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(54) **METHOD AND APPARATUS FOR
MONITORING IMPLANTABLE DEVICE FOR
URINARY CONTINENCE**

(71) Applicant: **Uromedica, Inc.**, Plymouth, MN (US)

(72) Inventors: **John H. Burton**, Minnetonka, MN
(US); **Timothy C Cook**, Wayzata, MN
(US)

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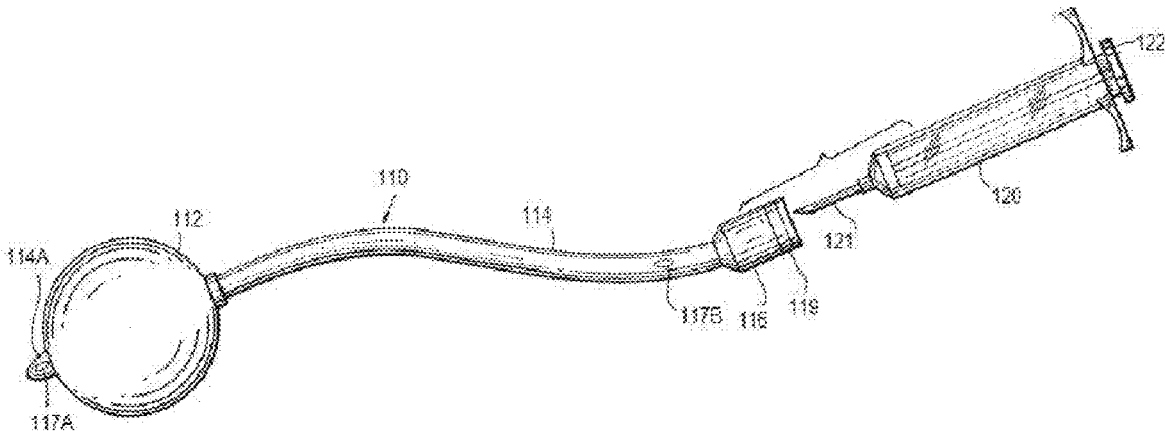
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(57) **ABSTRACT**

One or more sensors are incorporated onto one or more of an implantable device and a surgical tool used for placement and/or adjustment of the implantable device. The implantable device includes an adjustable membrane element for controllable coaptation of a body lumen, such as coaptation of a urethra as treatment for urinary incontinence. In various embodiments, the one or more sensors can be configured to detect information indicative of at least one of a shape of the adjustable membrane element, a position of the adjustable membrane element relative to the body lumen, or a shape of the body lumen.



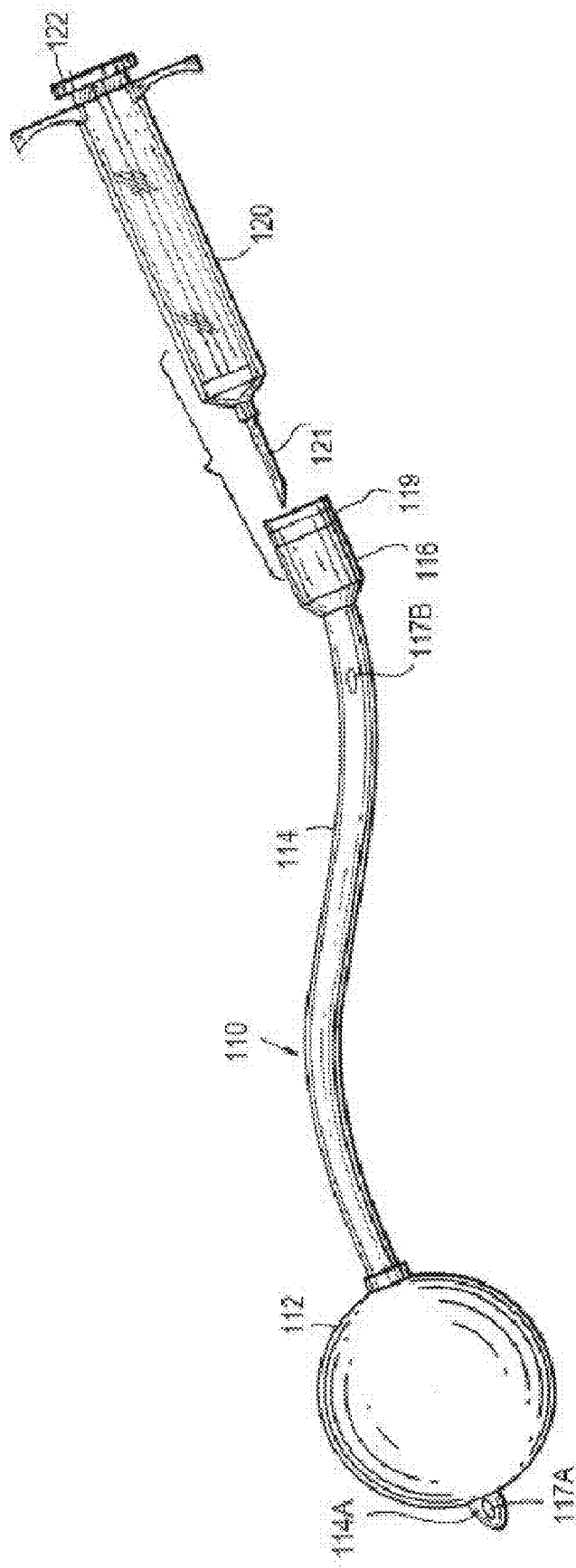
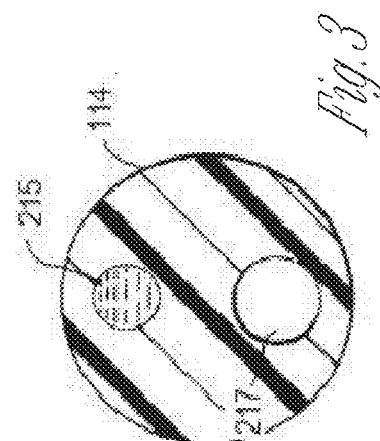
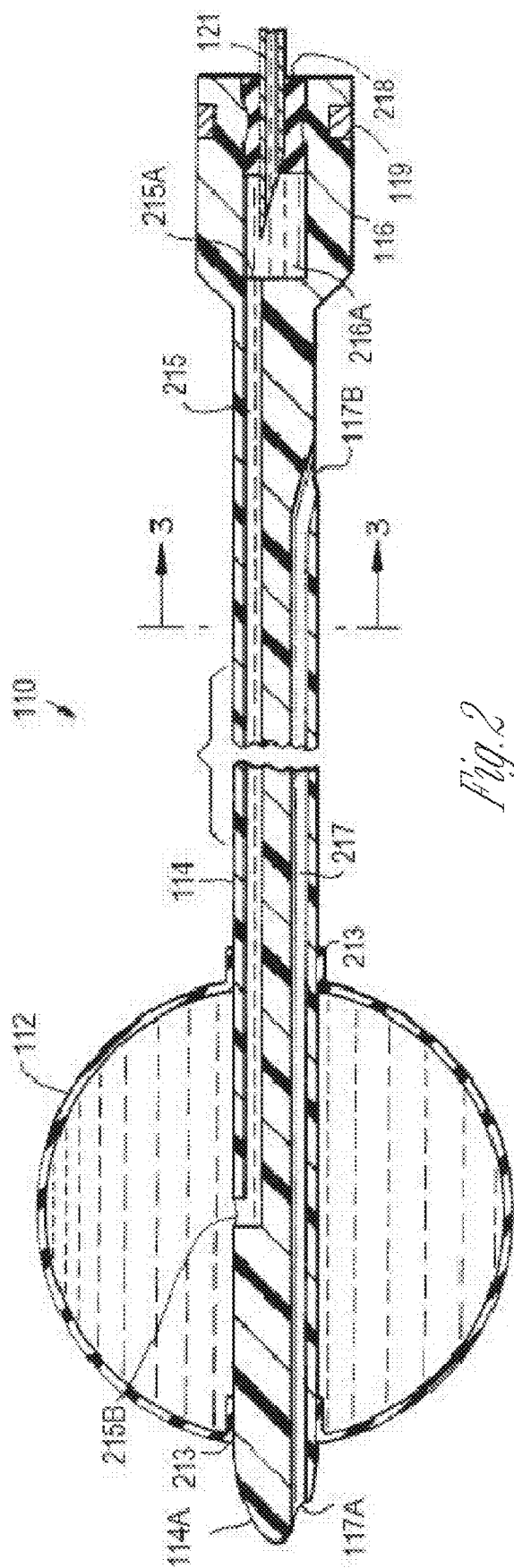


Fig. 1



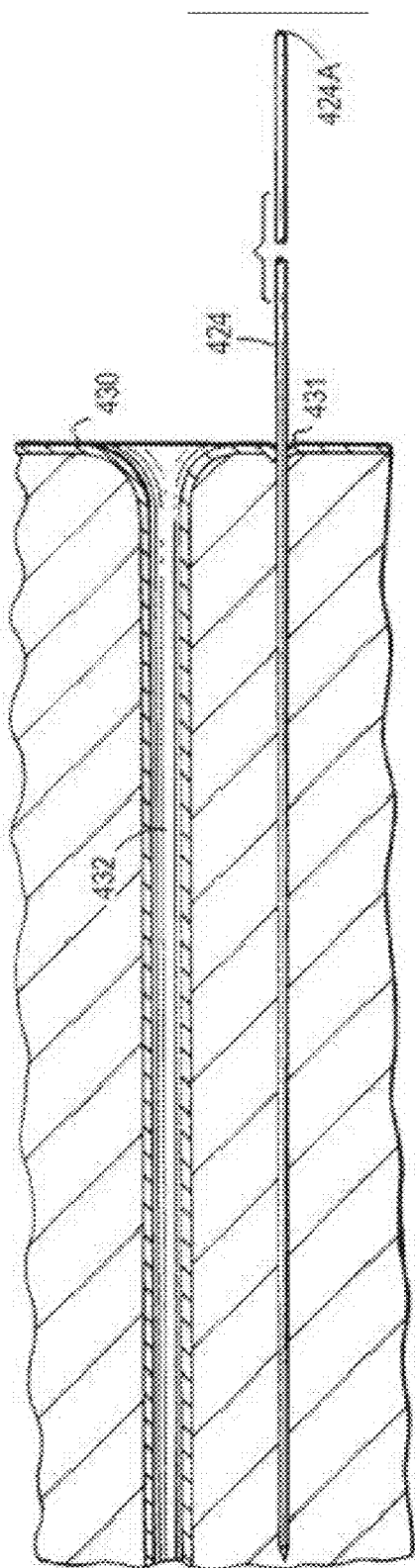


Fig. 4

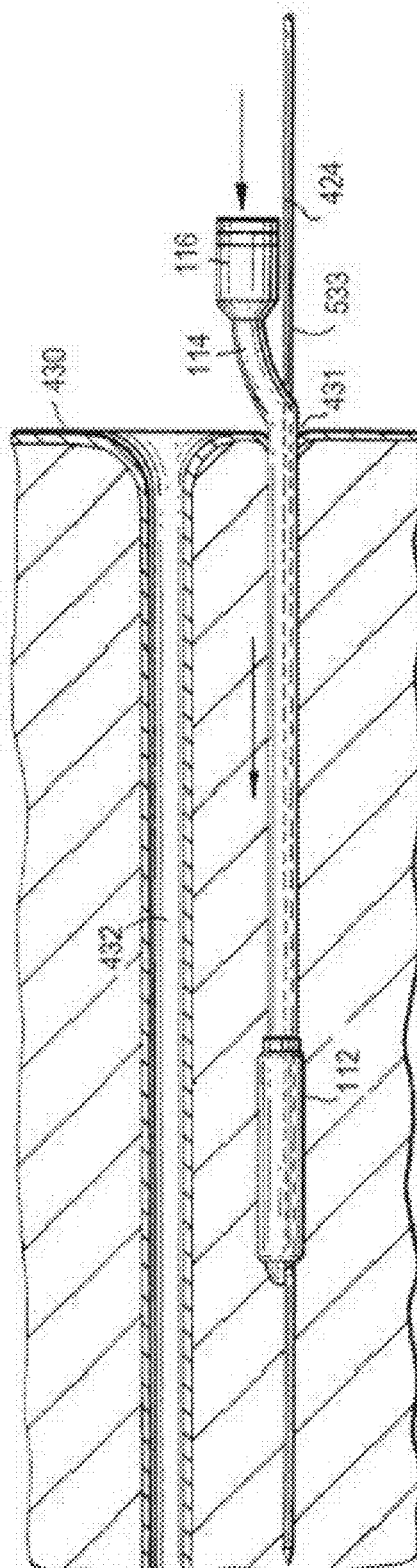


Fig. 5

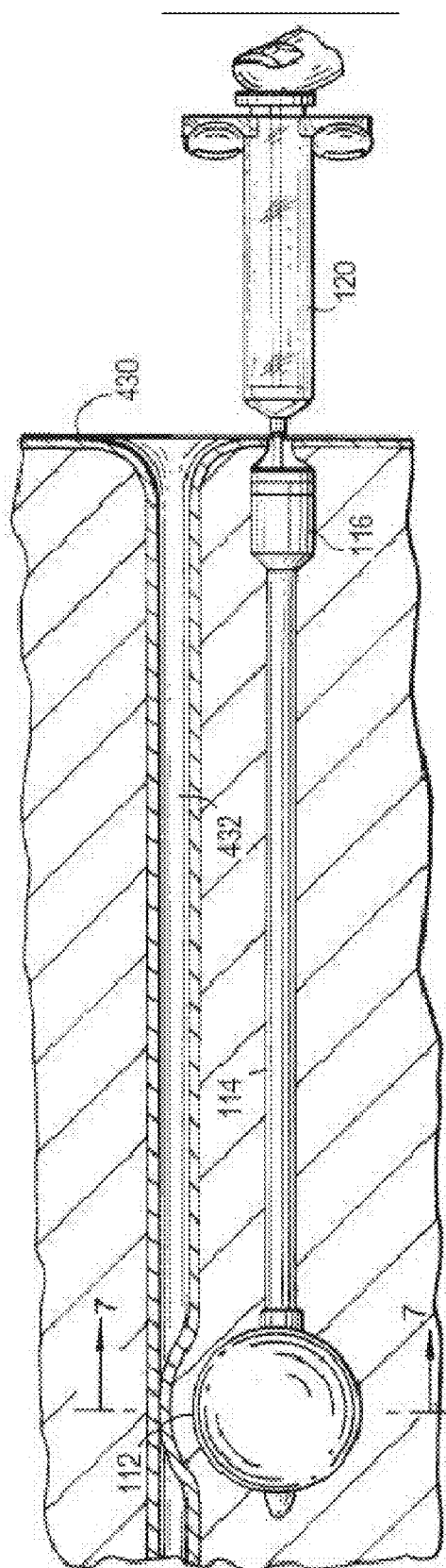


Fig. 6

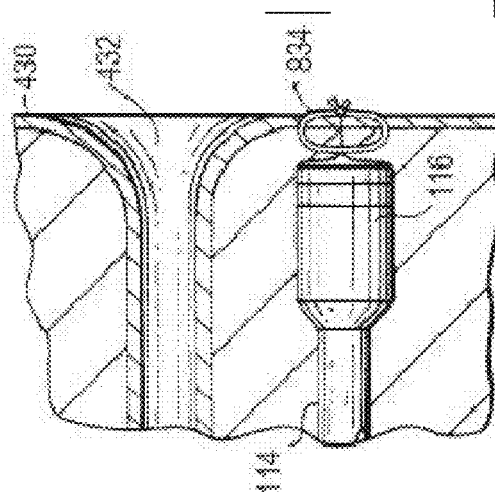


Fig. 8

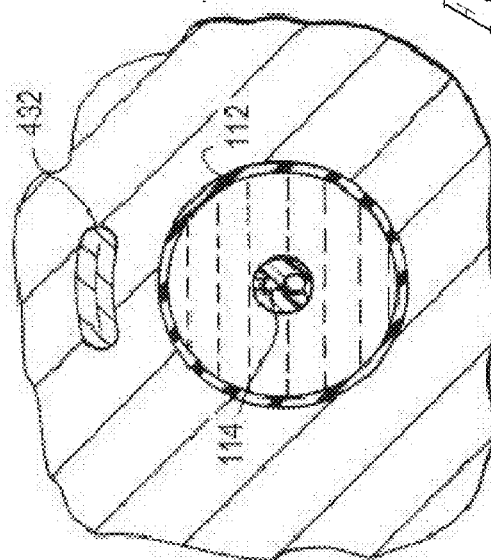
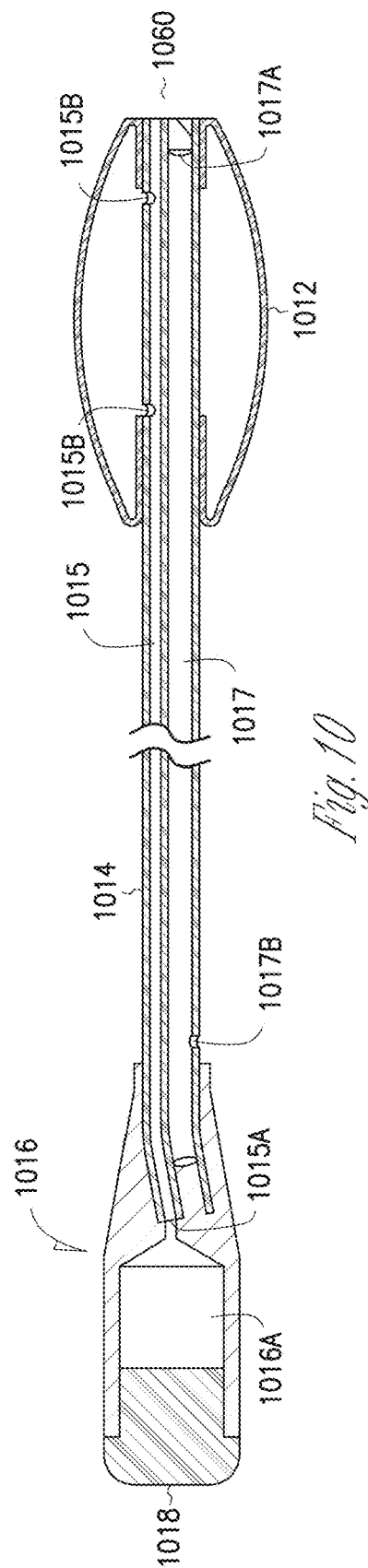
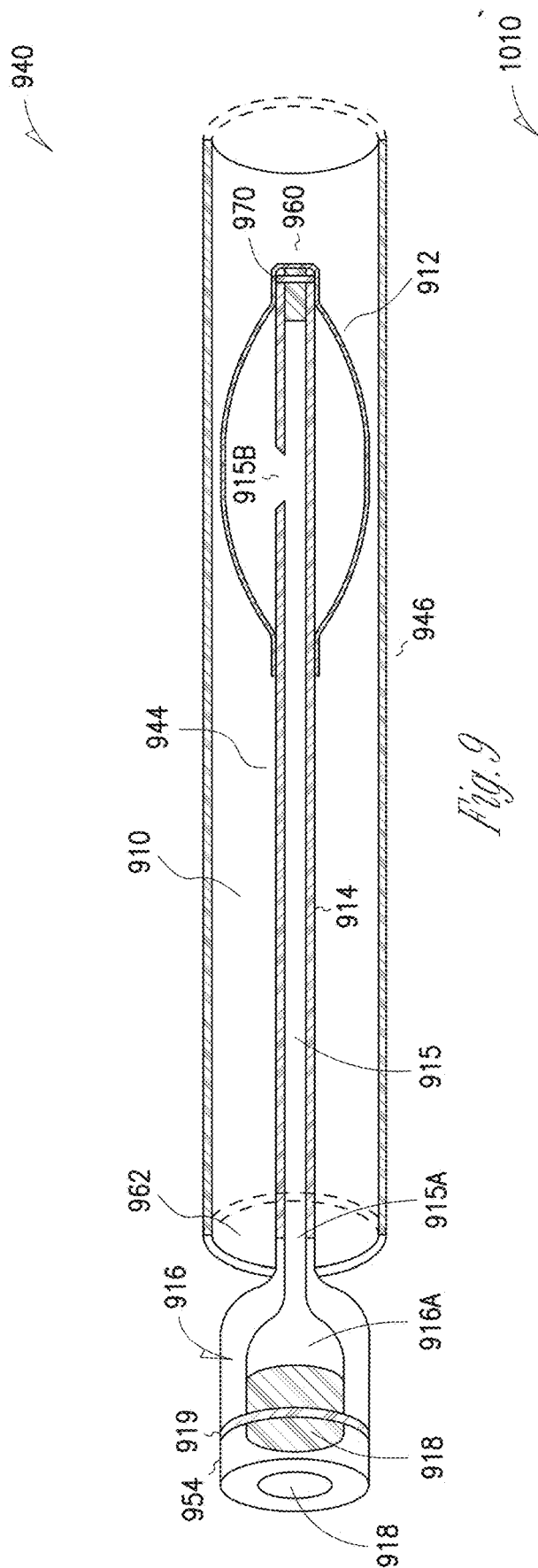


Fig. 7



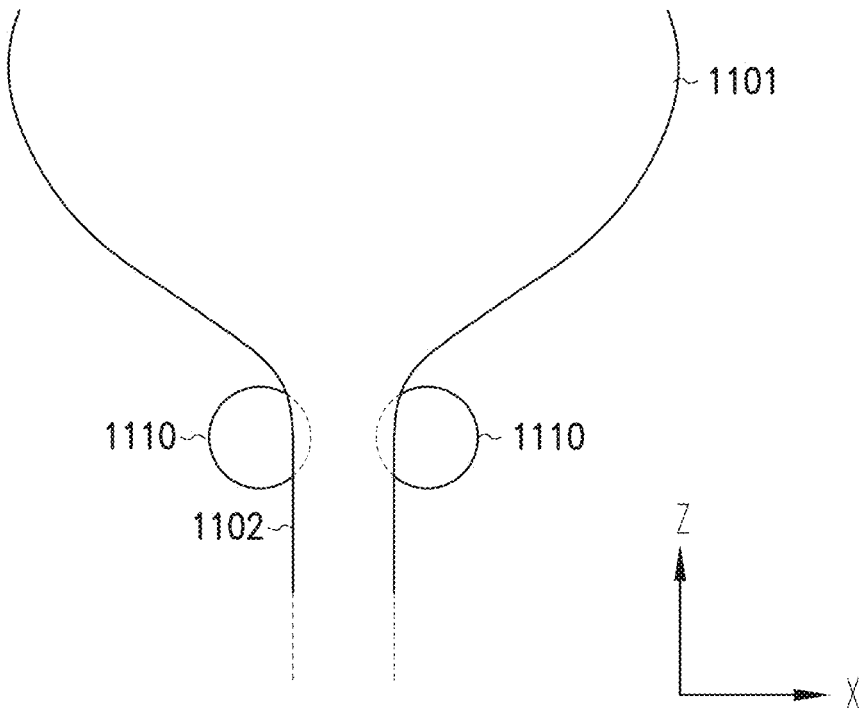


Fig. 11

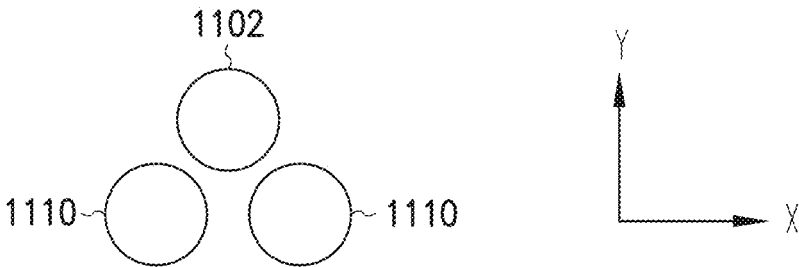


Fig. 12

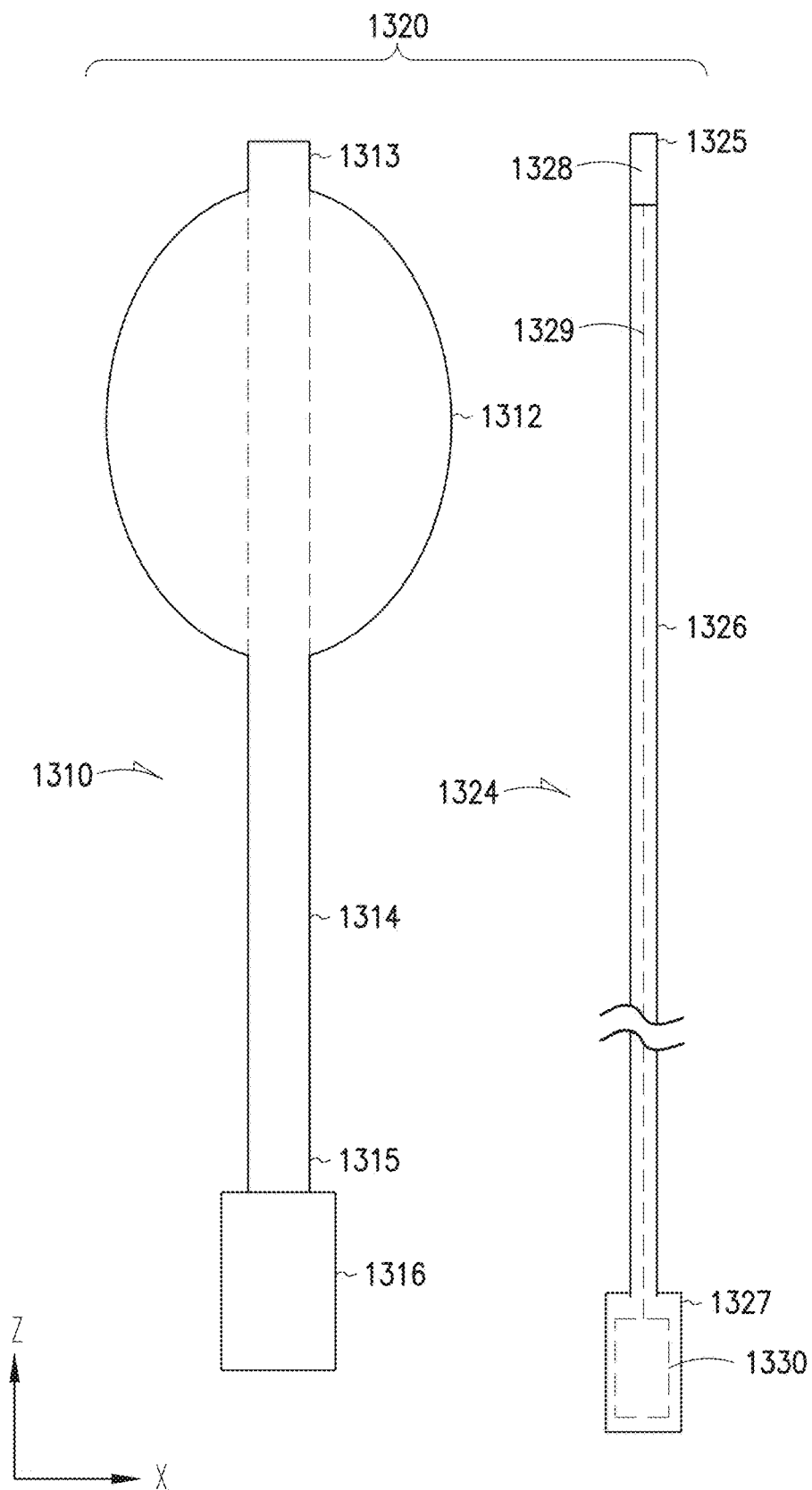


Fig. 13

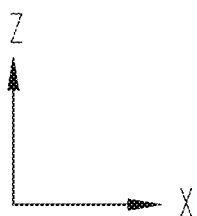
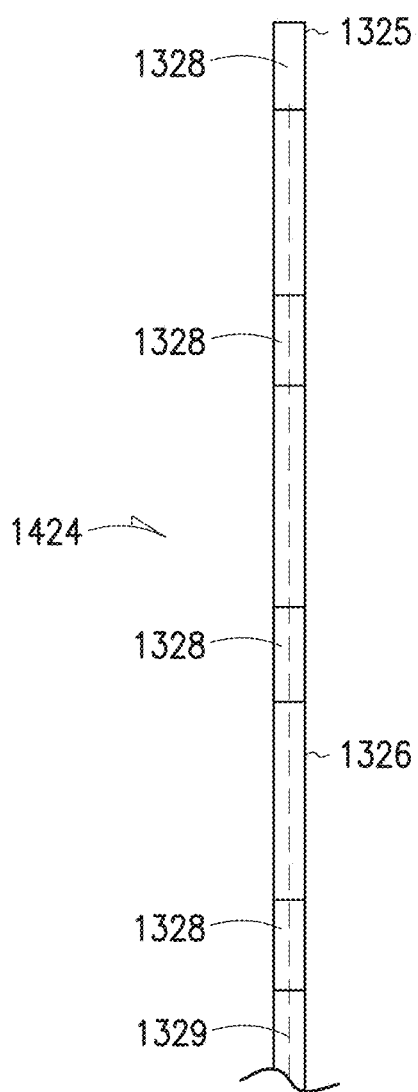


Fig. 14

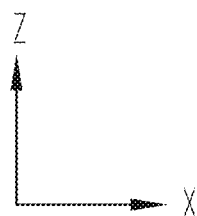
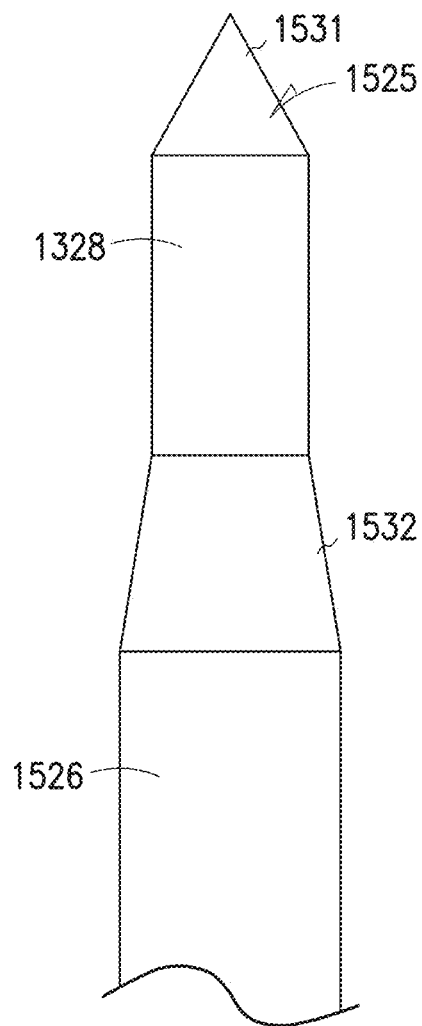


Fig. 15

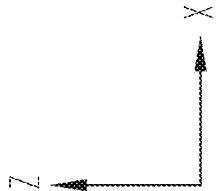
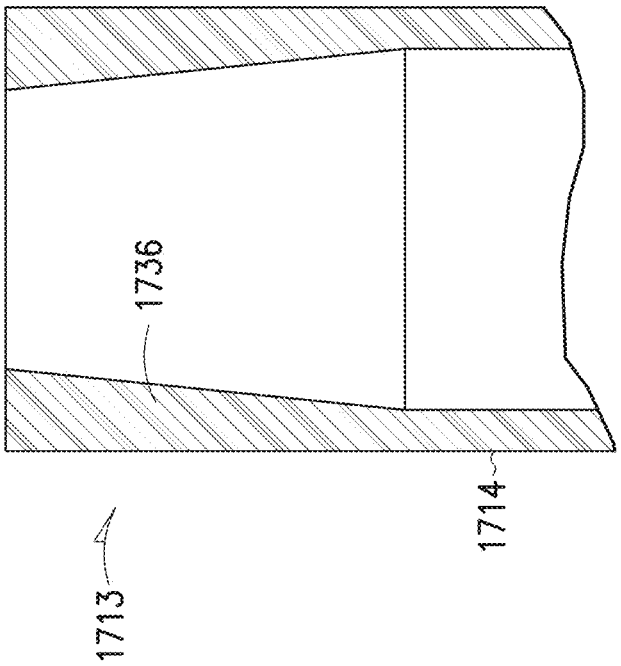


Fig. 17

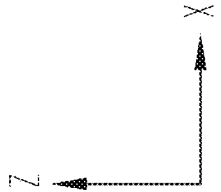
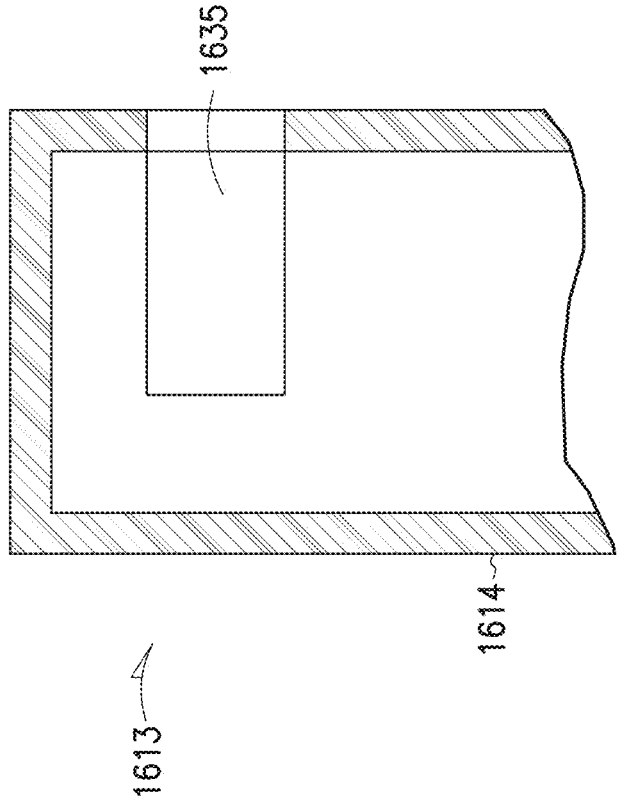


Fig. 16

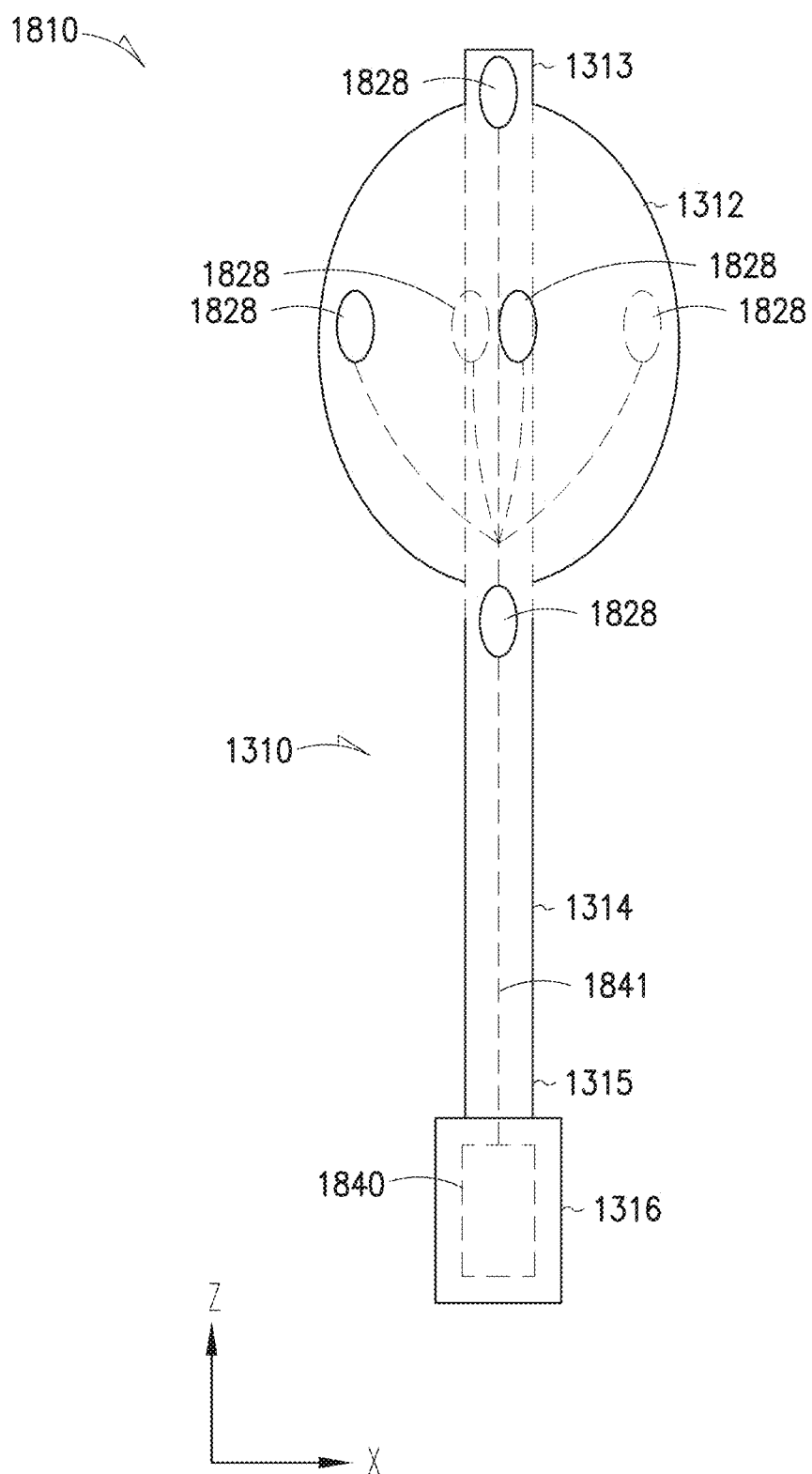


Fig. 18

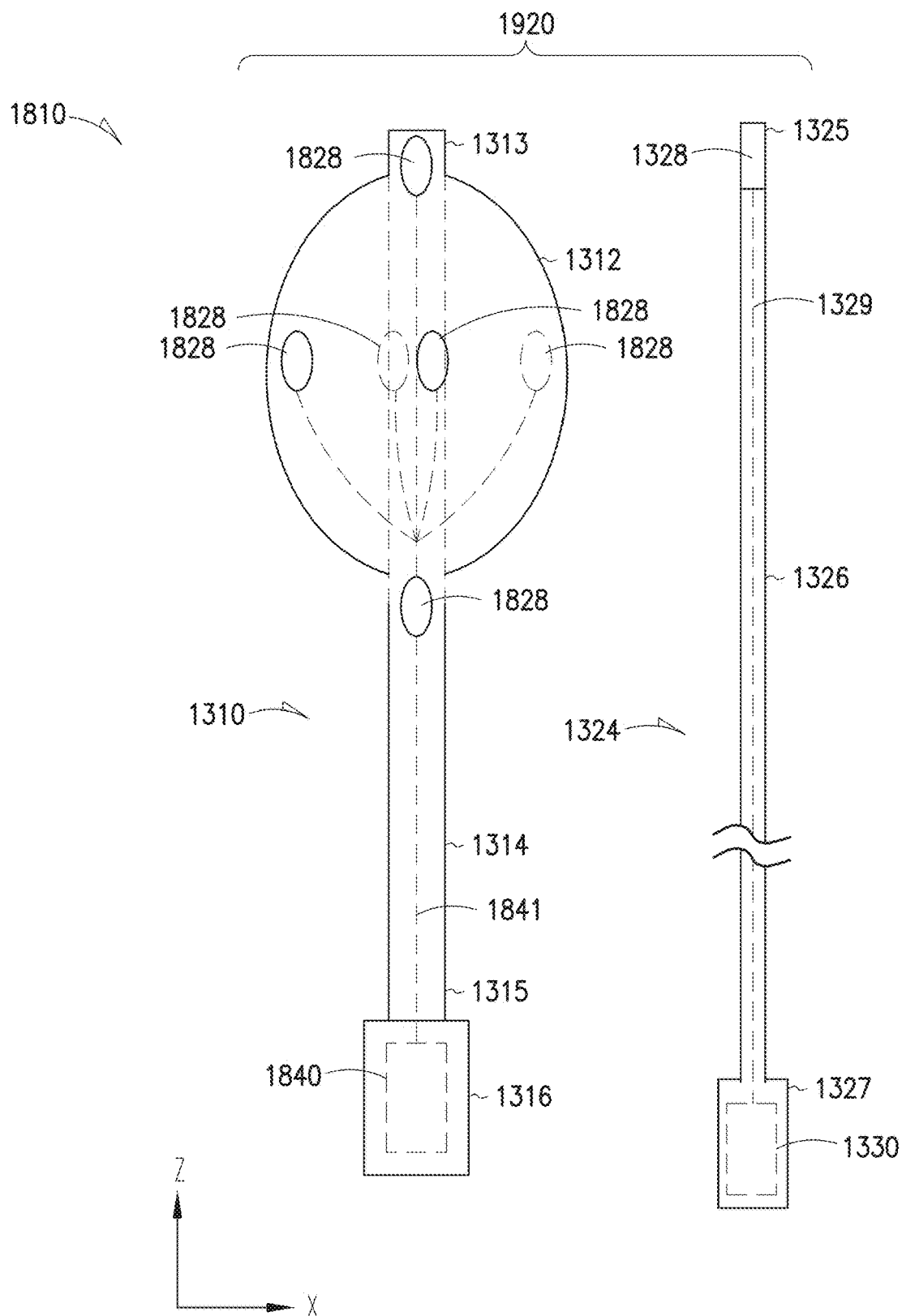


Fig. 19

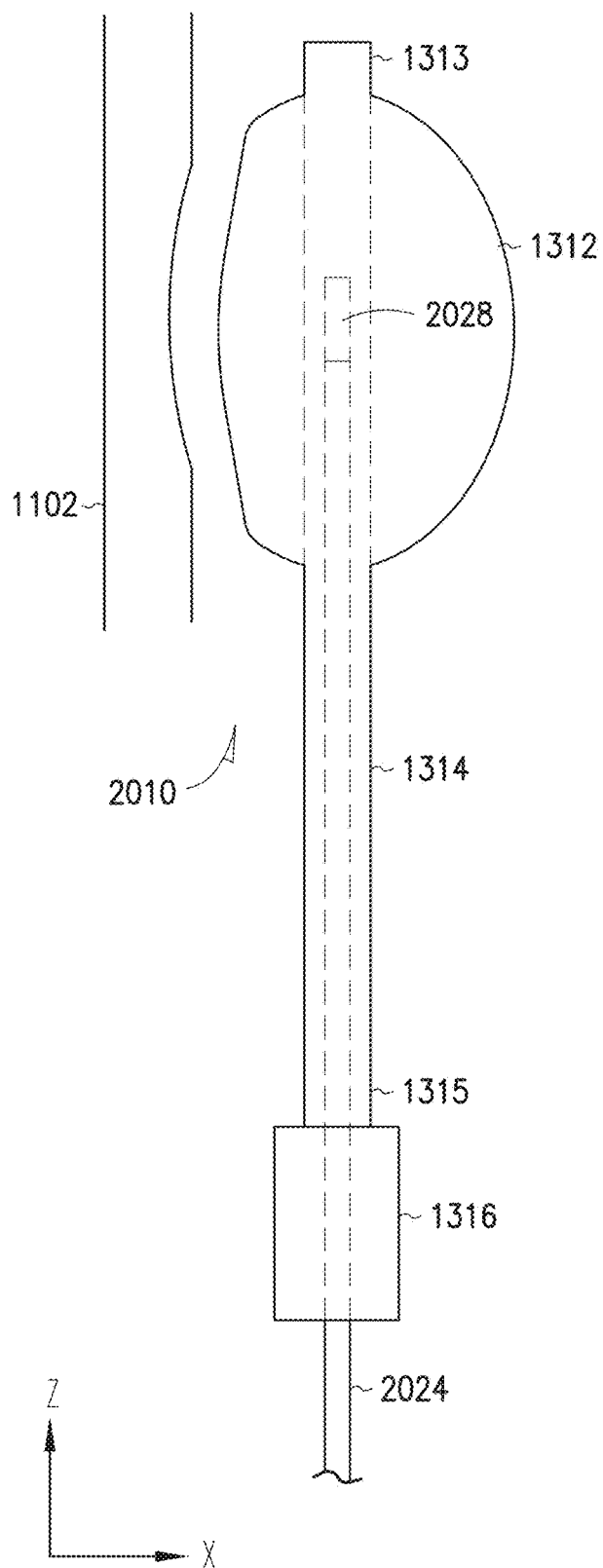


Fig. 20

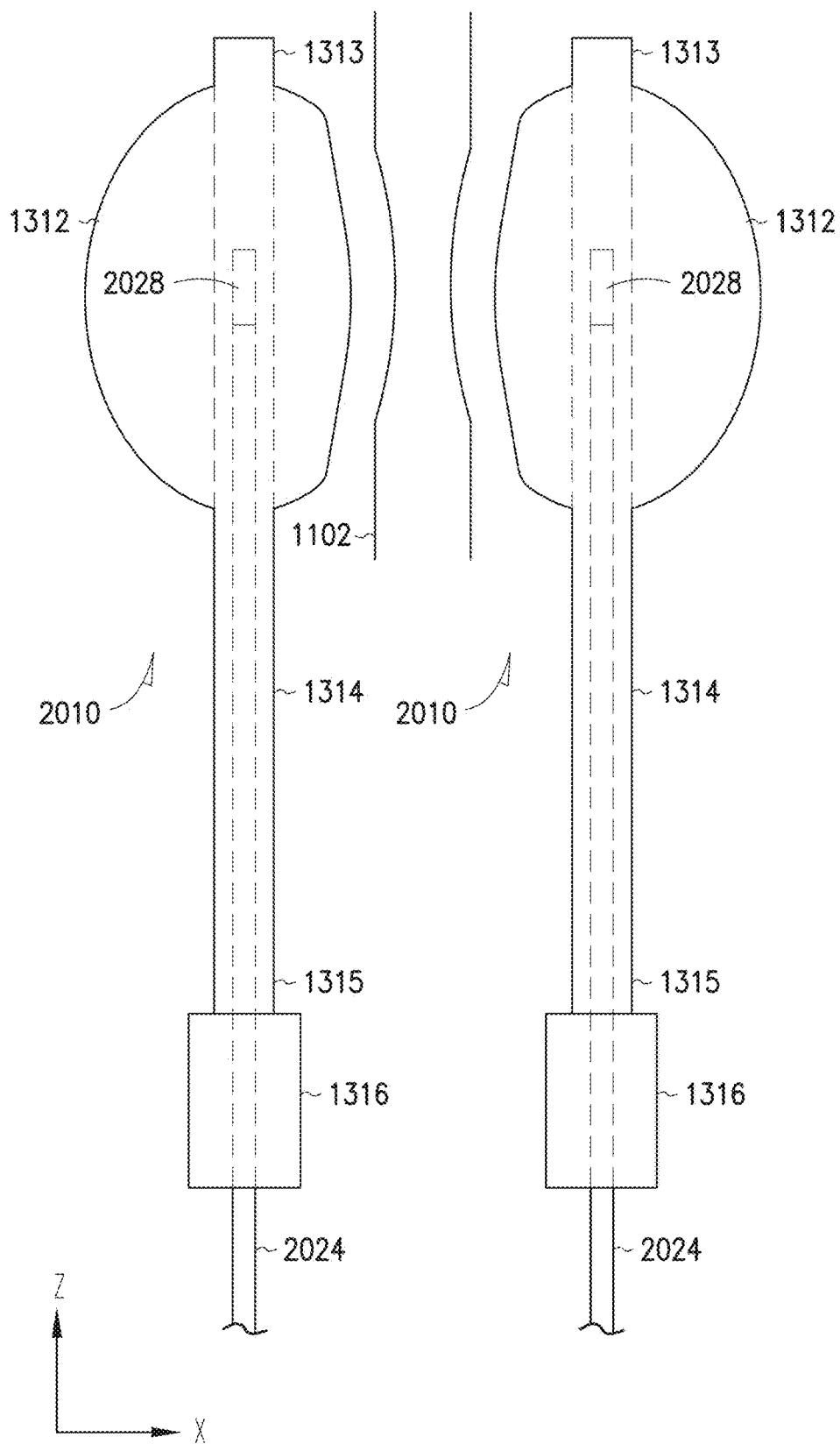


Fig. 21

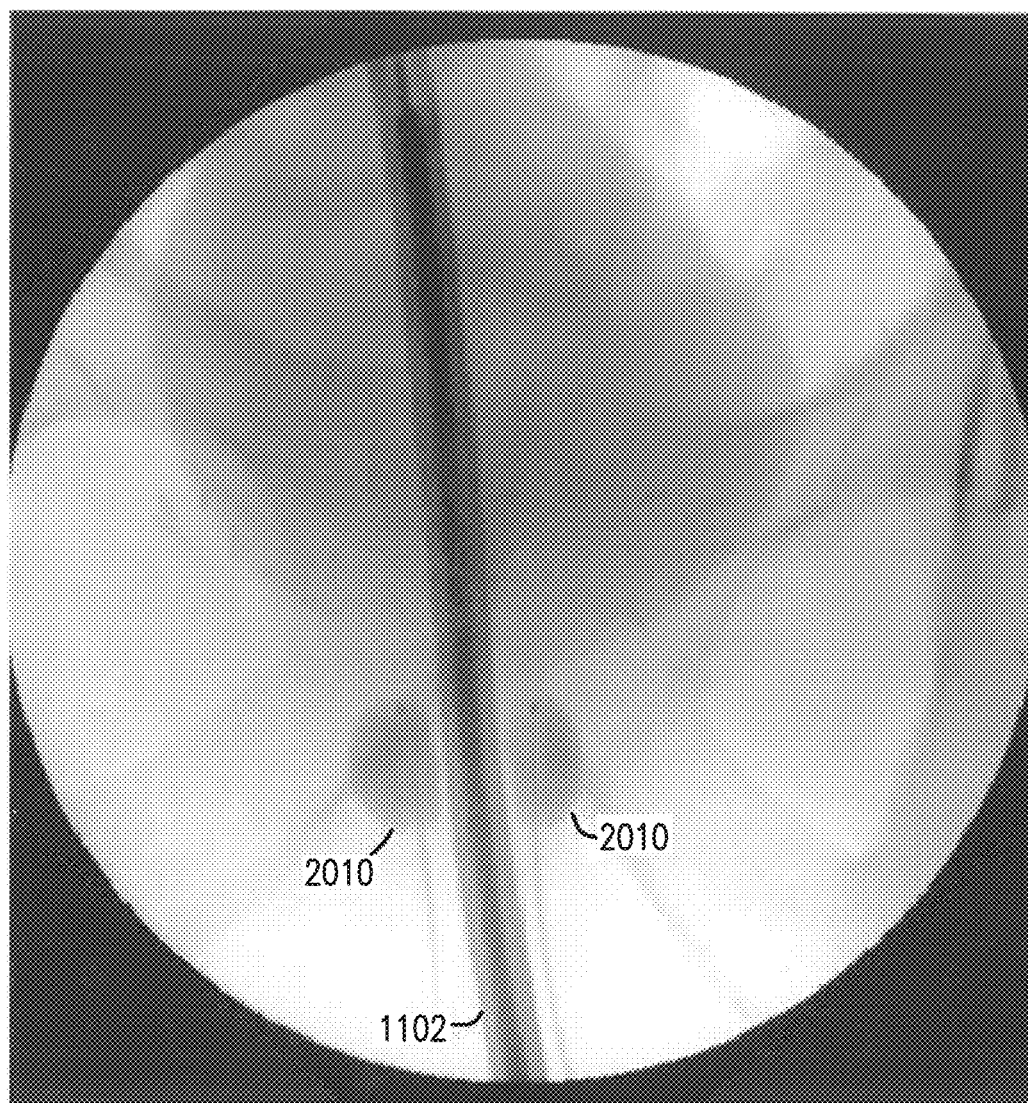
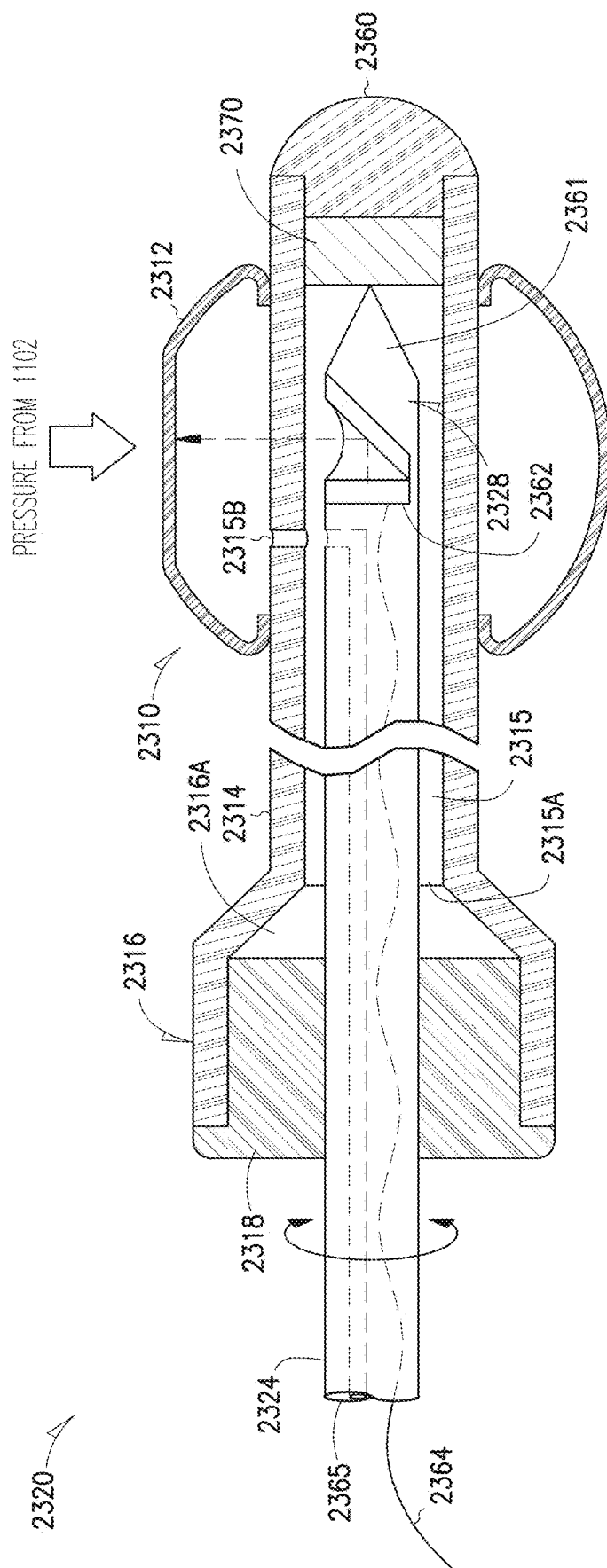


Fig. 22



METHOD AND APPARATUS FOR MONITORING IMPLANTABLE DEVICE FOR URINARY CONTINENCE

CLAIM OF PRIORITY

[0001] This application is a divisional application of U.S. patent application Ser. No. 16/450,246, filed Jun. 24, 2019, now issued as U.S. Pat. No. 11,510,766, which claims the benefit of priority under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application Ser. No. 62/805,503, entitled “METHOD AND APPARATUS FOR MONITORING URINARY INCONTINENCE IMPLANTABLE DEVICE”, filed on Feb. 14, 2019, which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] This document relates generally to implantable medical devices and more particularly to a method and system for monitoring placement and/or adjustment of an implantable devices for treating urinary incontinence.

BACKGROUND

[0003] An example of an implantable device for treating urinary incontinence includes an adjustable membrane element, such as a balloon, connected to a rear port with a conduit. The implantable device can be implanted in a patient with the adjustable membrane element placed adjacent to the patient's urethra and the rear port placed underneath the patient's skin by a minimally invasive surgery. The adjustable membrane element can be adjusted during and after the surgery by injecting fluid into the rear port or extracting fluid from the rear port percutaneously using a needle. In an exemplary treatment, two of such implantable devices are placed in the patient such that the two adjustable membrane elements provide pressure and support at the patient's bladder neck to protect against accidental leaking of urine during sneeze, cough, or physical activity. The efficacy of this treatment depends on proper placement in the patient and adjustment of the adjustable membrane element after the placement.

SUMMARY

[0004] One or more sensors are incorporated onto one or more of an implantable device and a surgical tool used for placement and/or adjustment of the implantable device. The implantable device includes an adjustable membrane element for controllable coaptation of a body lumen, such as coaptation of a urethra as treatment for urinary incontinence. In various embodiments, the one or more sensors can be configured to detect information indicative of at least one of a shape of the adjustable membrane element, a position of the adjustable membrane element relative to the body lumen, or a shape of the body lumen.

[0005] In various embodiments, an implantable device for controllable coaptation of a body lumen can include an adjustable membrane element and an elongate conduit. The adjustable membrane element can include a continuous wall having an inner surface defining a chamber. The elongate conduit can include a peripheral surface connected to and sealed to the adjustable membrane element, a rear end, a front end, and a lumen extending longitudinally in the elongate conduit from a first opening at the rear end to a second opening in fluid communication with the chamber of

the implantable device for adjustably expanding or contracting the adjustable membrane element by applied flowable material introduced through the first opening. One or more sensors can be incorporated into the implantable device and/or a sensor probe for monitoring positioning of the implantable device, adjustment of the implantable device, and/or state of coaptation of the body lumen. In one embodiment, one or more sensors are incorporated onto at least one of the adjustable membrane element or the elongate conduit of the implantable device. In another embodiment, a sensor probe includes a front end into which a sensor incorporated. In one embodiment, the lumen of the elongate conduit is configured to accommodate a portion of the sensor probe including its front end. In another embodiment, the implantable device includes another lumen extending longitudinally in the elongate conduit and having an inlet configured to receive a portion of the sensor probe and a closed end to stop the sensor probe or an outlet configured to allow a portion of the sensor probe including its front end to exit. In various embodiments, the one or more sensors can include one or more optical sensors, such as cameras or borescopes, and/or one or more ultrasonic transducers for producing an ultrasonic image.

[0006] This summary is an overview of some of the teachings of the present application and not intended to be an exclusive or exhaustive treatment of the present subject matter. Further details about the present subject matter are found in the detailed description and appended claims. The scope of the present invention is defined by the appended claims and their legal equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a perspective view of an implantable device and a syringe source for providing a flowable material to an adjustable membrane element of the implantable device, according to an embodiment of the present subject matter.

[0008] FIG. 2 is a longitudinal cross-sectional view of the implantable device shown in FIG. 1, according to an embodiment of the present subject matter.

[0009] FIG. 3 is a cross-sectional view taken along line 3-3 of FIG. 2, according to an embodiment of the present subject matter.

[0010] FIG. 4 illustrates a guide probe inserted into body tissue to an implant location adjacent a body lumen of a patient prior to insertion of the implantable device, according to an embodiment of the present subject matter.

[0011] FIG. 5 shows the implantable device placed over the guide probe and partially advanced to the desired location with the adjustable membrane element being deflated, according to an embodiment of the present subject matter.

[0012] FIG. 6 shows the implanted device after being expanded at the desired location in the body tissue of the patient to displace body tissue toward the body lumen for causing adjustable restriction of the body lumen, according to an embodiment of the present subject matter.

[0013] FIG. 7 is a cross-sectional view taken along line 7-7 of FIG. 6, according to an embodiment of the present subject matter.

[0014] FIG. 8 shows the implantable device after being inserted with its rear port underneath the skin of a patient, according to an embodiment of the present subject matter.

[0015] FIG. 9 is a schematic of another implantable device, according to an embodiment of the present subject matter.

[0016] FIG. 10 is a schematic of another implantable device, according to an embodiment of the present subject matter.

[0017] FIG. 11 is a top view showing approximate target sites of placement of implantable devices to improve coaptation of a urethra, according to an embodiment of present subject matter.

[0018] FIG. 12 is a view along the length of the urethra in the area of implantation showing approximate target sites of placement of implantable devices to improve coaptation of a urethra, according to an embodiment of present subject matter.

[0019] FIG. 13 is an illustration of an implantable device and a sensor probe, according to an embodiment of present subject matter.

[0020] FIG. 14 is an illustration of a portion of a sensor probe, according to an embodiment of present subject matter.

[0021] FIG. 15 is an illustration of a front end of a sensor probe, according to an embodiment of present subject matter.

[0022] FIG. 16 is a cross-sectional view of a portion of a front end of an implantable device, according to an embodiment of present subject matter.

[0023] FIG. 17 is a cross-sectional view of a portion of a front end of an implantable device, according to an embodiment of present subject matter.

[0024] FIG. 18 is an illustration of an implantable device with one or more sensors, according to an embodiment of present subject matter.

[0025] FIG. 19 is an illustration of an implantable device kit, according to an embodiment of present subject matter.

[0026] FIG. 20 is an illustration of coaptation of a body lumen using an implantable device, according to an embodiment of present subject matter.

[0027] FIG. 21 is an illustration of coaptation of a body lumen using two implantable devices, according to an embodiment of present subject matter.

[0028] FIG. 22 is an image showing two implantable devices implanted in a patient adjacent to a body lumen for coaptation of that body lumen, according to an embodiment of present subject matter.

[0029] FIG. 23 is an illustration of a single-lumen implantable device and a sensor probe, according to an embodiment of present subject matter.

DETAILED DESCRIPTION

[0030] The following detailed description of the present subject matter refers to subject matter in the accompanying drawings which show, by way of illustration, specific aspects and embodiments in which the present subject matter may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the present subject matter. References to “an”, “one”, or “various” embodiments in this disclosure are not necessarily to the same embodiment, and such references contemplate more than one embodiment. The following detailed description is demonstrative and not to be taken in a limiting sense. The scope of the present subject matter is defined by the appended claims, along with the full scope of legal equivalents to which such claims are entitled.

[0031] This document discusses, among other things, a system and method for monitoring placement and/or adjustment of an implantable device for treating urinary incontinence. The implantable device can include, for example, an adjustable membrane element connected to a rear port with a conduit that has a lumen providing for fluid communication between a chamber of the adjustable membrane element and an interior cavity of the rear port. Various structural elements of the implantable device (e.g., the implantable device 110 shown in FIG. 1) discussed in this document may each be referred to by various terms. The “adjustable membrane element” (e.g., the adjustable membrane element 112 shown in FIG. 1) can also be referred to as, for example, an adjustable element, an expandable element, an expandable membrane element, a forward expandable membrane element, a balloon, or an adjustable balloon. The “conduit” (e.g., the conduit 114 shown in FIG. 1) can also be referred to as, for example, a central conduit element, a device conduit, a connecting conduit, a connecting conduit tube, or a tubular elongate body. The “rear port” (e.g., the rear port 116 shown in FIG. 1) can also be referred to as, for example, a rearward port portion or a rear port element. The “lumen” (e.g., the first lumen 215 and the second lumen 217 shown in FIG. 2) can also be referred to as, for example, a passageway, an inner passageway, or an interior passageway.

[0032] In an example, the implantable device includes an adjustable balloon connected to a port with a conduit. The balloon is placed adjacent the urethra to exert non-circumferential compression upon the urethral wall. The effectiveness of the therapy depends on proper positioning of the balloon in a patient's body, such as in retropubic space (resulting from a radical prostatectomy) near the urethra-vesical anastomosis above the urogenital diaphragm in close proximity to the urethral walls. When two balloons (e.g., of two implantable devices) are used, their preferred positioning is usually symmetrical and lateral with respect to the urethra. Fluoroscopy or transrectal ultrasonography can be used to visually monitor the positioning of the balloon(s) during the implantation of the implantable device(s). Fluoroscopy has become a standard technique, but exposes the patient to radiation and provides a two-dimensional view that presents viewing difficulties under some circumstances. For examples, when the patient is on operation table, the fluoroscopic image does not show the location of the balloons on the anterior-posterior plane, and therefore does not show whether the balloons are properly positioned to exert compression upon the urethral wall. Transrectal ultrasonography (TRUS) can provide for better viewing (e.g., the location of the balloons on the anterior-posterior plane) but requires the surgeon to be familiar with this imaging technique. During an implantable process, implantable device(s) are initially placed in the patient with the balloon(s) positioned in the target space(s). The balloon(s) can be left slightly inflated to allow for encapsulation (by the patient's tissue) without migration from the target space(s). After the encapsulation, the patient will go through one or more adjustment procedures during which the balloon(s) are adjusted to obtain and maintain urinary continence without causing undesirable obstruction.

[0033] The present subject matter uses one or more sensors incorporated onto the implantable device and/or a surgical tool for implanting the implantable device to monitor the placement and/or adjustment of the implantable device(s). This monitoring technique avoids use of fluoros-

copy or transrectal ultrasonography and their disadvantages such as exposure to x-ray or rectal insertion of ultrasonic probe. In one embodiment, the one or more sensors include one or more ultrasonic transducers on the implantable device and/or the surgical tool allow for ultrasonic imaging to be used to monitor the placement and adjustment of the balloon(s) during device implantation. The ultrasonic sensor(s) on the implantable device can further allow for post-operative adjustment of the balloon(s).

[0034] In various embodiments, the present subject matter provides sensing means for monitoring, for example, location of each balloon and amount of inflation (expansion) of each balloon. In various embodiments, the sensing means can also be used for monitoring various states of the urethra that can indicate an amount of compression resulting from a degree of expansion of the balloon, such as excessive compression resulting from over-inflation of the balloon, adequate compression (target of the treatment), and insufficient compression resulting from under-inflation of the balloon. The target of the treatment is to provide the patient with continence without undesirable obstruction, and this requires the right amount of coaptation of the urethra resulting from placing the balloon(s) in the right position(s) and giving each balloon the right amount of inflation. The present subject matter allows for determination of the right position and right amount of inflation for each balloon.

[0035] FIGS. 1-10 illustrate various embodiments of an implantable medical device and a surgical tool. The surgical tool includes an elongate body and can be used as a base device onto which the one or more sensors can be incorporated. The implantable medical device can be used with the surgical tool including the sensor(s), or can be used as a base device onto which the one or more sensors can be incorporated. The various embodiments of the implantable device and the surgical tool are illustrated in FIGS. 1-10 and discussed below by way of example, and not by way of restriction. These examples as well as additional examples of the implantable device and the surgical tool are discussed in U.S. Pat. Nos. 5,964,806, 6,045,498, 6,419,624, 6,579,224, and 8,926,494, all assigned to UroMedica, Inc., which are incorporated by reference herein in their entireties. FIGS. 11-23 illustrate various embodiments of the one or more sensors incorporated onto an implantable device and/or a surgical tool such as those discussed in the document.

[0036] According to the present subject matter as shown by FIG. 1, there is provided an elongate implantable device 110, which includes an adjustable membrane element 112 shown in its full expanded size, and is attached pressure-tightly to an elongate conduit 114, which is connected to a rear port 116 communicating with the expandable element 112 through a first lumen 215 (see FIG. 2). The conduit 114 has a pointed forward end 114A which extends slightly beyond the expandable element 112. A syringe 120 including a hollow needle 121 and a rear axially-movable plunger 122 is provided for adjustably injecting a suitable flowable material into the implantable device 110 through the rear port 116 to expand the adjustable membrane element 112.

[0037] As further shown in FIGS. 2 and 3, the conduit 114 contains two elongate lumens or passageways. The first lumen 215 provides an internal passage by which the flowable material is directed from a cavity 216A in the rear port 116 to expand the adjustable membrane element 112. The conduit 114 is attached integrally to the rear port 116 at its rearward end. A second lumen 217 extends from a front

opening 117A to a rearward opening 117B and serves to receive an elongate guide probe (see FIG. 4) and effect delivery of the implantable device 110 to a desired location in the body tissue of a patient.

[0038] An important feature of the implantable device 110 having the first lumen 215 includes a first opening port 215A located in cavity 216A of the rear port 116 between an elastic septum 218 and the conduit 114 and is connected to the first lumen 215, so that a flowable material can be infused therethrough, and a second port 215B serves to direct the working fluid to the adjustable membrane element 112. During adjustment of the volume of the membrane fluid provided from a hollow needle 121 of syringe 120, is infused through the septum 218 and continues through the conduit 114 connected to the adjustable membrane element 112. The rear port 116 preferably has a diameter greater than conduit 114 to accommodate the cavity 216A and the septum 218, which is retained securely by a clamp ring 119.

[0039] The entire implantable device 110 including the adjustable membrane element 112 is formed of a biocompatible material such as silicone or polyurethane elastomer, and the conduit 114 and the rear port 116 may be formed as a unitary construction. Optionally, the adjustable membrane element 112, the rear port 116, and the conduit 114 can be molded as one piece. As shown in FIG. 2, the adjustable membrane element 112 is adhered at 213 to conduit tube 114 at its forward end by a suitable adhesive material.

[0040] The implantable device and assembly according to the present subject matter can include three main members. The first member provided is an elongate guide in the form of a stiff solid elongate guide probe 424 (see FIG. 4) configured for delivery of the implantable device 110 to the desired site in the body tissue of a patient as generally shown by FIGS. 4 and 5. Alternatively, the elongate guide member can be in the form of a flexible guidewire which has been initially delivered into the body tissue through a separate hollow stiff probe that has been inserted to the desired location in the body tissue. The second member of the assembly is the implantable device 110 which includes the adjustable membrane element 112, the conduit 114 containing the two lumens 215 and 217, and the rear port 116. During its implantation, the implantable device 110 is guided to a pre-determined location adjacent a body lumen in a patient's body after the elongate solid guide probe 424 is first surgically inserted into the body tissue of the patient to establish an initial pathway. The lumen forward end opening 117A of the implantable device 110 is then disposed over the rear end of the guide probe 424 to guide the implantable device 110 and deliver the adjustable membrane element 112 (in its contracted shape) to the pre-determined location in the body tissue adjacent to the lumen which is to be adjustably restricted. The diameter of the second lumen 217 is made slightly larger than that of the guide probe 424 to permit the implantable device 110 to slide easily over the probe member.

[0041] During the implantation of the implantable device 110, a physician can first make a small incision in the skin 430 of the patient near a body lumen 432 that needs to be restricted, and then by visualization means such as fluoroscopy or ultrasonic imaging, the solid guide probe 424 is directed to the desired location, depending upon the anatomy of the patient. Thereafter, the opening 117A of the second lumen 117 of the conduit 114 with the adjustable membrane element 112 in its initial deflated or contracted

condition, is slid over the rear end 424A of the guide probe 424. The guide probe 424 slides through the second lumen 217 of the conduit 114 and exits at the rearward opening 117B. As illustrated in FIG. 2, the opening 117B is between the adjustable membrane element 112 and the rear port 116. However, it may be advantageous to locate the opening 117B close to the adjustable membrane element 112 or, alternatively, to have the second lumen 217 extend through the rear port 116.

[0042] If desired, a mark 533 can be provided on the guide probe 424 which when aligned with a feature on the implantable device 110 such as the rear port 116 can assure that the implantable device 110 is appropriately placed at the correct depth in the patient's body tissue 430. It may be necessary to provide the conduit 114 in multiple lengths to facilitate placement of the septum 218 near the patient's skin. Alternatively, an effective length of the conduit 114 can be made adjustable by it having a helical shape similar to that of a coiled spring.

[0043] After the implantable device 110 has been advanced over guide probe 424 so that the contracted adjustable membrane element 112 is in the desired position adjacent to the body lumen 432, the body lumen 432 may be restricted to a desired degree by piercing septum 218 with the needle 121 of syringe 120 and injecting a flowable material through the first lumen 215 into the adjustable membrane element 112. The physician can determine the desired degree of restriction of body lumen 432 by means such as infusing fluid through the body lumen past the restriction and measuring the back pressure.

[0044] As illustrated by FIGS. 1 and 6, the source of flowable material is usually a syringe 120 with a hollow needle used to pierce the elastic septum 218. However, alternate fluid containers with means for making a reversible connection to the implantable device 110 could be used. The flowable material may be, for example, a saline solution, a flowable gel, or a slurry of particles in a liquid carrier. It may be advantageous to make the flowable material radiopaque so that the degree of membrane inflation may be viewed by x-ray.

[0045] An alternative method of delivery of the implantable device 110 can be to first withdraw the guide probe 24 from the body tissue and then inflate the adjustable membrane element 112. A further alternative would be to first place the implantable device 110 over the solid guide probe 424 outside the body and then insert them both into the body tissue as a unit. To facilitate this latter procedure, it may be desirable that there be some friction between the solid guide probe 424 and the second lumen 217 in the conduit 114.

[0046] After the implantable device 110 has been properly positioned with the adjustable membrane element 112 located near the body lumen 432 and the septum 218 in the rear port 116 located near the skin 430, the device is injected with a flowable material from the syringe 120. The expandable member can be inflated to a certain extent and then deflated to an extent suitable for encapsulation of the expandable member by body tissue. The guide probe 24 is then withdrawn from the device, leaving the slightly expanded membrane element in the body tissue. Then the skin incision 431 is closed over the port 116 by means such as a suture 834 as shown in FIG. 8.

[0047] The present subject matter provides the implantable device 110 with adjustability of the membrane expansion post-operatively. This adjustability is effected because

the septum 218 is located remote from the adjustable membrane element 112 but near and under the patient's skin. The port and septum is located by, for instance, manual palpation of the skin region and the needle of the syringe is inserted through the skin and septum to add or remove material from the expandable member, thus increasing or decreasing the restriction of the body lumen.

[0048] To assure proper sealing of the septum 218, it is placed in compression within a cavity 216A by providing a tight metal ring 119 that surrounds the rear port 116 and is smaller in diameter than the port. When the needle 121 of the syringe 120 is withdrawn from the septum 218 after expansion or adjustment of the adjustable membrane element 112, there is positive sealing around the perimeter of the septum 218.

[0049] FIGS. 4-8 generally illustrate the method or procedure for properly implanting the implantable device 110 into the body tissue of a patient. As shown by FIG. 4, a physician, after locating the body lumen such as a urethra of the patient, makes a small incision 431 and inserts the guide probe 424 in the body tissue to a desired location adjacent the body lumen 432. This procedure is usually carried out under a local anesthetic with visual guidance, for instance under fluoroscopy, by the physician. Next, the physician takes the implantable device 110 and places it over the guide probe 424 through the second lumen 217 as shown in FIGS. 1 and 2. The guide probe 424 enters the rear opening 117B and exits the forward opening 117A. The implantable device 110, with the conduit 114 being sufficiently flexible, is advanced along the guide probe 424 into the body tissue.

[0050] After the desired location within the body tissue has been reached, a suitable flowable material is introduced into the implantable device 110 from a source such as the syringe 120 having hollow needle 121 inserted through septum 218 to at least partially expand the adjustable membrane element 112, as shown by FIG. 6. Next, the guide probe 424 is removed and the adjustable membrane element 112 is expanded further to the desired enlarged size for restriction of the body lumen 432. The syringe 120 is removed from the implantable device 110, after which the desired size of the adjustable membrane element 112 is maintained by the elastic septum 218. Next, the patient's incision at 431 is surgically closed over the port 116 and septum 218 by sutures at 834.

[0051] FIG. 9 is an illustration of an implantable device kit 940, showing a cross-sectional view, according to one embodiment of the present subject matter. The implantable device kit 940 includes an implantable device 910 having an adjustable membrane element 912 and an elongate conduit 914, where the conduit 914 includes at least a first lumen 915 which extends longitudinally in the conduit 914 from a first opening 915A at a rear end (also referred to as a proximal end) 962 to a second opening 915B, and where the implantable device 910 is shown positioned within a channel 944 of a sheath 946.

[0052] The implantable device kit 940 further includes a rear port 916, where the rear port 916 is coupled to the rear end 962 of the conduit 914. In one embodiment, the rear port 916 is coupled to the rear end 962 of the elongate body 914 using chemical adhesives, or alternatively, using sonic welding techniques as are known in the art. In an additional embodiment, the rear port 916 and rear end 962 are formed together in a polymer molding process, such as liquid injection molding, as are known in the art.

[0053] The rear port 916 includes a cavity 916A, where the cavity 916A is in fluid communication with the first opening 915A of the conduit 914. In one embodiment, the rear port 916 also includes an elastic septum 918 through which the cavity 916A is accessed, where the elastic septum 918 is a sealable after repeated pierces, for example, with a needle. In one embodiment, the elastic septum 918 is retained in the rear port 916 by a clamp ring 919 located around the rear port 916. In one embodiment, the clamp ring 919 is made of a biocompatible material, such as, for example, titanium. In one embodiment, the elastic septum 918 is made of a biocompatible material, such as, for example, silicone or polyurethane. The rear port 916 has an outer diameter defined by an outer surface 954 of the rear port 916. In one embodiment, the rear port 916 has an outer diameter of 1 to 15 millimeters, with 4.5 millimeters being a specific example.

[0054] In one embodiment, the outer surface of the rear port 916 and the adjustable membrane element 912 are of a size (e.g., a diameter) that is smaller than an inner size (e.g., a diameter) of the channel 944 to allow the implantable device 910 to be moved longitudinally through the channel 944 of the sheath 946. In an alternative embodiment, the rear port 916 is constructed of at least one material flexible enough to allow the size of the rear port 916 in its relaxed state to be compressed to a size sufficiently small so that the implantable device 910 can be moved longitudinally through the channel 944 of the sheath 946. In various embodiments, the conduit 914 has a stiffness sufficient to allow force applied at the rear end of its tubular elongate body to move the implantable device 910 at least partially through the channel 944 of the sheath 946. In one embodiment, the stiffness of the conduit 914 is determined based on the type of material used in constructing its tubular elongate body. Alternatively, support elements can be added to the tubular elongate body. For example, a metal coil can be placed longitudinally within the tubular elongate body to increase the stiffness of the tubular elongate body.

[0055] Once the implantable device 910 is positioned within a body, the adjustable membrane element 912 is inflated by releasably connecting a flowable material source to the rear port 916. In one embodiment, the flowable material source includes a syringe with a non-coring needle, where the needle is inserted through the elastic septum 918. A measured supply of fluid volume can be introduced into the implantable device 910, and the adjustable membrane element 912 expands or contracts due to a volume of flowable material introduced into the cavity 916A of the rear port 916 from the flowable material source. The adjustable membrane element 912 is then used to at least partially and adjustably restrict the body lumen. Fluids suitable for infusing into the prosthesis include, but are not limited to, sterile saline solutions, polymer gels such as silicone gels or hydrogels of polyvinylpyrrolidone, polyethylene glycol, or carboxy methyl cellulose for example, high viscosity liquids such as hyaluronic acid, dextran, polyacrylic acid, polyvinyl alcohol, or a radio-opaque fluid for example. Once the adjustable membrane element 912 has been inflated, the needle is withdrawn from the septum of the rear port 916. In an additional embodiment, a detectable marker 970 is imbedded in the continuous wall of the adjustable membrane element 912. The detectable marker 970 allows the adjustable membrane element 912 to be located within the tissues of a patient using any number of visualization techniques

which employ electromagnetic energy as a means of locating objects within the body. In one embodiment, the detectable marker 970 is constructed of tantalum and the visualization techniques used to visualize the adjustable membrane element 912 are x-ray or fluoroscopy as are known in the art.

[0056] In an additional embodiment, a detectable marker is imbedded in the implantable device 910. For example, the detectable marker 970 is located at a front end (also referred to as a distal end) 960 (e.g., the tip) of the conduit 914. Alternatively, the detectable marker can be located in the continuous wall of the adjustable membrane element 912. The detectable marker 970 allows the front end 960, or the adjustable membrane element 912, to be located within the tissues of a patient using any number of visualization techniques which employ electromagnetic energy as a means of locating objects within the body. In one embodiment, the detectable marker 970 is constructed of tantalum and the visualization techniques used to visualize the front end 960, or the adjustable membrane element 912, are x-ray or fluoroscopy as are known in the art. In an additional embodiment, the sheath could also have a detectable marker, where the marker could be incorporated into, or on, the wall of the sheath. Alternatively, the entire sheath could be constructed to be radio-opaque.

[0057] FIG. 10 is an illustration of an additional embodiment of an implantable device 1010 according to the present subject matter. The implantable device 1010 includes an adjustable membrane element 1012 and a conduit 1014. The conduit 1014 has a front end 1060. In one embodiment, the peripheral surface of the conduit 1014 is connected to and sealed to the adjustable membrane element 1012. In one embodiment, the adjustable membrane element 1012 includes a continuous wall having an inner surface defining a chamber.

[0058] The conduit 1014 includes a first lumen 1015 and a second lumen 1017. In one embodiment, the first lumen 1015 extends longitudinally in the conduit 1014 from a first opening 1015A to one or more second openings 1015B (e.g., two openings as shown in FIG. 10). The second opening(s) 1015B is in fluid communication with the chamber of adjustable membrane element 1012 for adjustably expanding or contracting the adjustable membrane element 1012 by flowable material introduced through the first opening 1015A.

[0059] The second lumen 1017 extends longitudinally along the conduit 1014 from an inlet 1017B to a closed end 1017A at the front end 1060. In one embodiment, the second lumen 1017 and the inlet 1017B are each of sufficient diameter to receive a push rod that can be used to advance the implantable device 1010 in the tissue.

[0060] The implantable device 1010 further includes a rear port 1016, which is coupled to the rear end of the conduit 1014. In one embodiment, the rear port 1016 is similar to the rear port 916 and includes a cavity 1016A and an elastic septum 1018. The cavity 1016A coupled to and in fluid communication with the first lumen 1015 at the first opening 1015A. The elastic septum 1018 allows for excess to the cavity 1016A using a needle, for introducing and/or withdrawing fluid to expand and/or extract the adjustable membrane element 1012.

[0061] FIG. 11 is a top view of a bladder 1101 and a urethra 1102 showing approximate target sites of placement of the implantable devices 1110 to improve coaptation of a

urethra, according to an embodiment of present subject matter. The implantable devices **1110** can present any embodiment of the implantable device as discussed in this document (with the expandable membrane element or the adjustable membrane element shown in the figure to illustrate its location), including but not limited to the implantable device **110**, the implantable device **910**, the implantable device **1010**, or an implantable device including various combinations of features of the implantable devices **110**, **910**, and **1010**. A Cartesian coordinate system with X-, Y-, and Z-axes is shown in FIGS. **11-21** (with two of the X-, Y-, and Z-axes seen in each of these figures) as a reference for exemplary orientations of structures illustrated in these figures. The orientation of the Z-axis is along the direction of the urethra **1002** in the approximate location of implantation. The location is near the bladder neck and urethral vesical anastomosis in the case of radical prostatectomy or further down the urethra at the apex of the prostate after Trans-Urethral Resection of the Prostate (TURP).

[0062] FIG. **12** is a view along the length of the urethra **1102** in the area of implantation (or along the y-axis) showing approximate target sites of placement of the implantable devices **1110** to improve coaptation of a urethra, according to an embodiment of present subject matter. The present subject can assist in the proper placement of the implantable devices **1110** during implantation into the patient and/or adjustment of the implantable devices **1110** after the implantation. In particular, the accurate placement of the implantable devices **1110** along the Y-axis (sagittal view) is facilitated by the applications of the present subject matter.

[0063] FIG. **13** is an illustration of an implantable device kit **1320**, including an implantable device **1310** and a sensor probe **1324**, according to an embodiment of present subject matter. The implantable device **1310** and the sensor probe **1324** can be provided as a device kit, which may also include other accessories. The implantable device **1310** can be used to coapt a lumen in a body, and can include an adjustable membrane element **1312**, an elongate the conduit **1314**, and a rear port **1316**. The adjustable membrane element **1312** is configured to coapt the lumen and includes a continuous wall having an inner surface defining a chamber. The conduit **1314** has a rear end **1315**, a front end **1313** coupled to the adjustable membrane element **1312**, a peripheral surface connected to and sealed to the adjustable membrane element **1312** near the front end **1313**, and an lumen (not shown in FIG. **13**) extending longitudinally in the conduit **1314** from a first opening at the rear end **1315** to a second opening at or near the front end **1313** in fluid communication with the chamber. The rear port **1316** is coupled to the rear end **1315**, and includes a cavity in fluid communication with the first opening of the first lumen and an elastic septum allowing access to the cavity by a needle. In some embodiments, the rear port **1316** is releasably coupled to the rear end of the conduit **1314**. The implantable devices **1310** can present any embodiment of the implantable device as discussed in this document, including but not limited to the implantable device **110**, the implantable device **910**, the implantable device **1010**, or an implantable device including various combinations of features of the implantable devices **110**, **910**, and **1010**.

[0064] The sensor probe **1324** has an elongate body **1326** having a rear end **1327** a front end **1325**, and one or more sensors **1328** incorporated onto the elongate body **1326**. In

various embodiments, the sensor probe **1324** can be constructed by incorporating the sensor(s) **1328** into any surgical tool that is used during the implantation and/or adjustment of the implantable device **1310** and has an elongate body. Examples of such a surgical tool include a push rod (e.g., push rod **1450**) and a guide probe (or guide rod or guide wire, e.g., guide probe **424**). In one embodiment, as illustrated in FIG. **13**, one sensor **1328** at the front end **1325** is illustrated. In another embodiment, as illustrated in FIG. **14**, which shows a portion of a sensor probe **1424** according to an embodiment of present subject matter, a plurality of sensors **1328** is distributed over at least a portion of the elongate body **1326**.

[0065] In various embodiments, the sensor(s) **1328** can be rotated by rotating the elongate body **1326**, such as by rotating the rear end **1327**. The elongate body **1326** can include a sensor connection circuit **1330**, such as at the rear end **1327**. Conductors **1329** extend within the elongate body **1326** to provide connections between sensor(s) **1328** and sensor connection circuit **1330**. In one embodiment, sensor connection circuit **1330** includes a connector for connection to an external system that processes signals sensed by sensor(s) **1328**. In another embodiment, sensor connection circuit **1330** includes a telemetry circuit and a battery such that it can communicate with the external system wirelessly. The telemetry circuit can perform the wireless communication using, for example, electromagnetic, magnetic, acoustic, or optical telemetry.

[0066] In various embodiments, sensor(s) **1328** can include one or more ultrasonic transducers each to convert an electrical input signal to ultrasound, transmit the ultrasound, receive a reflected ultrasound (echo of the transmitted ultrasound), and convert the received reflected ultrasound to an electrical image signal. The external system can receive the electrical image signal and produce an ultrasonic image based on the electrical image signal. The one or more ultrasonic transducers can each include a piezoelectric transducer or a capacitive transducer, and each have an ultrasonic beam direction and an ultrasonic beam angle.

[0067] In various embodiments, sensor(s) **1328** can include one or more optical sensors. The one or more optical sensors can each include a charge-coupled device (CCD) image sensor or an active pixel sensor (APS, also known as complementary metal-oxide-semiconductor (CMOS) image sensor) to convert captured image to an electrical image signal. The external system can receive the electrical image signal and produce a visual image based on the electrical image signal.

[0068] In various embodiments, the lumen of the implantable device **1310** that is in fluid communication with the chamber is also configured to receive the sensor probe **1324**, which is used as a push rod (e.g., as illustrated in FIG. **9**). The end of lumen at the front end **1313** is configured to receive a force applied through the sensor probe **1324** to move the implantable device **1310**. The lumen includes a closed end near the front end **1313**. The closed end has sufficient strength and hardness to receive the front end **1325** of the sensor probe **1324** and transfers force applied at the rear end **1327** of the sensor probe to the implantable device **1310**.

[0069] In various other embodiments, a first lumen of the implantable device **1310** is in fluid communication with the chamber for adjusting the volume of the chamber, and the implantable device **1310** includes a second lumen extending

longitudinally within at least a portion of the conduit **1314** and configured to receive the sensor probe **1324** (e.g., as illustrated in FIGS. **2**, **3**, **5**, and **10**). The second lumen includes an inlet at or near the rear end **1315** of the conduit **1314** and an outlet at or near the front end **1313** of the conduit **1314**. The front end **1313** is configured to receive a force applied through the sensor probe **1324** to move the implantable device **1310**.

[0070] In one embodiment, the second lumen includes a closed end near the front end **1313** of the conduit **1314**. This closed end has sufficient strength and hardness to receive the front end **1325** of the sensor probe **1324** and transfers force applied at the rear end **1327** of the sensor probe **1324** to the implantable device **1310**. FIG. **16** is a cross-sectional view of a portion of the front end **1613** of an elongate conduit **1614** showing a closed end of the first or second interior passage way that is configured to receive the force applied through the sensor probe **1324** to move the implantable device **1310**, according to an embodiment of present subject matter. The front end **1613** can represent an example of the front end **1313**. In one embodiment, the front end **1613** includes a sensor window **1635** to provide for transparency to the signals to be sensed. For example, ultrasound transparent material can be used for the sensor window **1635**. The sensor window **1635** can be configured for a specified overall ultrasonic beam angle, up to 360 degrees (i.e., the sensor window has a length equal to the circumference of the second lumen).

[0071] In another embodiment, the sensor probe **1324** includes a sharp tip suitable for penetrating tissue, as in the example illustrated in FIG. **10**. FIG. **15** is an illustration showing a front end **1525** of a sensor probe **1524**, according to an embodiment of present subject matter. The sensor probe **1524** can represent an example of the sensor probe **1324** and includes a sharp tip **1531** at the front end **1525**. The second lumen includes an outlet near the front end **1313** of the conduit **1314**. The outlet allowing a portion of the sensor probe **1524** including the sharp tip **1531** to protrude from the conduit **1314**. FIG. **17** is a cross-sectional view of a portion of a front end **1713** of an elongate conduit **1714**, according to an embodiment of present subject matter. The front end **1713** can represent an example of the front end **1313**. The second lumen includes a first shoulder **1736** and the sensor probe **1524** includes a second shoulder **1532** configured to abut the first shoulder **1736** to allow transfer of force applied at a rear end **1327** of the sensor probe **1324** to the implantable device **1310**. In one embodiment, as illustrated in FIGS. **15** and **17**, the first shoulder **1736** is formed by a change in diameter of the second lumen, and the second shoulder **1532** is formed by a change in diameter of the sensor probe **1524**. Sensor(s) **1328** can be incorporated on to an elongate body **1526** of the sensor probe **1524** at the front end **1525** such that both the sharp tip **1531** and the sensor(s) **1328** can protrude from the conduit **1314** of implantable device **1310**.

[0072] FIG. **18** is an illustration of an implantable device **1810** with one or more sensors, according to an embodiment of present subject matter. Implantable device **1810** includes the implantable device **1310** as discussed above and one or more sensors **1828** incorporated onto the implantable device **1310**. Implantable device **1810** further includes a sensor connection circuit **1840**, such as at the rear end **1315**, and conductors **1841** that extend within the elongate body **1314** to provide connections between sensor(s) **1828** and sensor connection circuit **1840**. In the illustrated embodiment,

implantable device **1810** includes six sensors **1828** at a distal connection between the adjustable membrane element **1312** and the conduit **1314**, a rare connection between the adjustable membrane element **1312** and the conduit **1314**, and along a midline of the adjustable membrane element **1312** that is perpendicular to the conduit (i.e., perpendicular to the Z-axis). In various embodiments, any number of sensors incorporated onto any location on the implantable device **1810**. For example, one or more sensors **1828** can be incorporated onto the conduit **1314** (e.g., at or adjacent the front end **1313**, at or adjacent the distal connection between the adjustable membrane element **1312** and the conduit **1314**, and/or at or adjacent the rear connection between the adjustable membrane element **1312** and the conduit **1314**) and/or the adjustable membrane element **1312** (e.g., on a midline of the adjustable membrane element **1312** that is perpendicular to the conduit **1314**, adjacent the distal connection between the adjustable membrane element **1312** and the conduit **1314**, and/or adjacent the rear connection between the adjustable membrane element **1312** and the conduit **1314**).

[0073] In various embodiments, sensor(s) **1828** can include one or more ultrasonic transducers each to convert an electrical input signal to ultrasound, transmit the ultrasound, receive a reflected ultrasound (echo of the transmitted ultrasound), and convert the received reflected ultrasound to an electrical image signal. An external system can receive the electrical image signal and produce an ultrasonic image based on the electrical image signal. The one or more ultrasonic transducers can each include a piezoelectric transducer or a capacitive transducer, and each have an ultrasonic beam direction and an ultrasonic beam angle. A plurality of ultrasonic transducers can be arranged on the implantable device **1810** to provide a specified overall ultrasonic beam angle (e.g., 90, 180, 270, or 360 degrees).

[0074] In various embodiments, sensor(s) **1828** can include one or more optical sensors. The one or more optical sensors can each include a CCD image sensor or an APS to convert captured image to an electrical image signal. The external system can receive the electrical image signal and produce a visual image based on the electrical image signal.

[0075] In various embodiments, sensor(s) **1828** can include one or more of any type that can sense signals useful in assisting the placement and adjustment of the implantable device **1810**, such as pressure sensors and strain gauges.

[0076] The sensor connection circuit **1840** can be within the rear port **1316** and provide for access to the one or more sensors **1828** via the rear port **1316**. In one embodiment, the implantable device **1810** can communicate with the external system using a wired connection. The sensor connection circuit **1840** includes a connector. The external system includes a percutaneous connector to pierce the elastic septum of the rear port **1316** and mate the connector in the rear port **1316**. In another embodiment, the implantable device **1810** can communicate with the external system wirelessly. The sensor connection circuit **1840** includes a telemetry circuit and a battery or inductive power receiver. The telemetry circuit can transmit power to the implantable device **1810** and receive the sensed signals from the implantable device **1810**.

[0077] FIG. **19** is an illustration of an implantable device kit **1920**, according to an embodiment of present subject matter. Implantable device kit includes at least an implantable device **1810** and a sensor probe **1324**, as illustrated in

FIG. 19, and can also include other tools or accessories used for implantation of the implantable device 1810. One or more sensors selected from sensor(s) 1828 and sensor(s) 1328 can be used to provide for monitoring of the implantable device 1810 during implantation and/or adjustment. For various purposes and circumstances, a user can use one or more sensors of implantable device 1810 only, one or more sensors of sensor probe 1324 only, or sensors of both implantable device 1810 and sensor probe 1324 for the monitoring.

[0078] FIG. 20 is an illustration of coaptation of the body lumen 1102 using an implantable device 2010 and a probe 2024, according to an embodiment of present subject matter. Examples of implantable device 2010 include, but are not limited to, any implantable device (with or without the one or more sensors) discussed in this document, such as implantable devices 110, 910, 1010, 1310 and 1810. Examples of the probe 2024 include, but are not limited to, any probes (with or without the one or more sensors) discussed in this document, such as the guide probe 424, the push rod 1450, and the sensor probes 1324, 1424, and 1524. A sensor 2028 represents any one or more sensors that are incorporated onto implantable device 2010 and/or probe 2024. In one embodiment, sensor 2028 provides an image such as the one shown in FIG. 22 for guiding the placement of the implantable device 2010 adjacent the lumen 1102 (e.g., the urethra) for coaptation of the lumen, and/or allows for determination of whether the body lumen is coapted to a desirable extent.

[0079] FIG. 21 is an illustration of coaptation of the body lumen 1102 using two implantable devices 2010 and two probes 2024, according to an embodiment of present subject matter. FIG. 22 shows an example of an image of this therapy. When the body lumen (e.g., the urethra) is properly coapted, flattening of the adjustable membrane elements 1312 of each implantable device facing the lumen is observed. In various embodiments, sensors 2028 can be used to provide images and/or other information indicative of the position of each of the implantable devices 2010, the degree of flattening of the adjustable membrane elements 1312, and/or the shape of the body lumen, thereby providing for guidance in placing and/or adjusting the implantable devices 2010. The shape of the body lumen can indicate a degree of the coaptation of the body lumen. In various embodiments, sensor 2028 placed in each of the implantable device 2010 can detect information indicative of a shape of the adjustable membrane element 1312 of the same implantable device, a position of the adjustable membrane element 1312 of the same implantable device (e.g., relative to the body lumen 1102), a shape of the adjustable membrane element 1312 of the other implantable device 2010, a position of the adjustable membrane element 1312 of the other implantable device 2010 (e.g., relative to the body lumen 1102), and/or a shape of the body lumen 1102. In various embodiments, sensor 2028 placed in the implantable device 2010 can detect information indicative of a shape and/or a position of another implantable device, or a portion thereof, that is present in the tissue near the implantable device 2010.

[0080] FIG. 23 is an illustration of an implantable device kit 2320, including a single-lumen implantable device 2310 and a sensor probe 2324, according to an embodiment of present subject matter. The implantable device kit 2320 can represent an example of implantable device kit 1320, with the implantable device 2310 used for coaptation of a urethra

and the sensor probe 2324 used for detecting one or more indications of a state or degree of the coaptation of the urethra and adjusting the volume in an adjustable membrane element 2312 of implantable device 2310 for optimal efficacy in treating urinary incontinence without creating obstruction of the urethra. The implantable device 2310 includes a front end 2360, a rear port 2316, and an elongate conduit 2314 connected between the front end 2360 and the rear port 2316. The adjustable membrane element 2312 is affixed onto the conduit 2314 near the front end 2360 and includes a continuous wall having an inner surface defining a chamber. A lumen 2315 extends longitudinally within the conduit 2314 and is in fluid communication with the chamber of the adjustable membrane element 2312 at a distal opening 2315B and with a cavity 2316A of the rear port 2316 at rear opening 2315A. In the illustrated embodiment, the sensor probe 2324 is a 3-in-1 device that can also be used as (1) a sensing device including a sensor 2328 at a front end of the sensor probe 2324, (2) a push rod to advance the implantable device 2310 in tissue by applying force against a closed front end of the lumen 2315 at the front end 2360, and (3) a hollow needle that includes a lumen 2365 through which a fluid can be introduced and withdrawn for inflating and deflating the adjustable membrane element 2312, respectively, through the distal opening 2315B of the lumen 2315. The lumen 2315 is configured to accommodate the front portion of the sensor probe 2324 with the front end of the sensor probe 2324 reach the closed front end of the lumen 2315. As shown in FIG. 23, pressure from the urethra may flatten a side of the adjustable membrane element 2312 when the adjustable membrane element 2312 is placed adjacent the urethra and inflated. The sensor 2328 can allow for observation of such flattening, which indicates the amount of pressure that can be adjusted for the optical efficacy of treating the urinary incontinence.

[0081] As shown in FIG. 23, the adjustable membrane element 2312 is inflated to provide urethral coaptation and has a flattened portion where it meets resistance to expansion from the urethra. The implantable device 2310 includes a radiopaque marker 2370 at the front end 2360. The radiopaque marker 2370 also serves as a stop for the sensing probe 2324 to assure that it is in the right position for sensing. The stop also serves as a stop for a push rod (e.g., the sensor probe 2324 used as the push rod) for placement of the implantable device 2310 in an initial implantation procedure. When the sensor probe 2324 is used as the push rod, the placement and/or initial adjustment of the implantable device 2310 can be guided using the sensor 2328 to observe the coaptation of the urethra. The rear port 2316 includes a self-sealing septum 2318 to allow access to the lumen 2315 by the sensor probe 2324 (as well as other push rod or push-wire, if used). The front end of the sensor probe 2324 has a sharp tip for piercing through the septum 2318. The advantage of a single lumen implantable device includes providing more cross-sectional area to accommodate the sensor 2328 in the conduit 2314 of a given diameter.

[0082] In the illustrated embodiment, the sensor 2328 is an optical sensor for visually observing the flattening of the adjustable membrane element 2312 against the urethra as a proxy for actual visualization of coaptation within the urethra. In another embodiment, the sensor 2328 is an ultrasonic sensor. In addition to directly observing the coaptation of the urethra, if the ultrasonic sensor transmits an ultrasound having sufficient depth of penetration within the

tissue, it may also allow for visualization of the adjustable membrane element **2312** in relation to anatomic structures such as the bladder neck and the rectum. Such visualization can be used to aid placement of the adjustable membrane element **2312** during the implantation of the implantable device **2310**. In various embodiments, the sensor **2328** can include any type of sensor that allows for detection of the flattening of the adjustable membrane element **2312** and/or visualization of the adjustable membrane element **2312** in the tissue in relation to various anatomic structures.

[0083] In the illustrated embodiment, the sensor **2328** (i.e., the optical sensor) includes an optical sensing element **2361** for observing the flattening of the adjustable membrane element **2312** with a CCD or CMOS chip **2362** that obtains a radial view with the aid of a mirror **2363**. The chip **2362** is powered, and data acquired by the sensor **2328** are returned, via filament **2364**. The filament **2364** can also be used to power a light source such as an LED to aid in visualization (which is unnecessary if the chip **2362** is an infrared CCD or CMOS chip). The sensor probe **2324** can be rotated about its longitudinal axis within the lumen **2315** to scan circumferentially to find the point of maximum coaptation where the adjustable membrane element **2312** is flattened. Rotating the sensor probe **2324** can also aid in passing it through curves in the conduit **2314**, especial when the rear port **2316** is routed into the scrotum or labia. At least for this reason, the sensor probe **2324** is provided with a certain amount of flexibility. In one embodiment, the sensor probe **2324** with the optical sensor **2328** is equipped with a wide-angle lens to allow for viewing the entire internal surface of the adjustable membrane element **2312** such that circumferential scanning would not be necessary.

[0084] In another embodiment, the sensor probe **2324** can include a borescope for optical visualization with a fiber optic bundle extending through the sensor probe. A light source within the sensor probe **2324** is unnecessary because the fibers can also be used to transmit light from a light source externally connected to the sensor probe. The fiber optic bundle may have a diameter that is substantially smaller when compared to the size of a CCD or CMOS chip, thereby reducing the diameter of the sensor probe **2324** and hence the diameter of the conduit **2314** and rear port **2316**. This allows for a reduction of the overall size of the implantable device **2310** and the overall size of the sensor probe **2328**. A smaller diameter for the sensor probe **2324** is desirable because it has to pass through the skin of the scrotum or labia to reach the rear port **2316** of the implantable device **2310** after it is implanted in the patient. Additionally, the fiber optic implementation of the sensor probe **2324** may reduce the cost of production when compared to the optical sensor implementation with CCD or CMOS chip, thereby improving affordability of making the sensor probe **2324** as a disposable device.

[0085] This application is intended to cover adaptations or variations of the present subject matter. It is to be understood that the above description is intended to be illustrative, and not restrictive. The scope of the present subject matter should be determined with reference to the appended claims, along with the full scope of legal equivalents to which such claims are entitled.

What is claimed is:

1. An implantable device configured to be implanted within body tissue adjacent to a body lumen for controllable coaptation of the body lumen, the implantable device comprising:
 - an adjustable membrane element including a continuous wall having an inner surface defining a chamber;
 - an elongate conduit including:
 - a conduit peripheral surface connected to and sealed to the adjustable membrane element;
 - a conduit rear end;
 - a conduit front end; and
 - a conduit lumen extending longitudinally in the conduit from a first opening at the rear end to a second opening in fluid communication with the chamber of the implantable device for adjustably expanding or contracting the adjustable membrane element by a flowable material introduced through the first opening; and
 - one or more sensors incorporated into at least one of the adjustable membrane element or the elongate conduit and configured to detect information indicative of at least one of a shape of the adjustable membrane element, a position of the adjustable membrane element, or a shape of the body lumen.
2. The implantable device of claim 1, wherein the one or more sensors comprise at least one ultrasonic sensor.
3. The implantable device of claim 2, further comprising an additional conduit lumen extending longitudinally in the conduit, the additional conduit lumen having an inlet configured to receive a portion of a push rod.
4. The implantable device of claim 3, wherein the additional conduit lumen comprises an outlet configured to allow a portion of the push rod to exit.
5. The implantable device of claim 2, further comprising a rear port connected to the elongate conduit at the conduit rear end, the rear port including a cavity and an elastic septum configured to seal the cavity, the cavity configured to contain the flowable material and being in fluid communication with the conduit lumen.
6. The implantable device of claim 2, wherein the at least one ultrasonic sensor is affixed onto the adjustable membrane element.
7. The implantable device of claim 6, wherein the at least one ultrasonic sensor is on a midline of the adjustable membrane element that is perpendicular to the elongate conduit.
8. The implantable device of claim 6, wherein the at least one ultrasonic sensor is adjacent a connection between the adjustable membrane element and the elongate conduit.
9. The implantable device of claim 2, wherein the at least one ultrasonic sensor is affixed onto the inner surface of the continuous wall of the adjustable membrane element.
10. The implantable device of claim 2, wherein the at least one ultrasonic sensor is incorporated into the elongate conduit.
11. The implantable device of claim 10, wherein the at least one ultrasonic sensor is at or adjacent the conduit front end.
12. The implantable device of claim 11, wherein the at least one ultrasonic sensor is adjacent a connection between the adjustable membrane element and the elongate conduit.
13. The implantable device of claim 1, wherein the one or more sensors comprise at least one optical sensor.

14. An implantable device configured to be implanted within body tissue adjacent to a body lumen for controllable coaptation of the body lumen, the implantable device comprising:

- an adjustable membrane element including a continuous wall having an inner surface defining a chamber;
- an elongate conduit including:
 - a conduit peripheral surface connected to and sealed to the adjustable membrane element;
 - a conduit rear end;
 - a conduit front end; and
 - a conduit lumen extending longitudinally in the conduit from a first opening at the rear end to a second opening in fluid communication with the chamber of the implantable device for adjustably expanding or contracting the adjustable membrane element by a flowable material introduced through the first opening; and
- multiple sensors incorporated into at least one of the adjustable membrane element or the elongate conduit and configured to detect information indicative of at least one of a shape of the adjustable membrane element, a position of the adjustable membrane element, or a shape of the body lumen.

15. The implantable device of claim **14**, wherein the multiple sensors comprise at least one of an ultrasonic sensor or an optical sensor.

16. The implantable device of claim **15**, wherein the multiple sensors further comprise at least one of a pressure sensor or a strain gauge.

17. An implantable device kit for controllable coaptation of a body lumen in tissue of a living body, the implantable device kit comprising:

- an implantable device configured to control the coaptation of the body lumen, the implantable device including:
 - an adjustable membrane element including a continuous wall having an inner surface defining a chamber;

an elongate conduit including:

- a conduit peripheral surface connected to and sealed to the adjustable membrane element;
 - a conduit rear end;
 - a conduit front end;
 - a first conduit lumen extending longitudinally in the conduit from a first opening at the rear end to a second opening in fluid communication with the chamber of the implantable device for adjustably expanding or contracting the adjustable membrane element by a flowable material introduced through the first opening; and
 - a second conduit lumen extending longitudinally in the conduit from an inlet on the conduit and an end at or near the conduit front end;
- a sensor probe including a probe front end configured to enter the inlet of the second conduit lumen and reach the end of the second conduit lumen through the second conduit lumen; and
- multiple sensors incorporated into the implantable device and the sensor probe and configured to detect information indicative of at least one of a shape of the adjustable membrane element, a position of the adjustable membrane element, or a shape of the body lumen.

18. The implantable device kit of claim **17**, wherein the multiple sensors comprise at least one of an ultrasonic sensor or an optical sensor incorporated into at least one of the adjustable membrane element or the elongate conduit of the implantable device.

19. The implantable device kit of claim **17**, wherein the multiple sensors comprise at least one of an ultrasonic sensor or an optical sensor incorporated into the probe front end.

20. The implantable device kit of claim **17**, wherein the multiple sensors comprise at least one of an ultrasonic sensor or an optical sensor and at least one of a pressure sensor or a strain gauge.

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