600
FIG. 18A
632
636
644
664
640
668
656
408
652
624
660
404
620
616
FIG. 18A
672
648

FIG. 17A

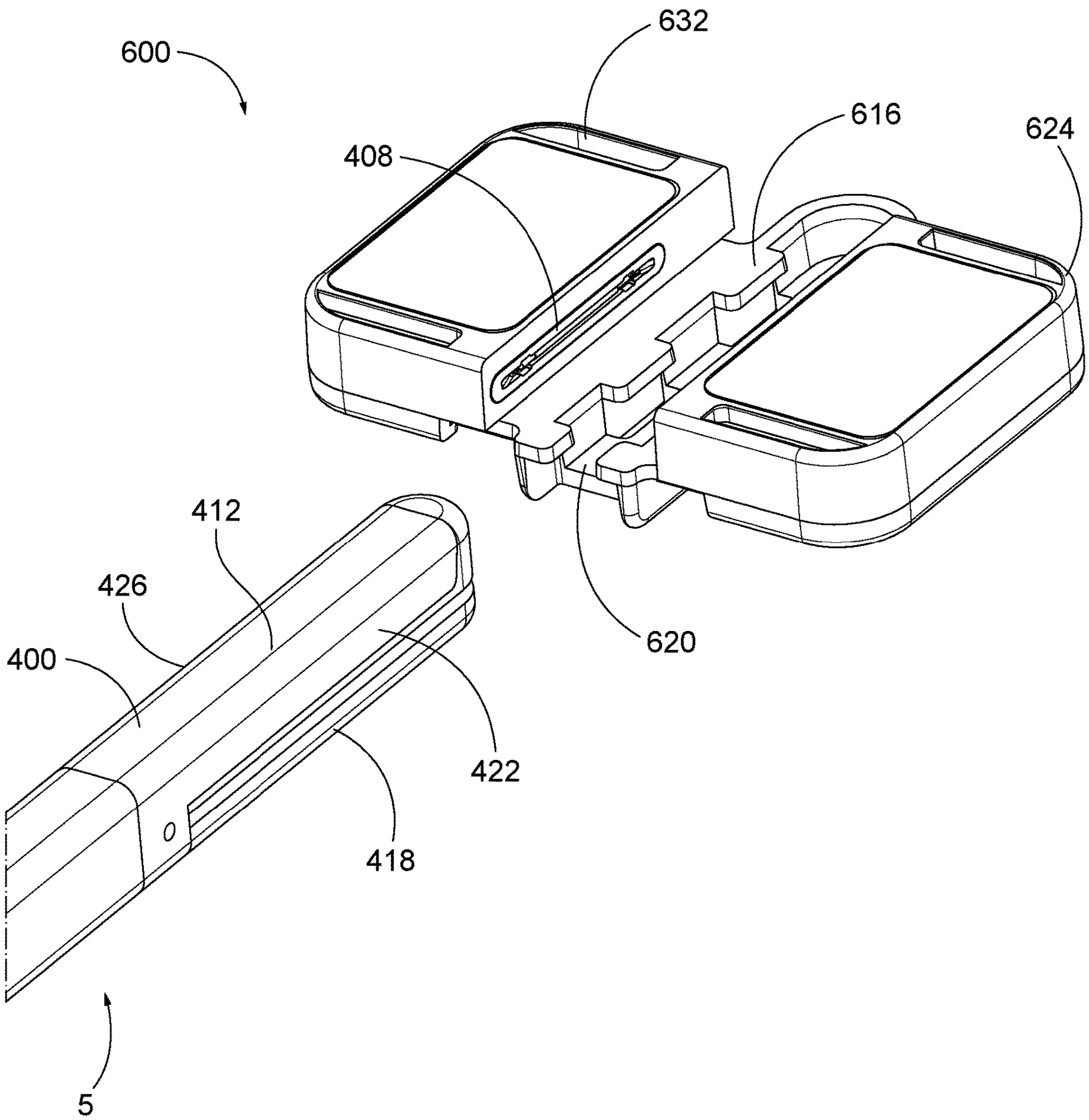


FIG. 17B

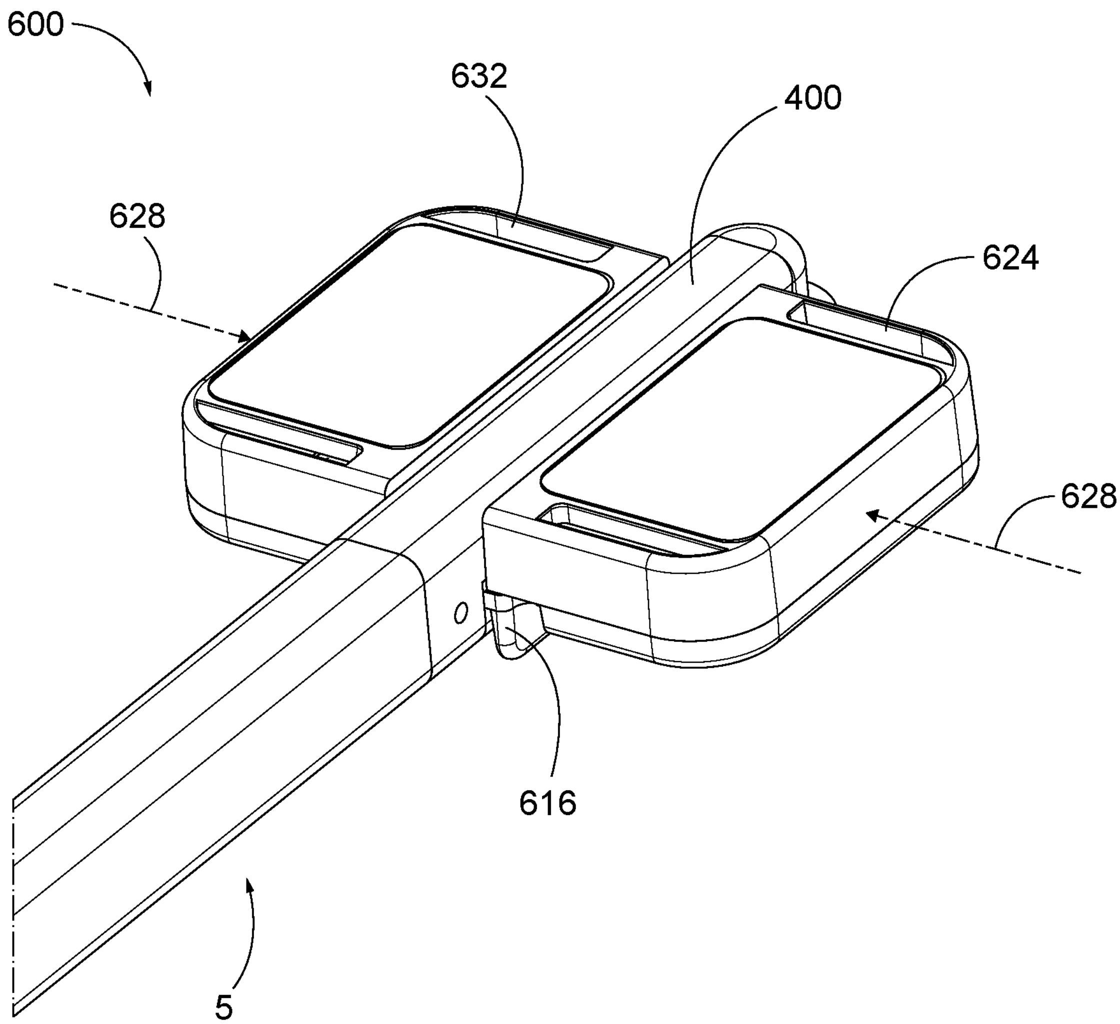


FIG. 17C

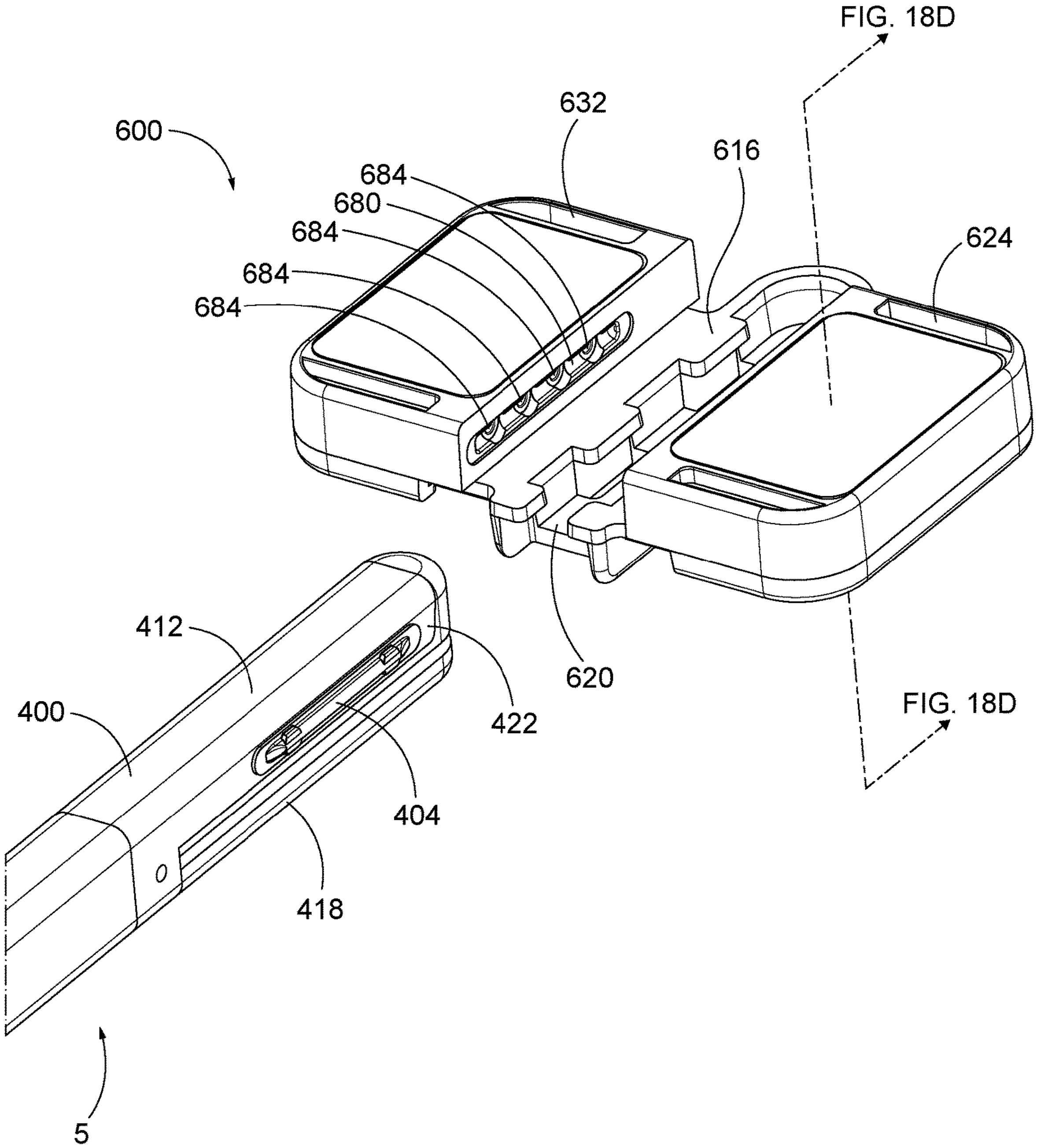


FIG. 18D
632
600
616
684
680
684
624
684
684
412
620
400
422
FIG. 18D
404
418
5

FIG. 17D

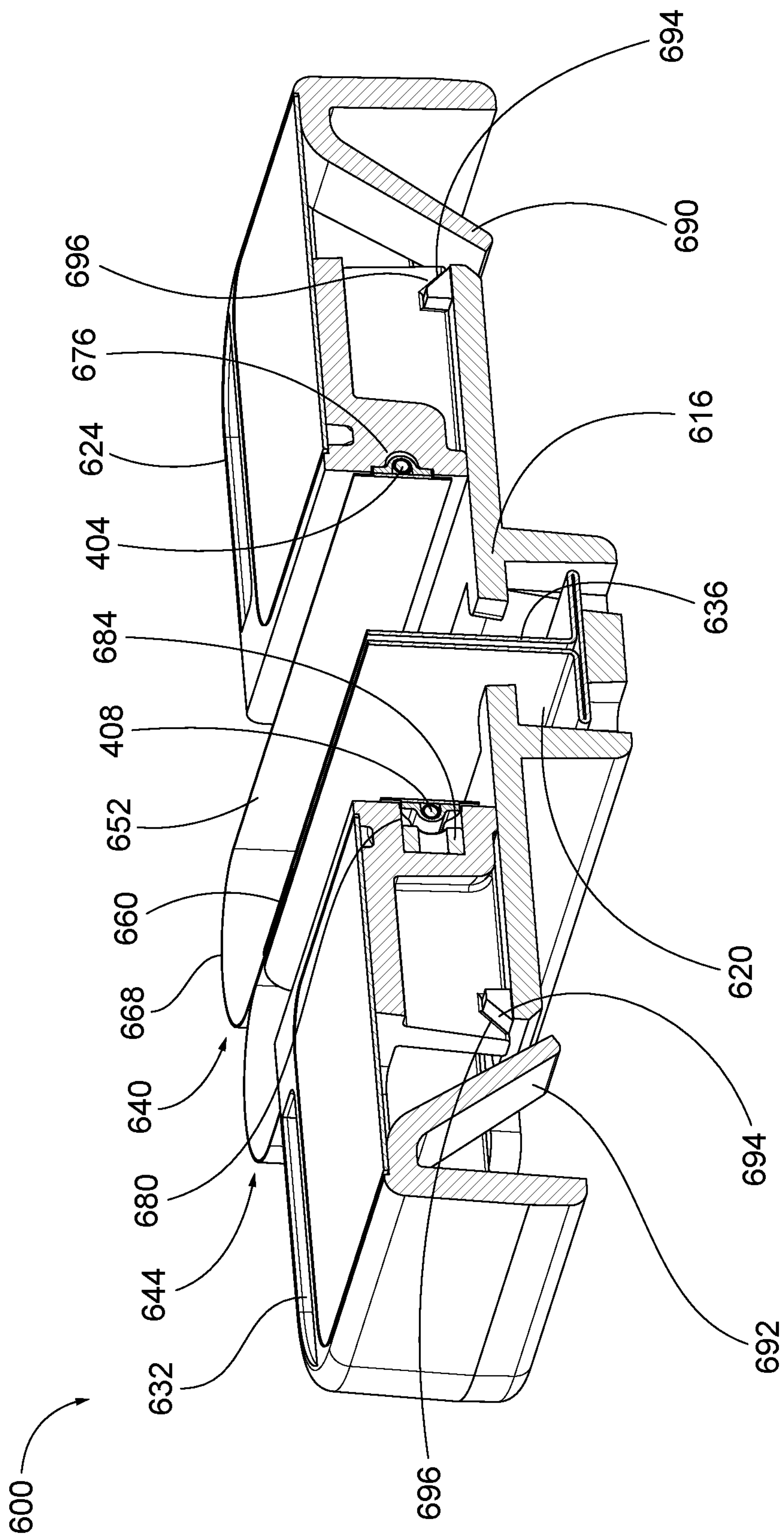
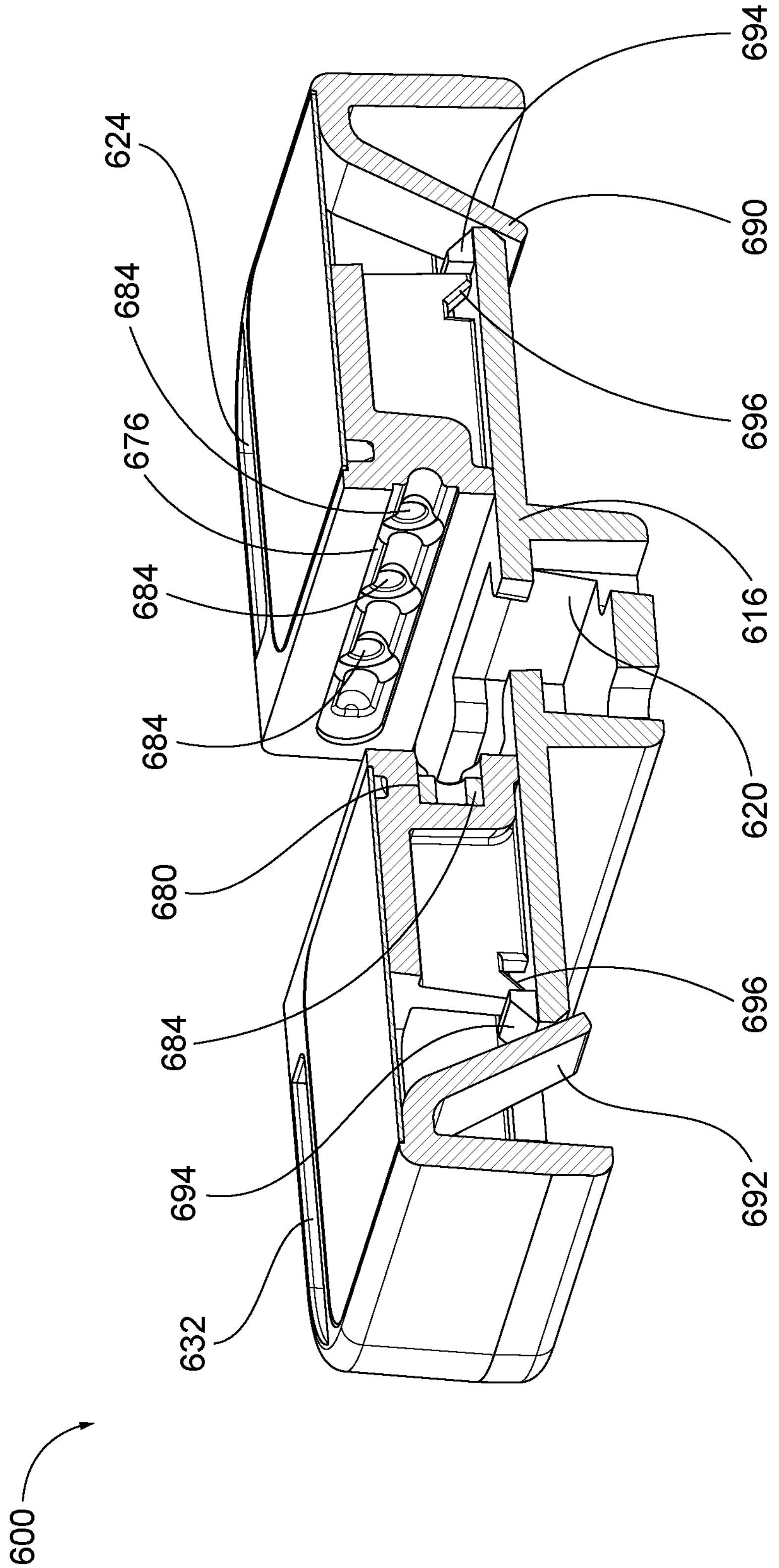

694
690
696
676
624
404
616
636
684
408
652
620
660
668
640
694
680
644
692
632
696
600

FIG. 18A


694
624
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676
696
684
616
684
620
680
684
696
694
692
632
600

FIG. 18B

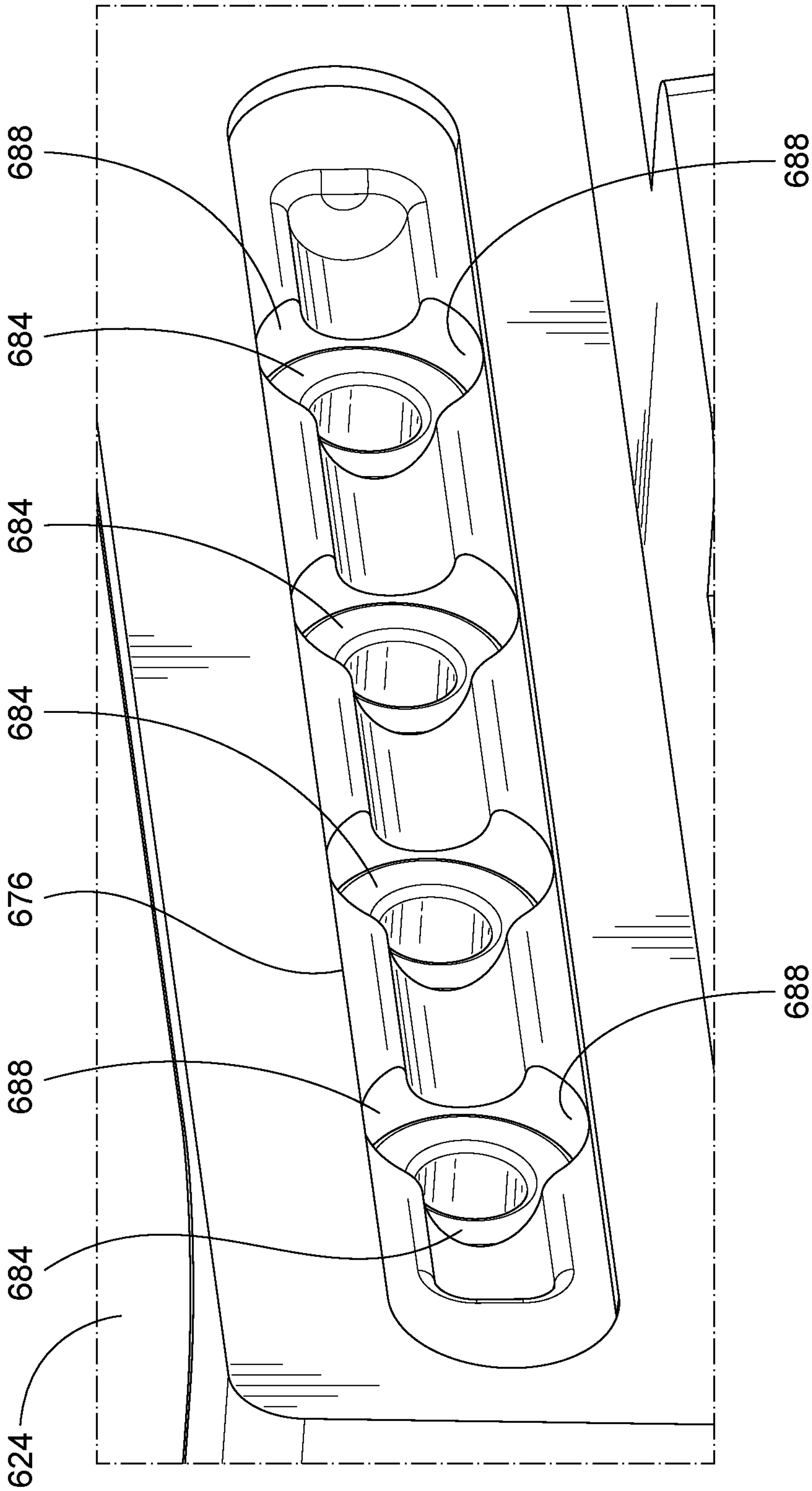

FIG. 19

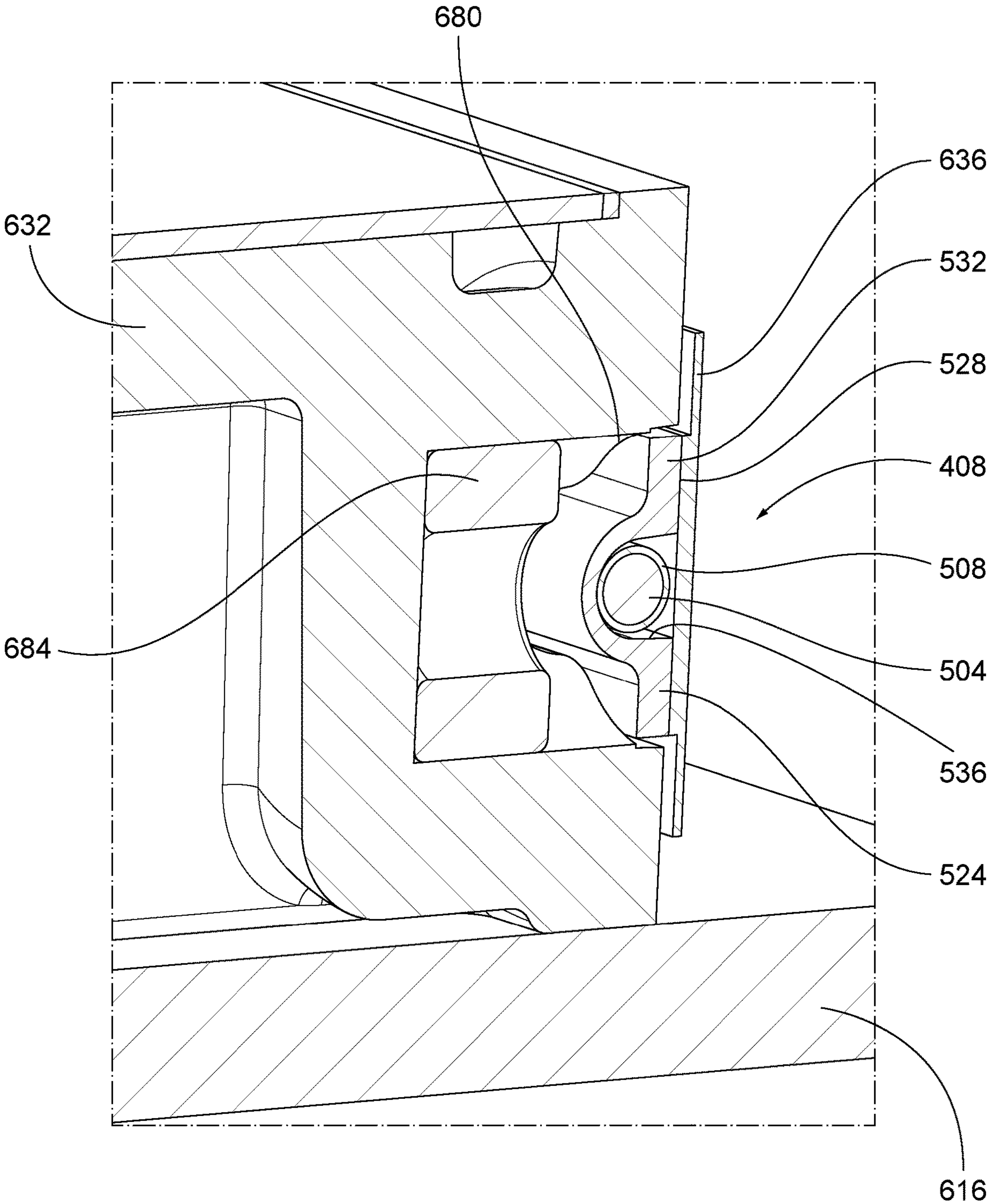

FIG. 20

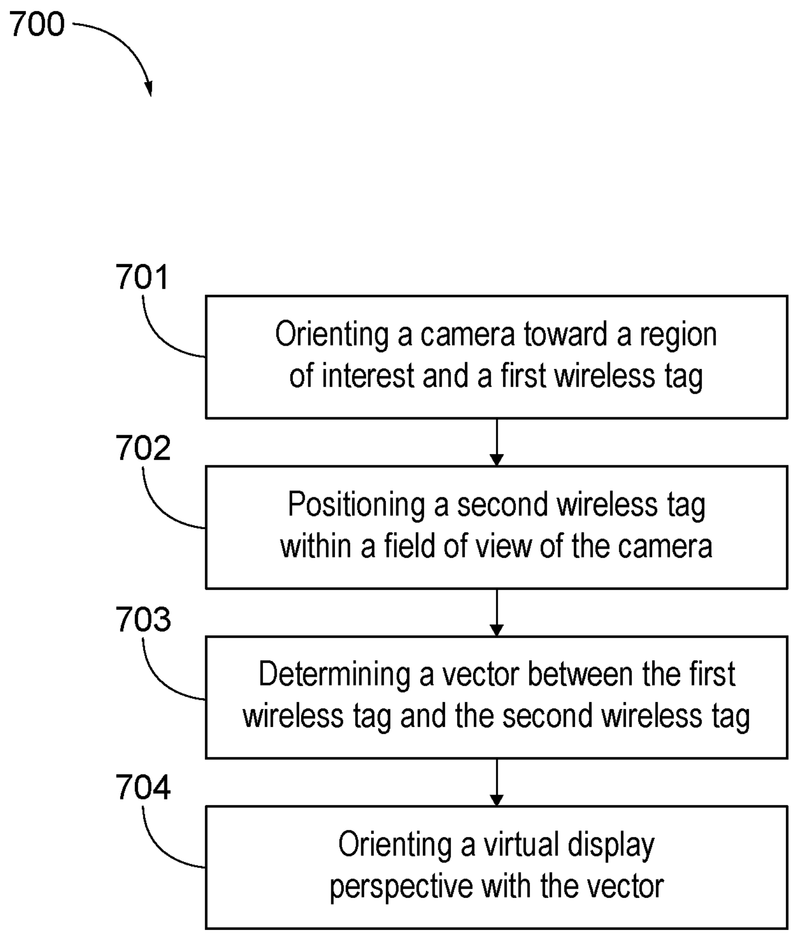
700
701
Orienting a camera toward a region of interest and a first wireless tag
702
Positioning a second wireless tag within a field of view of the camera
703
Determining a vector between the first wireless tag and the second wireless tag
704
Orienting a virtual display perspective with the vector

FIG. 21

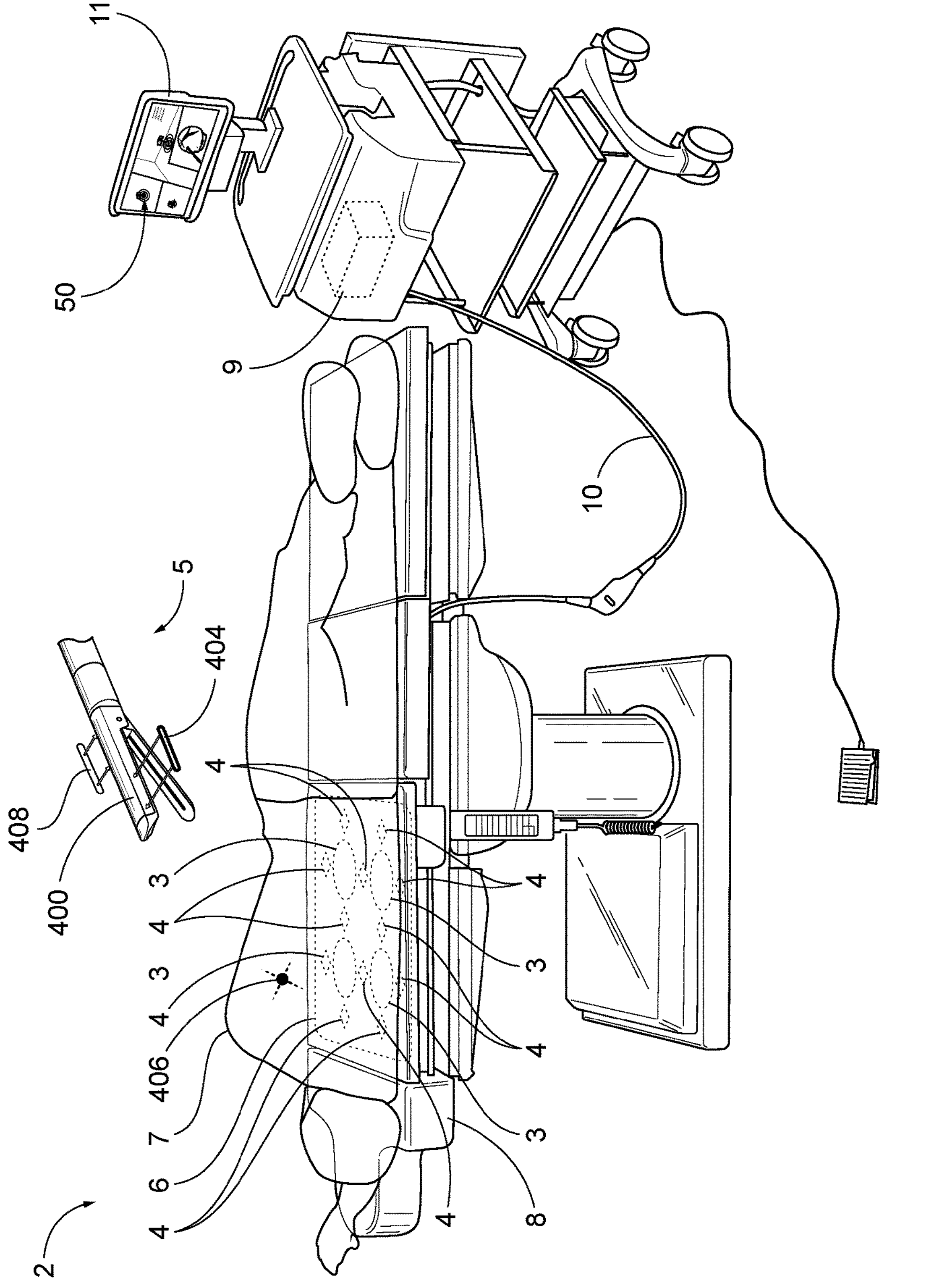

FIG. 22

SYSTEMS AND METHODS FOR WIRELESS LOCALIZATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to and the benefit of U.S. Provisional Patent Application No. 63/392,177, filed Jul. 26, 2022, and U.S. Provisional Patent Application No. 63/424,977, filed Nov. 14, 2022, and are incorporated herein by reference in their entirety for all purposes.

TECHNICAL FIELD

The present disclosure relates systems, devices, assemblies, and methods for wireless localization in surgical and medical procedures. The systems, devices, assemblies, and methods find use in a variety of applications including integration with a surgical tool.

BACKGROUND

A common and serious challenge for many medical procedures is the accurate location of treatment areas. For example, the location of lesions, such as tumors that are to undergo treatment, including surgical resection, continues to present a challenge to the medical community. Existing systems are expensive, complex, time-consuming, and often unpleasant for the patient.

Such issues are illustrated by the conventional surgical treatment of pulmonary nodules. In some cases where pulmonary nodules may be difficult to locate at conventional open surgery or at thoracoscopy, a hook wire, injection or visible dye, or a radionuclide is placed in or around the nodule in an attempt to improve localization prior to removal. This procedure usually takes place in the computerized tomography (CT) suite prior to the removal of the nodule. The patient is then transported to the surgical unit and the surgeon cuts down on the wire, uses a radionuclide detector, or uses visual landmarks to localize and remove the nodule.

A similar type of procedure is done to localize pulmonary nodules prior to resection. In some cases where pulmonary nodules may be difficult to locate at conventional open surgery or at thoracoscopy, a hook wire, injection of visible dye, or a radionuclide is place in or around the nodule in an attempt to improve localization prior to removal. This procedure usually takes place in the CT suite prior to the removal of the nodule. The patient is then transported to the surgical unit and the surgeon cuts down on the wire, uses a radionuclide detector, or uses visual landmarks to localize and remove the nodule.

In addition, the tools used during a medical procedure are also difficult to locate. For example, the location of a hand-held tool (e.g., a surgical stapler) utilized by a surgeon may not be known, other than intuitively by the surgeon. Any wired location sensor adds to the number of wires, tubes, etc. extending off from the hand-held tool—thereby reducing maneuverability of the tool.

Improved systems and methods are needed for tissue and tool localization for medical procedures performed in a variety of environments.

SUMMARY

The disclosure provides, in one aspect, a wireless localization system including an exciter coil, a sensor coil, a

surgical tool including a head defining a longitudinal axis, and a first wireless tag coupled to the head at a first position along the longitudinal axis. The first wireless tag is configured to generate a first signal in response to a magnetic field generated by the exciter coil. The wireless localization system further includes a second wireless tag coupled to the head at a second position along the longitudinal axis. The second position is spaced from the first position. The second wireless tag is configured to generate a second signal in response to the magnetic field generated by the exciter coil. The wireless localization system further includes a processor that determines the location of the head based on the first signal and the second signal detected by the sensor coil.

In some embodiments, the system further includes a third wireless tag configured to generate a third signal in response to the magnetic field generated by the exciter coil. The processor determines the location of the head with respect to the third wireless tag based on the first signal, the second signal, and the third signal detected by the sensor coil.

In some embodiments, the processor determines an orientation of the head.

In some embodiments, the first wireless tag defines a first volume no greater than 60 mm^3, and the second wireless tag defines a second volume no greater than 60 mm^3.

In some embodiments, the first wireless tag includes a ferrite rod, a coil wound around the ferrite rod, and an integrated circuit chip in electrical communication with the coil.

In some embodiments, the first wireless tag includes a shell, and wherein the rod, the coil, and the integrated circuit chip are positioned within the shell.

In some embodiments, the system further includes a high magnetic permeability backing positioned within the shell.

In some embodiments, the first wireless tag includes an adhesive layer, and the first wireless tag is secured to the head with the adhesive layer.

In some embodiments, the first wireless tag includes a first coil and a second coil, wherein the first coil is spaced from the second coil along the longitudinal axis.

In some embodiments, the magnetic field generated by the exciter coil is within a range of 1 μT to 50 μT at a frequency within a range of 125 kHz to 150 kHz.

In some embodiments, the first wireless tag has an inductance value at the frequency within a range of 0.5 mH to 20 mH.

In some embodiments, the antenna has a quality factor within a range of 5 to 20, wherein the quality factor is defined as the ratio of inductive reactance to resistance at the frequency.

In some embodiments, the system further includes a user display including a perspective view of a virtual head shown at the location of the head.

In some embodiments, the user display includes a top-down view, a side view, an endoscopic camera view, or any combination thereof.

In some embodiments, the user display includes a partial spherical shell that indicates a relative position of the head with respect to a third wireless tag.

In some embodiments, the user display includes a shortest distance path extending between the virtual head and the partial spherical shell.

In some embodiments, the virtual head includes a marker to indicate the location the shortest distance path intersects the virtual head.

The disclosure provides, in one aspect, a device including a wireless probe with a first end and a second end opposite the first end, and a handle removably coupled to the second end of the wireless probe. The wireless probe generates a signal in response to a magnetic field and is localized based on the signal.

In some embodiments, the device further includes a flexible tether coupled to the wireless probe. The tether is positioned within the handle when the handle is coupled to the second end of the wireless probe.

In some embodiments, the wireless probe includes a plurality of markings along a length of the wireless probe.

In some embodiments, the wireless probe includes an axis that extends between the first end and the second end. The handle is aligned with the axis when the handle is coupled to the second end of the wireless probe.

In some embodiments, the device is configured for manual operation with the handle coupled to the wireless probe, manual operation with the wireless probe grasped by a surgical tool, and robotic operation with the handle removed from the wireless probe.

The disclosure provides, in one aspect, a device including a wireless tag and a spool including a mount portion. The spool is configured to be attached to a workspace by the mount portion. The device further includes a tether extending between the wireless tag and the spool.

In some embodiments, the mount portion includes an adhesive.

In some embodiments, the device further includes a clip configured to at least partially receive the wireless tag.

In some embodiments, the adhesive is positioned on a first side of the mount portion and the clip is positioned on a second side of the mount portion.

In some embodiments, the wireless tag includes a plurality of markings spaced along a length of the wireless tag.

In some embodiments, the plurality of markings is equally spaced along the length of the wireless tag.

In some embodiments, the wireless tag includes an aperture and the tether extends through the aperture.

The disclosure provides, in one aspect, a wireless tag applicator for a tool. The wireless tag applicator comprising a mount including a groove configured to receive at least a portion of the tool, a slide movable with respect to the mount along an application axis, and a wireless tag movable with the slide. The wireless tag includes an adhesive oriented toward the groove. The wireless tag is coupled to the tool in response to the slide moving along the application axis.

In some embodiments, the slide is a first slide and the wireless tag is a first wireless tag; and wherein the applicator further includes a second slide movable with respect to the mount along the application axis and a second wireless tag movable with the second slide.

In some embodiments, the second wireless tag is coupled to the tool in response to the second slide moving along the application axis.

In some embodiments, the tool is a surgical stapler and wherein the wireless tag is coupled to a side surface of a first jaw.

In some embodiments, the groove receives a portion of a second jaw of the surgical stapler.

In some embodiments, the slide includes a cavity that at least partially receives the wireless tag.

In some embodiments, the applicator further includes a magnet positioned within the cavity, and wherein the wireless tag includes a ferromagnetic rod.

In some embodiments, the cavity includes a notch and the wireless tag includes a shell with a protrusion positioned within the notch.

In some embodiments, the applicator further includes a removable backing coupled to the slide. The removable backing abuts the adhesive of the wireless tag.

In some embodiments, the removable backing includes a graspable portion, a first portion extending along a first axis from the graspable portion, a second portion extending along a second axis, and an arcuate portion positioned between the first portion and the second portion.

In some embodiments, the second axis is spaced apart and parallel to the first axis.

In some embodiments, the slide further includes a spring lever, and wherein the spring lever deflects in response to the slide moving along the application axis.

In some embodiments, the spring lever biases the slide away from the groove.

In some embodiments, the mount further includes a ramp portion and the slide includes a cam portion configured to slide relative to the ramp portion in response to the slide moving along the application axis.

In some embodiments, the wireless tag applicator generates an audible feedback in response to the slide moving along the application axis.

The disclosure provides, in one aspect, a method of aligning a virtual display perspective to a camera perspective. The method comprising: orienting a camera toward a region of interest with a first wireless tag positioned in the region of interest; positioning a second wireless tag within a field of view of the camera; determining a vector between the first wireless tag and the second wireless tag; and orienting the virtual display perspective with the vector.

In some embodiments, the camera is part of an endoscope.

In some embodiments, the region of interest is a chest cavity of a patient.

In some embodiments, positioning the second wireless tag within the field of view of the camera includes positioning the second wireless tag at a center of the field of view.

In some embodiments, positioning the second wireless tag within the field of view of the camera includes positioning the second wireless tag within a threshold distance from the camera.

In some embodiments, positioning the second wireless tag within the field of view of the camera does not require a specific orientation of the second wireless tag.

In some embodiments, determining the vector is in response to receiving a user input.

In some embodiments, determining the vector between the first wireless tag and the second wireless tag includes receiving a first signal from the first wireless tag in response to a magnetic field and receiving a second signal from the second wireless tag in response to the magnetic field.

Other aspects of the disclosure will become apparent by consideration of the detailed description and accompanying drawings.

Definitions

As used herein, the terms “processor” and “central processing unit” or “CPU” are used interchangeably and refer to a device that is able to read a program from a computer memory (e.g., ROM or other computer memory) and perform a set of steps according to the program. As used herein, the term “processor” (e.g., a microprocessor, a microcontroller, a processing unit, or other suitable programmable device) can include, among other things, a control unit, an arithmetic logic unit (“ALC”), and a plurality of registers, and can be implemented using a known computer architecture (e.g., a modified Harvard architecture, a von Neumann architecture, etc.). In some embodiments the processor is a microprocessor that can be configured to communicate in a stand-alone and/or a distributed environment, and can be configured to communicate via wired or wireless communications with other processors, where such one or more processor can be configured to operate on one or more processor-controlled devices that can be similar or different devices.

As used herein, the term "memory" is any memory storage and is a non-transitory computer readable medium. The memory can include, for example, a program storage area and the data storage area. The program storage area and the data storage area can include combinations of different types of memory, such as a ROM, a RAM (e.g., DRAM, SDRAM, etc.), EEPROM, flash memory, a hard disk, a SD card, or other suitable magnetic, optical, physical, or electronic memory devices. The processor can be connected to the memory and execute software instructions that are capable of being stored in a RAM of the memory (e.g., during execution), a ROM of the memory (e.g., on a generally permanent bases), or another non-transitory computer readable medium such as another memory or a disc. In some embodiments, the memory includes one or more processor-readable and accessible memory elements and/or components that can be internal to the processor-controlled device, external to the processor-controlled device, and can be accessed via a wired or wireless network. Software included in the implementation of the methods disclosed herein can be stored in the memory. The software includes, for example, firmware, one or more applications, program data, filters, rules, one or more program modules, and other executable instructions. For example, the processor can be configured to retrieve from the memory and execute, among other things, instructions related to the processes and methods described herein.

As used herein, the term "computer readable medium" refers to any device or system for storing and providing information (e.g., data and instructions) to a computer processor. Examples of computer readable media include, but are not limited to, DVDs, CDs, hard disk drives, magnetic tape and servers for streaming media over networks, whether local or distant (e.g., cloud-based).

"About" and "approximately" are used to provide flexibility to a numerical range endpoint by providing that a given value may be "slightly above" or "slightly below" the endpoint without affecting the desired result.

The term "coupled," as used herein, is defined as "connected," although not necessarily directly, and not necessarily mechanically. The term coupled is to be understood to mean physically, magnetically, chemically, fluidly, electrically, or otherwise coupled, connected or linked and does not exclude the presence of intermediate elements between the coupled elements absent specific contrary language.

As used herein, the term "in electronic communication" refers to electrical devices (e.g., computers, processors, etc.) that are configured to communicate with one another through direct or indirect signaling. Likewise, a computer configured to transmit (e.g., through cables, wires, infrared signals, telephone lines, airwaves, etc.) information to another computer or device, is in electronic communication with the other computer or device.

As used herein, the term "transmitting" refers to the movement of information (e.g., data) from one location to another (e.g., from one device to another) using any suitable means.

As used herein, the term "network" generally refers to any suitable electronic network including, but not limited to, a wide area network ("WAN") (e.g., a TCP/IP based network), a local area network ("LAN"), a neighborhood area network ("NAN"), a home area network ("HAN"), or personal area network ("PAN") employing any of a variety of communications protocols, such as Wi-Fi, Bluetooth, ZigBee, etc. In some embodiments, the network is a cellular network, such as, for example, a Global System for Mobile Communications ("GSM") network, a General Packet Radio Service ("GPRS") network, an Evolution-Data Optimized ("EV-DO") network, an Enhanced Data Rates for GSM Evolution ("EDGE") network, a 3GSM network, a 4GSM network, a 5G New Radio, a Digital Enhanced Cordless Telecommunications ("DECT") network, a digital AMPS ("IS-136/TDMA") network, or an Integrated Digital Enhanced Network ("iDEN") network, etc.

As used herein, the term "subject" or "patient" refers to any animal (e.g., a mammal), including, but not limited to, humans, non-human primates, companion animals, livestock, equines, rodents, and the like, which is to be the recipient of a particular treatment. Typically, the terms "subject" and "patient" are used interchangeably herein in reference to a human subject.

As used herein, the term "subject/patient suspected of having cancer" refers to a subject that presents one or more symptoms indicative of a cancer (e.g., a noticeable lump or mass) or is being screened for a cancer (e.g., during a routine physical). A subject suspected of having cancer may also have one or more risk factors. A subject suspected of having cancer has generally not been tested for cancer. However, a "subject suspected of having cancer" encompasses an individual who has received an initial diagnosis (e.g., a CT scan showing a mass) but for whom the stage of cancer is not known. The term further includes people who once had cancer (e.g., an individual in remission).

As used herein, the term "biopsy tissue" refers to a sample of tissue (e.g., breast tissue) that is removed from a subject for the purpose of determining if the sample contains cancerous tissue. In some embodiments, biopsy tissue is obtained because a subject is suspected of having cancer. The biopsy tissue is then examined (e.g., by microscopy; by molecular testing) for the presence or absence of cancer.

As used herein, the term "sample" is used in its broadest sense. In one sense, it is meant to include a specimen or culture obtained from any source, as well as biological and environmental samples. Biological samples may be obtained from animals (including humans) and encompass fluids, solids, tissues, and gases. Biological samples include tissue, blood products, such as plasma, serum and the like. Such examples are not however to be construed as limiting the sample types applicable to the present invention.

As used herein, the term "tag," "marker tag," "wireless tag," or "SmartClip®" refers to the small marker that, when excited by an exciter's time varying magnetic field, will emit a "homing beacon" spectrum of frequency(ies) received by the "sensor coil(s)" or "witness coil(s)" and used to determine its location. It may be programmed to produce a unique spectrum, thus permitting multiple tags to be located simultaneously.

The terms "comprise(s)," "include(s)," "having," "has," "can," "contain(s)," and variants thereof, as used herein, are intended to be open-ended transitional phrases, terms, or words that do not preclude the possibility of additional acts or structures. The singular forms "a," "an" and "the" include plural references unless the context clearly dictates otherwise. The present disclosure also contemplates other embodiments "comprising," "consisting of" and "consisting essentially of," the embodiments or elements presented herein, whether explicitly set forth or not.

For the recitation of numeric ranges herein, each intervening number there between with the same degree of precision is explicitly contemplated. For example, for the range of 6-9, the numbers 7 and 8 are contemplated in addition to 6 and 9, and for the range 6.0-7.0, the number 6.0, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, and 7.0 are explicitly contemplated.

In the foregoing description of preferred embodiments, specific terminology has been resorted to for the sake of clarity. However, the invention is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar technical purpose. Terms such as "top" and "bottom", "front" and "rear", "inner" and "outer", "above", "below", "upper", "lower", "vertical", "horizontal", "upright" and the like are used as words of convenience to provide reference points.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an antenna coupled to a portion of a surgical stapler.

FIG. **2** is a graph of modeled Q and inductance values for different winding configurations for the antenna of FIG. **1**.

FIG. **3** is a schematic of a navigation display for locating a wireless tag embedded in a body with respect to a tracked probe.

FIGS. **4**A-**4**C are schematics of navigation displays with a tracked probe in positions relative to the wireless tag embedded in the body.

FIG. **5**A is a schematic of a navigation display with a surgical stapler wirelessly localized relative to the wireless tag embedded in the body.

FIG. **5**B is a schematic of a navigation display with the surgical stapler of FIG. **5**A in a closed or clamped configuration.

FIG. **6** is a navigation display with a surgical stapler wirelessly localized relative to a wireless tag.

FIG. **7** is a navigation display with a tracked probe wirelessly localized relative to a wireless tag.

FIG. **8** is a side view of a device including a wireless probe and a detachable handle.

FIG. **9** is a side view of the device of FIG. **8**.

FIG. **10** is a perspective view of a device including a wireless probe, a detachable handle, and a tether.

FIG. **11** is a front perspective view of a device including a wireless tag and a spool.

FIG. **12** is a rear perspective view of the device of FIG. **11**

FIG. **13** is a perspective view of the device of FIG. **11** with the spool attached to working environment and the wireless tag spaced from the spool.

FIG. **14** is a perspective view surgical stapler including wireless tags.

FIG. **15** is a rear perspective view of the wireless tag of FIG. **14**.

FIG. **16** is a front perspective view of the wireless tag of FIG. **15**.

FIG. **17**A is a perspective view of an applicator for applying wireless tags to a surgical stapler, shown in a storage configuration.

FIG. **17**B is a perspective view of a surgical stapler and an applicator, with the applicator shown in a ready configuration.

FIG. **17**C is a perspective view of a surgical stapler mounted to an applicator, with the applicator shown in an actuated configuration.

FIG. **17**D is a perspective view of a surgical stapler removed from an applicator, with wireless tags mounted to the surgical stapler and the applicator shown in a used configuration.

FIG. **18**A is a perspective view of a cross-section of the applicator taken along lines **18**A-**18**A, shown in FIG. **17**A.

FIG. **18**B is a perspective view of a cross-section of the applicator taken along lines **18**B-**18**B, shown in FIG. **17**D.

FIG. **19** is a perspective view of a portion of the applicator of FIG. **17**D.

FIG. **20** is a perspective cross-sectional view of the applicator of FIG. **17**A.

FIG. **21** is a flowchart of a method of aligning a virtual display perspective to a camera perspective.

FIG. **22** is a schematic view of a wireless localization system.

Before any embodiments are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways.

DETAILED DESCRIPTION

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art. In case of conflict, the present document, including definitions, will control. Preferred methods and materials are described below, although methods and materials similar or equivalent to those described herein can be used in practice or testing of the present disclosure. All publications, patent applications, patents and other references mentioned herein are incorporated by reference in their entirety. The materials, methods, and examples disclosed herein are illustrative only and not intended to be limiting.

Provided herein are systems, devices, assemblies, and methods for integrating a remotely located tag into medical procedures. While the specification focuses on medical uses in human tissues, it should be understood that the systems and methods find broader use, including non-human uses (e.g., use with non-human animals such as livestock companion animals, wild animals, or any veterinary settings). For example, the systems may be used in environmental settings, agricultural settings, industrial settings, or the like.

In addition to being located within human tissue, wireless tags can be integrated into tools to wirelessly track the location and orientation of tools utilized in various medical procedures. Such a wireless localization system is detailed in U.S. patent application Ser. No. 17/746,105, filed May 17, 2022, incorporated herein by reference in its entirety.

With reference to FIG. **22**, the present disclosure provides a wireless localization system **2** including an exciter coil **3**, a sensor coil **4**, and a tool **5** (e.g., a surgical stapler, a surgical tool, a robotic tool). In the illustrated embodiment, the exciter coil **3** and the sensor coil **4** are positioned within a pad **6** that is position under a patient **7**. In the illustrated embodiment, the pad **6** is positioned within a surgical table **8**. Such a pad is detailed further in U.S. patent application Ser. No. 17/746,105, filed May 17, 2022, incorporated herein by reference in its entirety.

With reference to FIG. **14**, in the illustrated embodiment, a first wireless tag **404** and a second wireless tag **408** are coupled to the tool **5**. In particular, the surgical tool **5** includes a head **400** defining a longitudinal axis **430**. In the illustrated embodiment, the head **400** defines a terminal end **434** of the surgical tool **5**. In the illustrated embodiment, the tracked tool **400** is a surgical stapler.

With continued reference to FIG. **14**, the first wireless tag **404** is coupled to the head **400** at a first position along the longitudinal axis **430**. The first wireless tag **404** generates a first signal in response to a magnetic field generated by the exciter coil **3**. The second wireless tag **408** is coupled to the head **400** at a second position along the longitudinal axis **430**. The second position is spaced from the first position. In some embodiments, the first wireless tag **404** partially overlaps the second wireless tag **408** along the longitudinal axis **430**. The second wireless tag **408** generates a second signal in response to the magnetic field generated by the exciter coil **3**. In other words, the wireless tags **404**, **408** are configured to generate a signal in response to a magnetic field generated by at least one exciter coil **3**.

With continued reference to FIG. **14**, the surgical stapler includes a first jaw **412** (e.g., a reload jaw) and a second jaw **418** (e.g., an anvil jaw). The first wireless tag **404** is coupled to a first side **422** of the first jaw **412** and the second wireless tag **408** is coupled to a second side **426** of the first jaw **412**, opposite the first side **422**. In the illustrated embodiment, the first wireless tag **404** is offset from the second wireless tag **408** along the axis **430** of the first jaw **412**. In other words, the first wireless tag **404** is positioned a first distance to the distal tip **434** of the first jaw **412** and the second wireless tag **408** is positioned a second distance to the distal tip **434**, where the first distance is shorter than the second distance. In the illustrated embodiment, the wireless tags **404**, **408** are applied to locations on the tool **400** such that the wireless tags do not impact the ability of the tool to pass through a port (e.g., port compatibility of the surgical tool remains unchanged by the addition of wireless tags).

With continued reference to FIG. **22**, signals generated by the wireless tags **404**, **408** are detected by at least one sensor coil **4**. The system **2** further includes a processor **9** configured to determine the location of the tool **5** based on the signals detected by the sensor coil **4**. In some embodiments, the processor **9** is configured to determine the orientation (or orientations) and location of the tool **5** (e.g., localization in six degrees-of-freedom, 6DOF). In the illustrated embodiment, the processor **9** is electrically coupled to the pad **6** by a wired connection **10**. In some embodiments, the processor **9** controls the magnetic field generated by the exciter coils **2** and receives the signals detected by the sensor coils **4**.

In some embodiments, the system **2** further includes a third wireless tag **406** that generates a third signal in response to the magnetic field generated by the exciter coil **3**. In some embodiments, the third wireless tag **408** is implanted within a patient. The processor **9** is configured to determine the location of the tool **5** with respect to the implanted wireless tag **406** based on the signals detected by the sensor coil **4**. In other words, the processor **9** determines the location of the tool head **400** and the orientation of the tool head **400** with respect to the third wireless tag **406** based on the signals detected by the sensor coil **4**.

Simultaneously tracking the location and orientation of both a surgical stapler and a wireless tag implanted in or on a patient has advantages. Given that the implanted wireless tag marks the target location (e.g., of the cancer, etc.), the margin of tissue from the target location can be confirmed after the stapler jaws have been closed (and after re-arrangement of the tissue caused by the stapler closure). In other words, before the stapler engages and cuts tissue, the positioning and margin is confirmed by a wireless localization system presented herein. If necessary, the stapler can be moved and reclosed before a cut occurs. Therefore, the margin can be confirmed with high confidence.

Surgical staplers are designed to fit through a port with limited space and clearance. It is challenging to design and manufacture staplers of small diameter, and staplers typically do not have extra space relative to the port. For example, a SureForm 45 stapler available from Intuitive Surgical is designed to pass through a 12 mm port, and there is little clearance between the stapler head and the port.

In some embodiments, the wireless localization system disclosed herein estimates the position and orientation of the stapler head from the shaft position and kinematic data coming from the device that controls or monitors the stapler head articulation. It is advantageous to track the stapler head itself instead of just tracking the stapler shaft outside the port, because the stapler head can articulate in various directions. Furthermore, tracking the location of the stapler head directly would require less integration and software implantation, validation, and communications.

With reference to FIG. **1**, a stapler head **12** (e.g., a head of the SureForm 45 stapler) has a narrow portion **14** where a wireless tag **18** is mounted. In some embodiments, the wireless tag **18** is coupled to the narrow portion **14** with an adhesive. In the illustrated embodiment, the wireless tag **18** has a thickness **22** within a range of approximately 0.3 mm to approximately 0.8 mm. In the illustrated embodiment, the wireless tag **18** has a width **26** within a range of approximately 2 mm to approximately 4 mm. In some embodiments, the wireless tag **18** has a length **30** of approximately 30 mm. In some embodiments, the wireless tag **18** defines a volume no greater than 60 mm^3. In other embodiments, the wireless tag **18** defines a volume no greater than 38 mm^3. In some embodiments, the thickness **22** of the wireless tag **18** is approximately 0.35 mm, the width **26** is approximately 3.5 mm, and the length **30** is approximately 30 mm. In other embodiments, the thickness **22** of the wireless tag **18** is approximately 0.75 mm, the width **26** is approximately 2.5 mm, and the length **30** is approximately 30 mm.

With continued reference to FIG. **1**, in the illustrated embodiment, the wireless tag **18** includes an antenna **34** and a backing **38**. In the illustrated embodiment, the antenna **34** includes a first coil **34**A and a second coil **34**B. The first coil **34**A is spaced from the second coil **34**B. In the illustrated embodiment, the first coil **34**A is spaced from the second coil **34**B along a longitudinal axis **38** of the tool **10** (e.g., the stapler head longitudinal axis). In the illustrated embodiment, the first coil **34** and the second coil **34**B are positioned the same distance from a longitudinal axis **40** of the stapler **12**. To achieve high inductance, thin wire is utilized for the coils **34**A, **34**B and as many turns as possible within the volume constraints are wound. In some embodiments, each of the coils **34**A, **34**B has approximately 100-150 turns. In some embodiments, each of the coils **34**A, **34**B has approximately 250-350 turns.

In the illustrated embodiment, the wireless tag **18** includes dual coil antenna **34** with a high magnetic permeability, low electrical conductivity material backing **38**. In some embodiments, the backing **38** is Flux Field Directional Material (FFDM) EM25TP available from 3M™. In some embodiments, the backing **38** has a relative permeability (μ') of approximately 2000.

Even with the small space constraints, the antenna **34** is capable of gathering enough power from a transmitted magnetic field from an exciter coil to power up and generate a signal. In some embodiments, the magnetic field generated by the exciter coil **3** is within a range of approximately 1 μT to approximately 50 μT at a frequency within a range of approximately 125 kHz to approximately 150 kHz. In some embodiments, the antenna transmits a signal at a frequency offset from the original transmitted signal.

In some embodiments, the wireless tag **18** (e.g., antenna, backing, etc.) has an inductance value at the frequency within a range of approximately 0.5 mH to approximately 20 mH. In some embodiments, the wireless tag **18** has a quality factor (Q) (e.g., the ratio of inductive reactance to resistance at a frequency) within a range of approximately 5 to approximately 20. A higher quality factor (Q) will reduce the bandwidth of the wireless tag **18** and a lower quality factor will produce insufficient signal. A lower inductance will produce inadequate voltage to power the wireless tag, and a higher inductance will reduce the field produced. To power the wireless tag **18**, the antenna **34** needs sufficient inductance to result in an adequate voltage and needs to have a high quality factor (e.g., high ratio of power stored in the circuit per cycle to power dissipated in the circuit per cycle). Furthermore, the antenna **34** must function in close proximity to metal because staplers, for example, are in general metallic.

With reference to FIG. **2**, modeling results for various configurations are illustrated. Specifically, the quality factor (Q) and the inductance of different configurations of windings are illustrated. In some embodiments, the Q is approximately 7.7 and the inductance is approximately 3.15 mH. In another embodiment, the Q is approximately 9.4 and the inductance is approximately 3.6 mH.

As detailed herein, the system **2** wirelessly tracks the tool **5** (e.g., a robotic surgical stapler, a manual surgical stapler) with a low-profile wireless tag (e.g., wireless tag **404**, wireless tag **408**, wireless tag **18**, etc.) that is adhered to the stapler head **400** without impacting the ability of the stapler to pass through the surgical port.

With reference to FIG. **22**, the system **2** further includes a display **11** (e.g., a monitor) showing a user display **50**. With reference to FIG. **3**, the user display **50** including a perspective view **54** of localization of a tool **52** (e.g., a wireless probe). In the illustrated embodiment, the user display **50** also includes a top-down view **58**, a side view **62**, and an endoscopic camera view **66** (e.g., a display drawn from a similar perspective as that of the endoscopic camera). The endoscopic camera view **66** can be on a separate screen or overlaid on the same screen as the views **54**, **58**, **62**. In some embodiments, the user display **50** includes a perspective view, a top-down view, a side view, an endoscopic camera view, or any combination thereof.

With continued reference to FIG. **3**, the user display **50** illustrates a wireless tag illustration **407** corresponding to the location of the physical wireless tag **406** implanted in the patient **7** (e.g., in a patient lung). In the illustrated embodiment, the wireless tag illustration **407** is positioned within a sphere **68**. In some embodiments, the sphere **68** is a user-defined margin around the implanted wireless tag **406**. In the illustrated embodiment, the views **54**, **58**, **62** include two rings **70**A, **70**B for the X-Y plane and one ring **74** for the Y-Z plane. The user display **50** simultaneously illustrates in real-time the tracked tool **52**. In the illustrated embodiment, the tracked tool **52** is represented virtually as a cylinder **78** in the user display **50**. In some embodiments, the tracked tool **52** is a wired probe configured for interrogating an area (FIG. **3**). In other embodiments, the tracked tool is a wirelessly localized stapler (FIG. **5**A). A line **82** illustrates the shortest path between the tracked tool **52** and the sphere **68** of the implanted wireless tag **406**. The user display **50** further includes a spherical shell **86** that indicates a relative position of the tool **52** with respect to the implanted wireless tag **406**.

With reference to FIGS. **4**A, **4**B, and **4**C, the spherical shell **86** indicates a relative position of the tool **52** with respect to the implanted wireless tag **406**. In other words, the spherical shell **86** provides context to allow the user looking at the display **50** to understand the relative position of the tool **52** with respect to the implanted wireless tag **406**, without referencing multiple views. In some embodiments, the spherical shell **86** increases in size as the distance between the tool **52** and the implanted wireless tag **406** increases. With reference to FIG. **4**C, when the tracked tool **52** is close to the targeted implanted wireless tag **406**, the curvature of the spherical shell **86** increases, and the segment appears to wrap around the target sphere **68**.

In some embodiments, the color of the spherical shell **86** indicates to a user looking at the display **50** which side of the spherical shell **86** (inner or outer) is facing the observer. In some embodiments, multiple sphere shells (each with different size or color) is used to display multiple tracked tools simultaneously. In some embodiments, the spherical shell **86** color is light blue when the inner surface of the sphere is viewed by the observer. This, along with the curvature, indicates to the user that the tracked tool **52** is behind the implanted wireless tag **406** (FIG. **4**A), from viewing just the perspective view **54**, without having to consult the top-down view **58**, for example. In some embodiments, the spherical shell **86** color is light purple when the outer surface of the sphere is viewed by the observer. This, along with the curvature, indicates to the user that the tracked tool **52** is in front of the implanted wireless tag **406** (FIG. **4**B), from just the perspective view **54**, without having to consult the top-down view **58**, for example,

With reference to FIGS. **5**A-**5**B, the localization of the stapler head **400** with respect to the implanted wireless tag **406** is illustrated in the user display **50**—with the stapler head **400** virtually represented as a cylinder **104**. In the illustrated embodiment, the cylinder **104** length is identical to the length of the stapler head **400**. In FIG. **5**A, the jaws of the stapler head **400** are open. In FIG. **5**B, the jaws of the stapler head **404** are closed. With the stapler jaws closed, the user can advantageously confirm the location of the stapler head **404** relative to the implanted wireless tag **406** before cutting any tissue. In other words, tissue may move as the stapler jaws close and the display **50** illustrates the relative position of the stapler head **400** relative to the implanted wireless tag **406** after the stapler jaws are closed.

With reference to FIG. **6**, a user display **150** is illustrated with a perspective view **154**, a top-down view **158**, and a side view **162** showing a virtual head representation **166** (e.g., a virtual head corresponding to the location of the physical stapler head **400**) relative to a virtual tag representation **407** (e.g., a virtual tag corresponding to the location of the physical wireless tag **406**) implanted in the patient **7**. The user display **150** includes a first user-defined volume **170** (e.g., sphere) positioned around the wireless tag representation **407** (e.g., to indicate a size and shape of a tumor), and a second user-defined volume **174** (e.g., a sphere) positioned around the first user-defined volume **170** (e.g., to represent a desired margin from the tumor). in some embodiments, the user-defined volumes **170**, **174** are not spherical. The user display **150** further includes a shortest distance path **178** extending between the virtual head representation **166** (e.g., virtual head) and a partial spherical shell **182**. In some embodiments, the partial spherical shell **182** operates similarly to the spherical shell **86** of the user display **50** discussed herein. The user display **150** further includes a marker **186** positioned on the virtual head **166** to indicate the location at which the shortest distance path **178** intersects the virtual head **166**. In other words, the marker **186** identifies what portion of the head **400** is closest to the wireless tag **406**. In the illustrated embodiment, the marker **186** is a ring wrapped around the virtual head representation **166**. In some embodiments, the user display **150** includes a virtual patient **190** representing the orientation of the patient **7** in any given view (e.g., views **154**, **158**, **162**).

With reference to FIG. **7**, the user display **150** is showing with a virtual wireless probe representation **194** (e.g., virtual tag corresponding to the location of a physical wireless probe **204**, FIG. **8**) relative to the virtual tag representation **407** (e.g., virtual tag corresponding to the location of the physical wireless tag **406**) implanted in the patient **7**. In some embodiments, the user display **150** toggles between visualizing the position and orientation of the tracked wireless tag (FIG. **7**) and visualizing the position and orientation of the tracked stapler (FIG. **6**).

In some embodiments, the user display is presented within a robotic console and/or drawn from nearly the same perspective as the endoscope view. In some embodiments, the wireless localization system subscribes to a robotic positioning stream to determine the endoscopic camera point of view. In some embodiment, the user display point of view is configured to correspond to the endoscopic view. In some embodiment, two video outputs to the robotic console are simultaneously presented to the user to provide a stereoscopic 3D view.

With reference to FIG. **21**, a method **700** of aligning a virtual display (e.g., display **150**, display **50**, etc.) to a camera perspective (e.g., an endoscopic camera perspective) is illustrated. The method **700** includes (STEP **701**) orienting a camera (e.g., an endoscopic camera) toward a region of interest with a first wireless tag position in the region of interest. In some embodiments, the camera is part of an endoscope. In some embodiments, the camera is part of a robotic surgical system. In some embodiments, the region of interest is a chest cavity of a patient. The method **700** further includes (STEP **702**) positioning a second wireless tag within a field of view of the camera. In some embodiments, positioning the second wireless tag within the field of view of the camera includes positioning the second wireless tag at a center of the field of view. In some embodiments, positioning the second wireless tag within the field of view of the camera includes positioning the second wireless tag within a threshold distance from the camera. In some embodiments, the threshold distance is approximately 6 inches. In other embodiments, the threshold distance is approximately 1 inch. In some embodiments, the threshold distance is within a range from approximately 1 inch to approximately 6 inches. Advantageously, positioning the second wireless tag within the field of view of the camera does not require a specific orientation of the second wireless tag.

The method **700** further includes (STEP **703**) determining a vector between the first wireless tag and the second wireless tag, and (STEP **704**) orienting the virtual display perspective view the vector. In some embodiments, determining the vector is in response to receiving a user input (e.g., a button press). In some embodiments, determining the vector between the first wireless tag and the second wireless tag includes receiving a first signal from the first wireless tag in response to a magnetic field and receiving a second signal from the second wireless tag in response to the magnetic field.

In one embodiment, the camera alignment method for an endoscopic procedure is summarized as follows: (a) the user orients the endoscope such that the expected position of the tumor is roughly centered in the endoscope display; (b) the user then inserts the probe into the chest cavity (if not already present); (c) the user moves the probe as close to the endoscope lens as reasonable and centers the probe in the endoscope display. Orientation of the probe does not have impact in this process; (d) the user presses a software button to direct they system to re-align the main user display with the camera; (e) the processor executes software to calculate the vector created between the probe center and the target wireless tag center; (f) the processor executes software that aligns the virtual camera in the user display with the vector; and (g) the endoscope and the user display are displayed in the same orientation. This process can be repeated as necessary if the endoscope has moved to an extent that the alignment is no longer accurate.

With reference to FIG. **8** and FIG. **9**, a device **200** including a wireless probe **204** and a handle **208** removably coupled to the wireless probe **204**. In some embodiments, the wireless probe **204** includes a wireless tag similar to those described herein. For embodiments where the wireless probe **204** includes a single wireless tag, the wireless tag is as large as possible without impacting port compatibility (e.g., the ability for the wireless probe **204** to pass through a given diameter circle). In some embodiments, the wireless probe **204** includes at least two wireless tags. For embodiments where the wireless probe **204** includes two wireless tags, the two wireless tags are positioned with an angle formed therebetween. In some embodiments, the angle between the two wireless tags in the wireless probe is up to approximately 90 degrees.

The wireless probe **204** includes a first end **212** and a second end **216** opposite the first end **212**. In the illustrated embodiment, the first end **212** is tapered and includes a point. The handle **208** is removably coupled to the second end **216** of the wireless probe **204**. In some embodiments, the handle **208** engages the wireless probe **204** with a releasable interference fit. In other embodiments, the handle selectively engages the wireless probe with a latch, a release, a hook, or any other suitable mechanism.

The wireless probe **204** assists with localizing another wireless tag that has been implanted within a patient, for example. See, for example, FIG. **3**. In other words, the device **200** is a wirelessly tracked tool where the wireless probe **204** is localized in response to electromagnetic fields (e.g., the electromagnetic fields generated by an exciter coil).

The device **200** is configured for manual operation and/or robotic operation. As one example of manual operation, the handle **208** can be attached to the wireless probe **204** and a user physically moves the wireless probe via the handle **208**. As another example of manual operation, the wireless probe **204** is grasped by a surgical tool (e.g., a surgical forceps) operated by a user. In some embodiments, handle **208** is replaced with the use of the surgical tool. For robotic operation, the handle **208** can be removed from the wireless probe **204** and the wireless probe **204** is directly grasped by, for example, a robotic actuator or a robotically operated surgical tool. In some embodiments, the wireless probe **204** includes a durable soft exterior that is easily grasped by robotic actuators. In other words, the wireless probe **204** includes a soft material that covers an outer shell such that the wireless probe **204** is easily grasped by either hand operated or robotically operated graspers.

With reference to FIG. **10**, a device **300** includes a wireless probe **304**, a handle **308** removably coupled to the wireless probe **304**, and a flexible tether **310** coupled to the wireless probe **304**. The wireless probe **304** includes a first end **312** and a second end **316** opposite the first end **312**. The handle **308** is removably coupled to the second end **316** of the wireless probe **304**. An axis **320** extends between the first end **312** and the second end **316**. When the handle **308** is coupled to the second end **316** of the wireless probe **304**, the handle **308** is aligned with the axis **320**. In the illustrated embodiment, the wireless probe **304** includes a plurality of length markings **324** that are spaced along the axis **320**. In some embodiments, the spacing between adjacent markings **324** is equal.

The flexible tether **310** is positioned within the handle **308** when the handle **308** is coupled to the second end **316** of the wireless probe **304**. In other words, the flexible tether **310** is exposed if and/or when the handle **308** is removed from the wireless probe **304**. In some embodiments, the handle is separable from the tether. In other embodiments, the handle is retained on the tether (e.g., a user slides the handle back and the tether remains within the handle core). The tether **310** can be utilized to receive the wireless probe if the wireless probe is dropped, for example, by a human or robot operator. In other words, the tether **310** allows for easy removal or retrieval of the wireless probe **304** from a cavity. In some embodiments, the tether is not included. In some embodiments, the handle is not included.

With reference to FIGS. **11-13**, a device **800** includes a wireless tag **804**, a spool **808**, and a tether **812** extending between the wireless tag **804** and the spool **808**. The spool **808** includes a mount portion **816** and the spool **808** is configured to be attached to a workspace **820** by the mount portion **816** (FIG. **13**). In the illustrated embodiment, the mount portion **806** includes an adhesive **824** with a removable backing **828**.

With reference to FIG. **11**, the device **800** includes a clip **832** configured to at least partially receive the wireless tag **804**. In other words, the wireless tag **804** is positioned within the clip **832** in a storage configuration. In the storage configuration, the tether **812** is wound around the spool **808**. In the illustrated embodiment, the adhesive **824** is positioned on a first side **817** of the mount portion **816** and the clip **832** is positioned on a second side **818** of the mount portion **816**.

With continued reference to FIGS. **11** and **13**, the wireless tag **804** includes a plurality of markings **836** spaced along a length **840** of the wireless tag **804**. In the illustrated embodiment, the markings **836** are equally spaced along the length **840** of the wireless tag **804**. The wireless tag **804** further includes an aperture **844** formed at one end. The tether **812** extends through the aperture **844** and is secured to the wireless tag **804**.

With reference to FIG. **13**, in operation, the spool **808** is attached to the working environment **820** and the tether **812** is at least partially unwound from the spool **808** with the wireless tag **804** spaced from the spool **808**. The wireless tag **804** of the device **800** can be deployed (e.g., positioned within a patient) and localized without any electrical wires connected to the wireless tag **804**, but the tether **812** advantageously allows for the wireless tag **804** to be easily retrieved, for example, by a surgeon after a procedure is complete.

With reference to FIGS. **15** and **16**, a wireless tag **500** is illustrated. In some embodiments, the wireless tag **500** corresponds to either one or both of the wireless tag **404** and the wireless tag **408**. The wireless tag **500** includes a rod **504** and a coil **508** coupled to the rod **504**. In some embodiments, the rod **504** is a ferrite rod. Ferrite is advantageous to have high permeability (μ') and low complex permeability (μ'') at operating frequency. High permeability increases inductance and low complex permeability decreases core losses. In some embodiments, the rod **504** has a large aspect ratio (e.g., length to diameter ratio is large). In some embodiments, the length of the rod **504** is within a range of approximately 15 mm to approximately 20 mm. In some embodiments, the diameter of the rod **504** is within a range of approximately 0.6 mm to approximately 0.75 mm.

The coil **508** includes several turns wound around the rod **504**. In some embodiments, the coil **508** includes a number of turns around the rod **504** within a range of approximately 500 to approximately 1000. In some embodiments, the number of turns is within a range of approximately 400 to approximately 1200. In some embodiments, the coil **508** is made of wire within a range of 47 AWG and 53 AWG. In some embodiments, the coil **508** has a number of layers of turns within a range of 1 layer to 3 layers. In some embodiments, the turns and layers of the coil **508** are selected to produce an inductance in a range of approximately 2 mH and approximately 5 mH. In the illustrated embodiment, the rod **504** and the coil **508** are aligned with an axis **512**.

The wireless tag **500** further includes an integrated circuit chip **516** electrically coupled to the coil **508**. In some embodiments, the integrated circuit chip **516** is a contactless identification device. In some embodiment, the wireless tag **500** further includes a high magnetic permeability backing. In some embodiments, the backing is Flux Field Directional Material (FFDM) EM25TP available from 3M™. In some embodiments, the backing has a relative permeability (μ') of approximately 2000. In some embodiment, the backing is positioned between the rod **504** and the tool, to increase overall inductance and Q valve.

The wireless tag **500** further includes a shell **524**. In some embodiments, the rod **504**, the coil **508**, and the integrated circuit chip **516** are positioned within the shell **524**. In some embodiments, the high magnetic permeability backing is positioned within the shell **524**. The wireless tag **500** further includes an adhesive layer **528**. In the illustrated embodiment, the adhesive layer **528** is coupled to the shell **524**. In some embodiment, the adhesive layer **528** couples the wireless tag **500** to a tool surface (e.g., the side **422** of the jaw **412**, FIG. **14**). In other words, the wireless tag **500** is configured to be secured to a tool with the adhesive layer **528**. In some embodiments, the wireless tag **500** is potted, glued, or epoxied to a tool surface.

With continued reference to FIG. **16**, the shell **524** includes a flange **532**, a recess **536** to receive the rod **504** and at least one protrusion **540**. In the illustrated embodiment, the shell **524** includes a plurality of protrusions **540**. As detailed further herein, the protrusions **540** advantageously ensures correct loading within, for example, an applicator (e.g., applicator **600**, FIG. **17**A). In some embodiments, the shell **524** is formed of glass.

With reference to FIG. **17A-17**D, an applicator **600** for applying the wireless tags **404**, **408** to the tool head **400** is illustrated. The applicator **600** includes a mount **616** with a groove **620** configured to receive at least a portion of the tool head **400**. The applicator **600** includes a first slide **624** movable with respect to the mount **616** along an application axis **628** (FIG. **17**C) and a second slide **632** movable with respect to the mount **616** along the application axis **628**. Before the wireless tags **404**, **408** are applied to the tool head **400**, the first wireless tag **404** is coupled to and movable with the first slide **624**, and the second wireless tag **408** is coupled to and movable with the second slide **632**. In the illustrated embodiment, the wireless tags **404**, **408** include an adhesive (e.g., the adhesive layer **528**, FIG. **15**) oriented toward the groove **620**. In other words, adhesive on the wireless tags **404**, **408** is oriented toward the tool head **400** when the tool is coupled to the mount **616**.

With reference to FIG. **17**A, the applicator **600** includes a removable backing **636** coupled to the first slide **624** and the second slide **632**. The removable backing **636** includes a first side **640** that abuts the adhesive of the first wireless tag **404** and a second side **644** that abuts the adhesive of the second wireless tag **408**. The removable backing **636** includes a graspable portion **648** that is graspable by a user to pull and remove the removable backing **636** from the applicator **600**—exposing the wireless tags **404**, **408**. Each side **640**, **644** includes a first portion **652** extending along a first axis **656** from the graspable portion **648**, a second portion **660** extending along a second axis **664**, and an arcuate portion **668** positioned between the first portion **652** and the second portion **660**. In the illustrated embodiment, the second axis **664** is spaced apart and parallel to the first axis **656**. Advantageously, the entire removable backing **636** is removable from both the first wireless tag **404** and the second wireless tag **408** with a single pulling motion of the graspable portion **648** by a user. In other words, the adhesives on both wireless tags **404**, **408** are exposed in response to a user pulling the graspable portion **648** in a removal direction **672**.

With reference to FIG. **17**B, in the illustrated embodiment, the tool is a surgical stapler and the groove **620** receives a portion of the second jaw **418** of the stapler head **400**.

With reference to FIG. **17**C, the wireless tags **404**, **408** are coupled to the tool head **400** in response to the slides **624**, **632** moving along the application axis **628**. Specifically, once the tool head **400** is in place on the applicator **600**, a user moves the slides **624**, **632** along the axis **628** to mount the wireless tags **404**, **408** onto the tool **5**.

With reference to FIG. **17**D, after contacting the tool head **400**, the slides **624**, **632** are retracted away from the tool head **400**, leaving the wireless tags **404**, **408** coupled to the tool **5**. In the illustrated embodiment, the wireless tag **404** is coupled to the side surface **422** of the jaw **412**, and the wireless tag **408** is coupled to an opposite side surface **426** of the jaw **412**. Advantageously, the applicator **600** physically aligns the stapler head **400** and jaws **412**, **418** to ensure the wireless tags **404**, **408** are applied at the correct positions on the stapler **5**.

With reference to FIGS. **17**D, **18**A, **19** and **20**, the first slide **624** includes a first cavity **676** that at least partially receives the first wireless tag **404**. Similarly, the second slide **632** includes a second cavity **680** that at least partially receives the second wireless tag **408**. At least one magnet **684** is positioned within the first cavity **676** and is magnetically coupled to the first wireless tag **404** (e.g., the ferromagnetic rod **504**). With reference to FIG. **19**, in the illustrated embodiment, a plurality of magnets **684** are positioned within the cavity **676** to magnetically support the wireless tag **404** within the cavity **676** before the wireless tag **404** is attached to the surgical stapler head **400**.

With continued reference to FIG. **19**, the cavity **676** includes notches **688**. In some embodiments, the notches **688** facilitate insertion of the magnets **684**. In some embodiments, the notches **688** receive the protrusions **540** formed on the shell **524** of the wireless tag **404**. In other words, the cavity **676** includes the notch **688** and the first wireless tag **404** includes the shell **524** with the protrusion **540** position within the notch **688** when the applicator **600** is in the configurations shown in FIGS. **17**A and **17**B.

With reference to FIGS. **18**A and **18**B, the first slide **624** includes a spring lever **690** and the second slide **632** includes a spring lever **692**. The spring lever **690** abuts a portion of the mount **616** as the first slide **624** moves relative to the mount **616**. Likewise, the spring lever **692** abuts a portion of the mount **616** as the second slide **632** moves relative to the mount **616**. In the illustrated embodiment, the spring lever **690**, **692** deflect in response to the slides **624**, **632**, respectively, moving along the application axis **628** to attach the wireless tag **404**, **408** to the stapler head **400**. After the compression of the slides **624**, **632** is removed, the spring levers **690**, **692** biases the slides **624**, **632** away from the groove **620** and the stapler head **400** positioned within the groove **620**. In other words, as the slides **624**, **632** are compressed by a user, the spring levers **690**, **692** deflect as they abut the mount **616**. When the slides **624**, **632** are released by the user, the spring levers **690**, **692** bias the slides **624**, **632** away from the tool head **400**. Advantageously, the slides **624**, **632** are biased away from the head **400** after the wireless tags **404**, **408** are attached to the tool head **400** with enough distance to provide clearance for the wireless tags **404**, **408** to exit the applicator **600** without contacting the applicator **600** as the surgical tool **5** is removed from the applicator **600**. In other words, the spring levers **690**, **692** bias the slides **624**, **632** outwards to provide clearance for the wireless tags **404**, **408** as they are removed with the stapler head **400**.

With continued reference to FIGS. **18**A and **18**B, the mount **616** further includes a ramp portion **694** and the first slide **624** includes a cam portion **696**. Likewise, the second slide **632** includes cam portion **696** corresponding to another ramp portion **694** formed on the mount **616**. The cam portion **696** is configured to slide relative to the ramp portion **694** in response to the slide **624**, **632** moving along the application axis **628**. In some embodiments, the wireless tag applicator **600** generates an audible feedback (e.g., a click) in response to the first slide **624** and/or the second slide **632** moving along the application axis **628**. In the illustrated embodiment, an audible click is generated in response to the cam portions **696** clearing the ramp portions **694** on the mount **616**. Advantageously, the audible feedback signals to a user the slides **624**, **632** have been compressed a sufficient distance to successfully apply the wireless tags **404**, **408** to the stapler head **400**.

Various features and advantages are set forth in the following claims.

What is claimed is:

1. A wireless localization system comprising:

an exciter coil;

a sensor coil;

a surgical stapler including a head defining a longitudinal axis; wherein the surgical stapler includes a first jaw and a second jaw;

a first wireless tag positioned on a first side of the first jaw at a first position along the longitudinal axis; the first wireless tag configured to generate a first signal in response to a magnetic field generated by the exciter coil;

a second wireless tag positioned on a second side of the first jaw at a second position along the longitudinal axis, the second position is spaced from the first position, the second wireless tag configured to generate a second signal in response to the magnetic field generated by the exciter coil; and a processor that determines a location of the head based on the first signal and the second signal detected by the sensor coil;

wherein the first wireless tag includes a first ferrite rod and a first coil wound around the first ferrite rod; and wherein the second wireless tag includes a second ferrite rod and a second coil would around the second ferrite rod; and wherein the first ferrite rod is oriented parallel to the second ferrite rod; and

wherein the first ferrite rod and the second ferrite rod are oriented parallel to the longitudinal axis of the head.

2. The system of claim **1**, wherein the system further includes a third wireless tag configured to generate a third signal in response to the magnetic field generated by the exciter coil; and wherein the processor determines the location of the head with respect to the third wireless tag based on the first signal, the second signal, and the third signal detected by the sensor coil.

3. The system of claim **1**, wherein the processor determines an orientation of the head.

4. The system of claim **1**, wherein the first wireless tag defines a first volume no greater than 60 mm^3, and the second wireless tag defines a second volume no greater than 60 mm^3.

5. The system of claim **1**, wherein the first wireless tag further includes an integrated circuit chip in electrical communication with the first coil.

6. The system of claim **5**, wherein the first wireless tag includes a shell, and wherein the first ferrite rod, the first coil, and the integrated circuit chip are positioned within the shell.

7. The system of claim **6**, further including a magnetic permeability backing positioned within the shell.

8. The system of claim **5**, wherein the first wireless tag has a thickness within a range of 0.3 mm to 0.8 mm.

9. The system of claim **1**, wherein the first wireless tag includes an adhesive layer, and the first wireless tag is secured to the head with the adhesive layer.

10. The system of claim **1**, wherein the first wireless tag further includes a secondary coil, wherein the first coil is spaced from the secondary coil along the longitudinal axis.

11. The system of claim **1**, wherein the magnetic field generated by the exciter coil is within a range of 1 μT to 50 μT at a frequency within a range of 125 kHz to 150 kHz.

12. The system of claim **11**, wherein the first wireless tag has an inductance value at the frequency within a range of 0.5 mH to 20 mH.

13. The system of claim **11**, wherein the first wireless tag has a quality factor within a range of 5 to 20, wherein the quality factor is defined as the ratio of inductive reactance to resistance at the frequency.

14. The system of claim **1**, further comprising a user display including a perspective view of a virtual head shown at the location of the head.

15. The system of claim **14**, wherein the user display includes a top-down view, a side view, an endoscopic camera view, or any combination thereof.

16. The system of claim **14**, wherein the user display includes a partial spherical shell that indicates a relative position of the head with respect to a third wireless tag.

17. The system of claim **16**, wherein the user display includes a shortest distance path extending between the virtual head and the partial spherical shell.

18. The system of claim **17**, wherein the virtual head includes a marker to indicate the location the shortest distance path intersects the virtual head.

19. The system of claim **1**, wherein the first wireless tag is positioned a first distance to a distal tip of the head and the second wireless tag is positioned a second distance to the distal tip; wherein the first distance is shorter than the second distance.

20. The system of claim **1**, wherein the head is configured to pass through a 12 mm port.

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