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Haessler, MD

(54) **DEVICES AND METHODS FOR STIMULATING NERVES**

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§ 371 (c)(1),
(2) Date: **Apr. 14, 2016**

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Publication Classification

(51) **Int. Cl.**

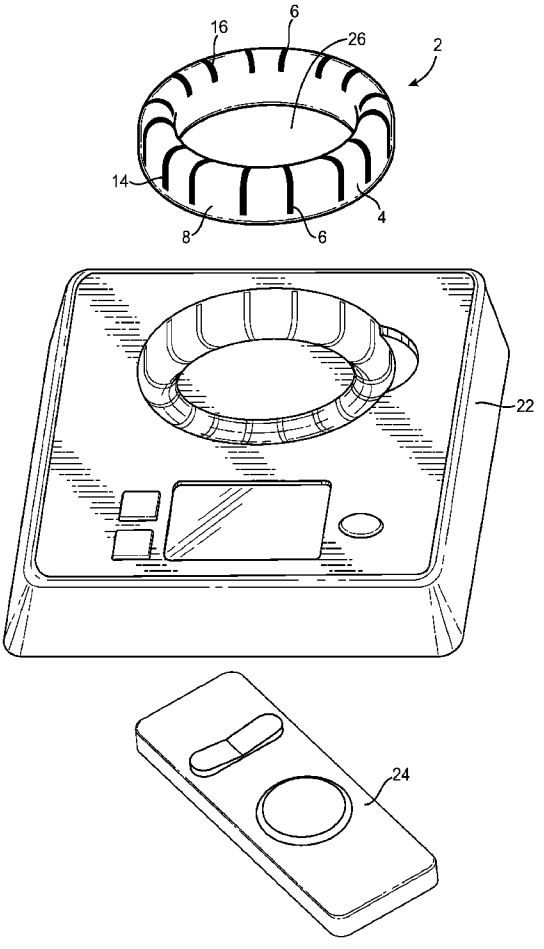
A61N 1/36	(2006.01)
A61M 31/00	(2006.01)
A61N 1/372	(2006.01)
A61N 1/05	(2006.01)
A61N 1/375	(2006.01)

(52) **U.S. Cl.**

CPC ***A61N 1/36007*** (2013.01); ***A61N 1/0524*** (2013.01); ***A61N 1/0551*** (2013.01); ***A61N 1/3756*** (2013.01); ***A61N 1/37205*** (2013.01); ***A61M 31/002*** (2013.01); *A61M 2230/005* (2013.01); *A61M 2230/30* (2013.01); *A61M 2230/06* (2013.01)

(57) **ABSTRACT**

A device positioned in the vagina includes a sensor. The sensor data is used to determine whether a condition is met or exists to trigger a therapeutic response by the device. A device for stimulating nerves adjacent the vagina includes a nerve stimulating element coupled to a main body. The nerve stimulating element is positioned and designed to stimulate the vesical, Frankenhauser's and/or inferior hypogastric plexuses. The device may reside in the vaginal fornices. An implant is also provided which has a nerve stimulating element in contact with a uterosacral ligament. The device positioned in the vagina may be used to charge a power source for an implant, which may be a capacitor.



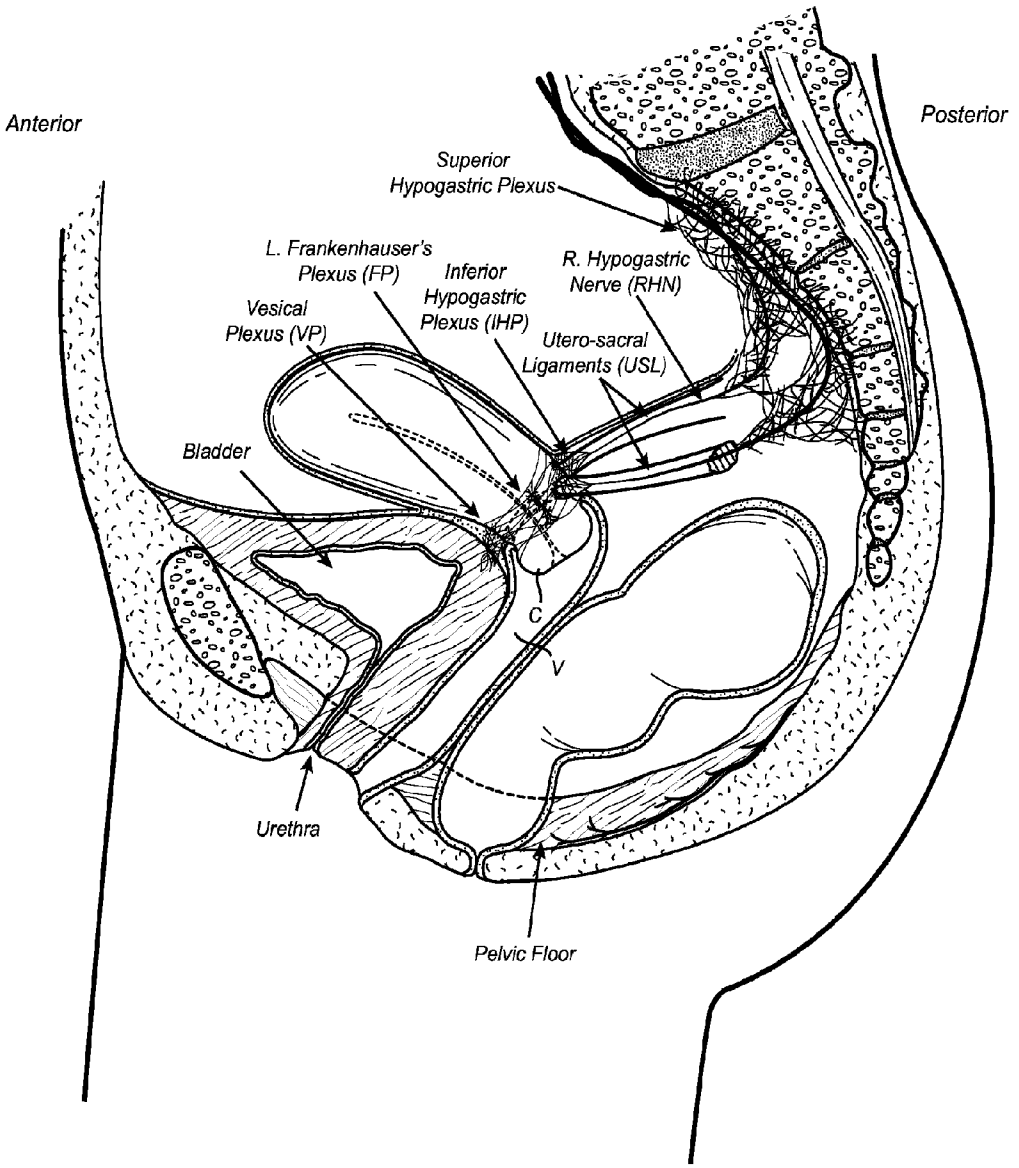

Anterior
Posterior
Superior
Hypogastric Plexus
L. Frankenhauser's
Plexus (FP)
Inferior
Hypogastric
Plexus (IHP)
R. Hypogastric
Nerve (RHN)
Vesical
Plexus (VP)
Utero-sacral
Ligaments (USL)
Bladder
C
V
Urethra
Pelvic Floor

FIG. 1

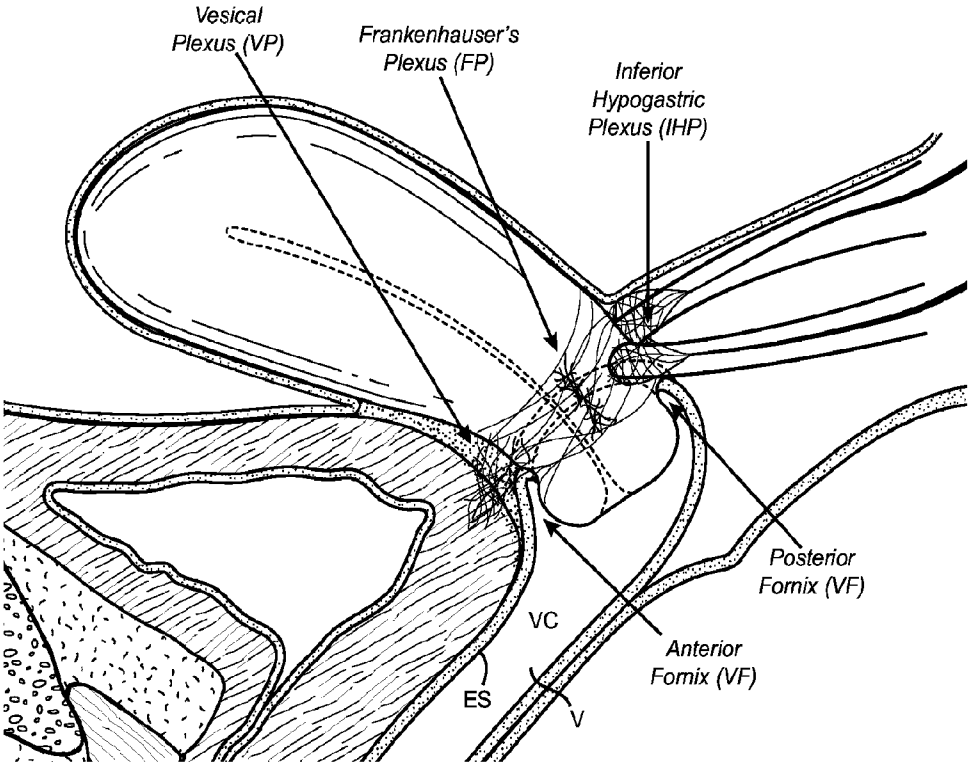

Vesical
Plexus (VP)
Frankenhauser's
Plexus (FP)
Inferior
Hypogastric
Plexus (IHP)
Posterior
Fornix (VF)
Anterior
Fornix (VF)
VC
ES
V

FIG. 2

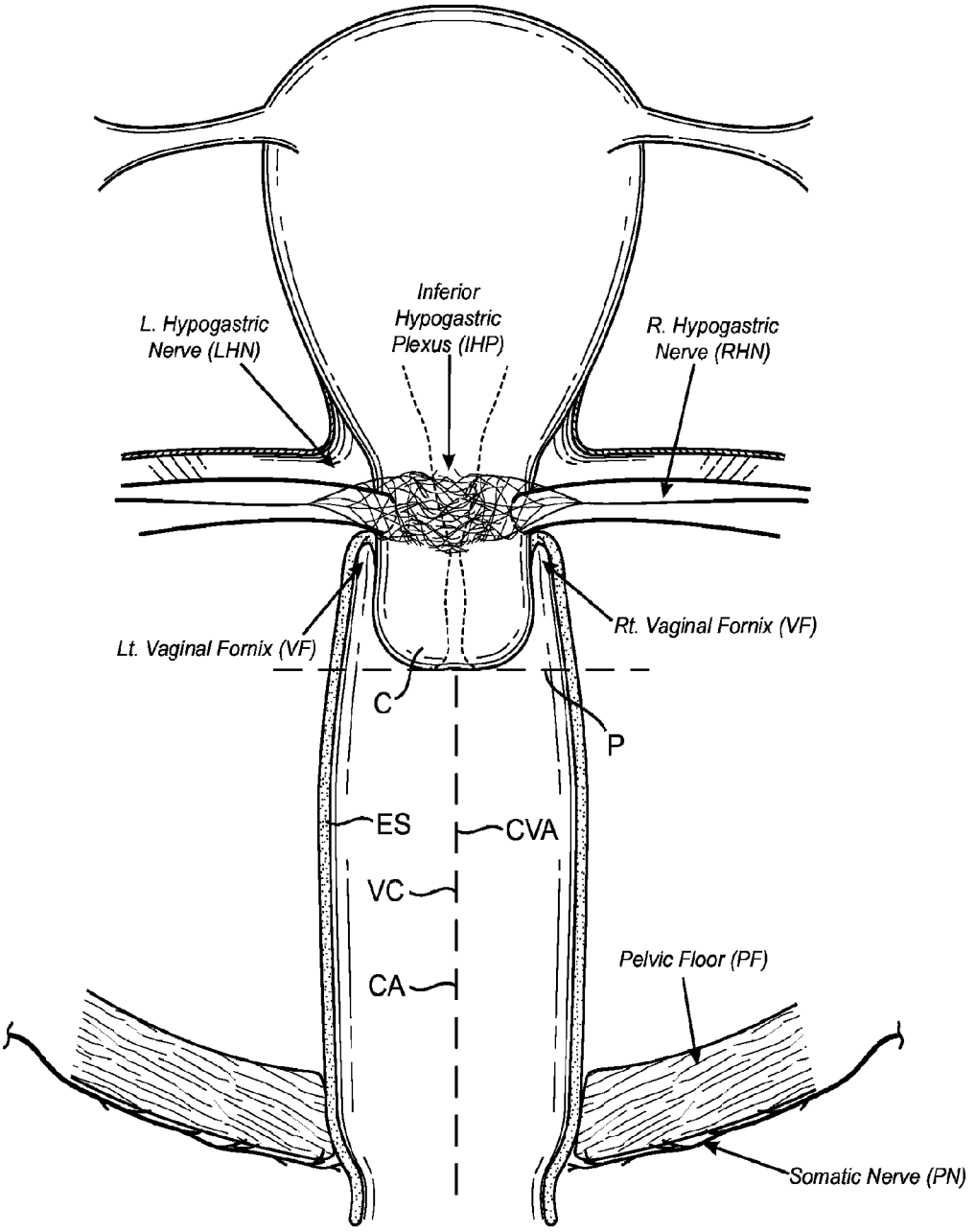

L. Hypogastric Nerve (LHN)
Inferior Hypogastric Plexus (IHP)
R. Hypogastric Nerve (RHN)
Lt. Vaginal Fornix (VF)
Rt. Vaginal Fornix (VF)
C
P
ES
CVA
VC
CA
Pelvic Floor (PF)
Somatic Nerve (PN)

FIG. 3

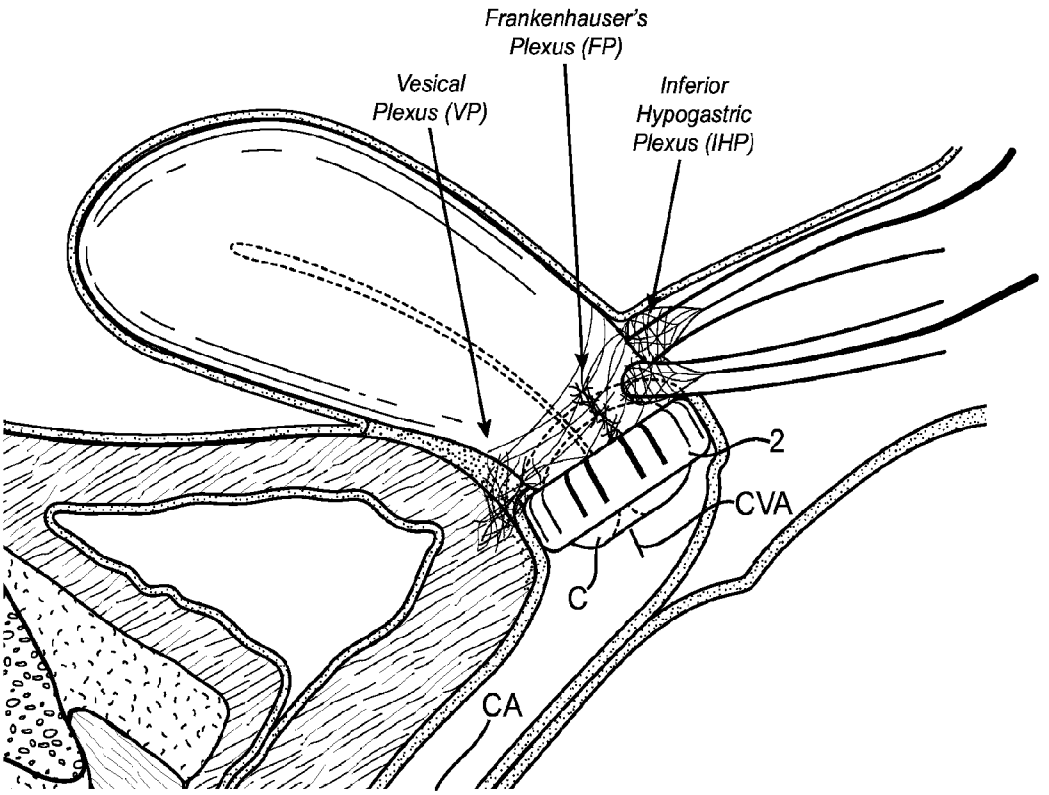

Frankenhauser's
Plexus (FP)
Vesical
Plexus (VP)
Inferior
Hypogastric
Plexus (IHP)
2
CVA
C
CA

FIG. 4

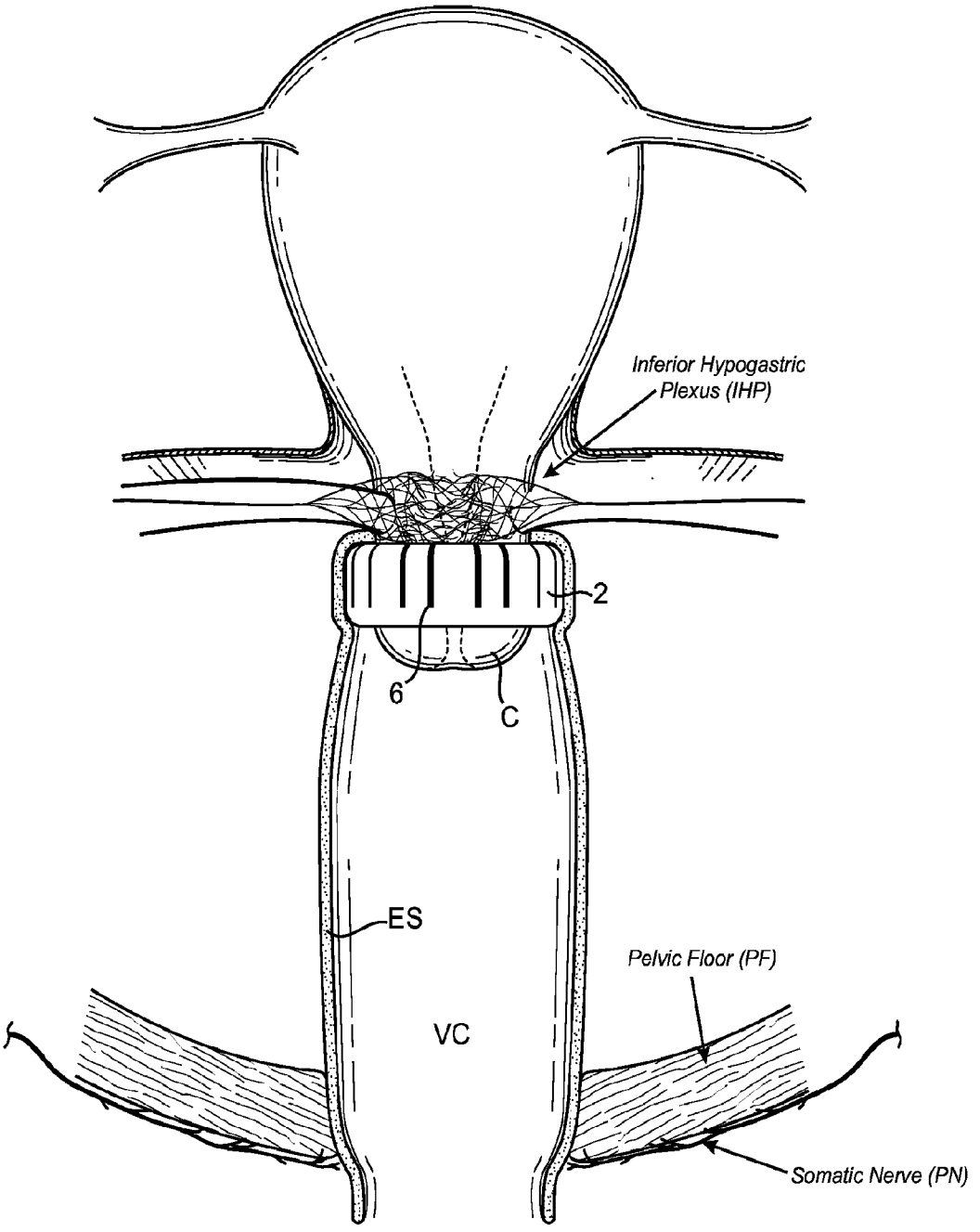

Inferior Hypogastric
Plexus (IHP)
2
6
C
ES
Pelvic Floor (PF)
VC
Somatic Nerve (PN)

FIG. 5

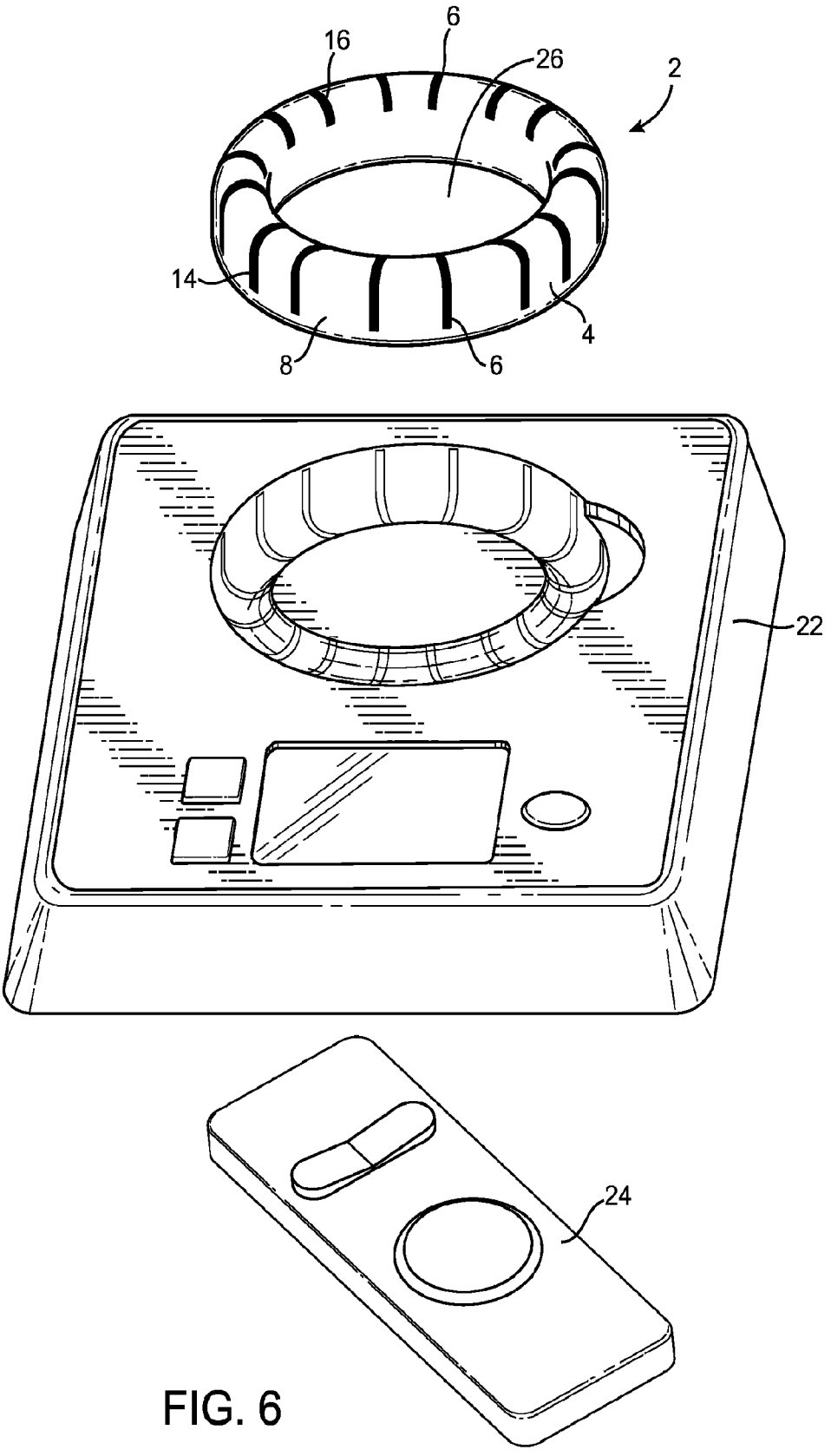


FIG. 6

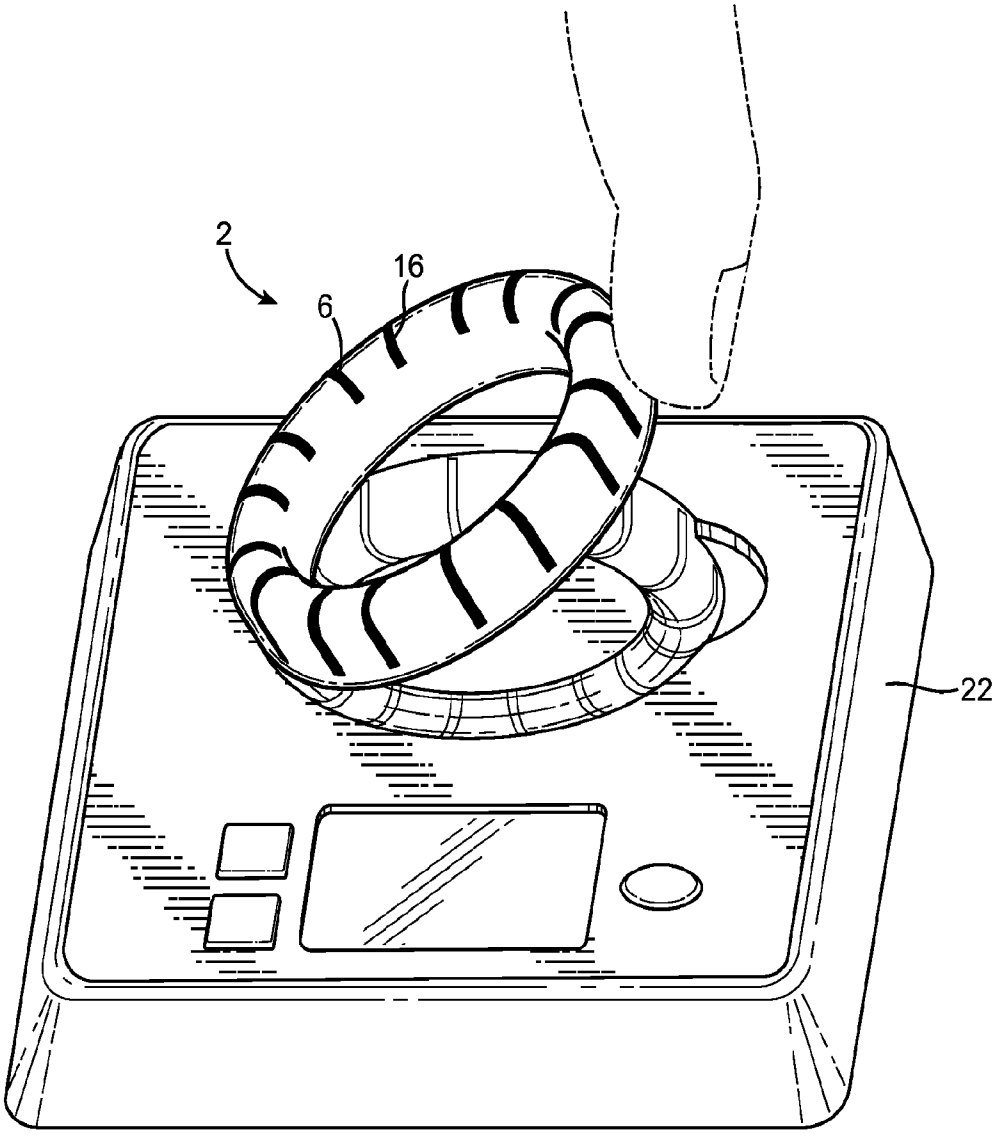


FIG. 7

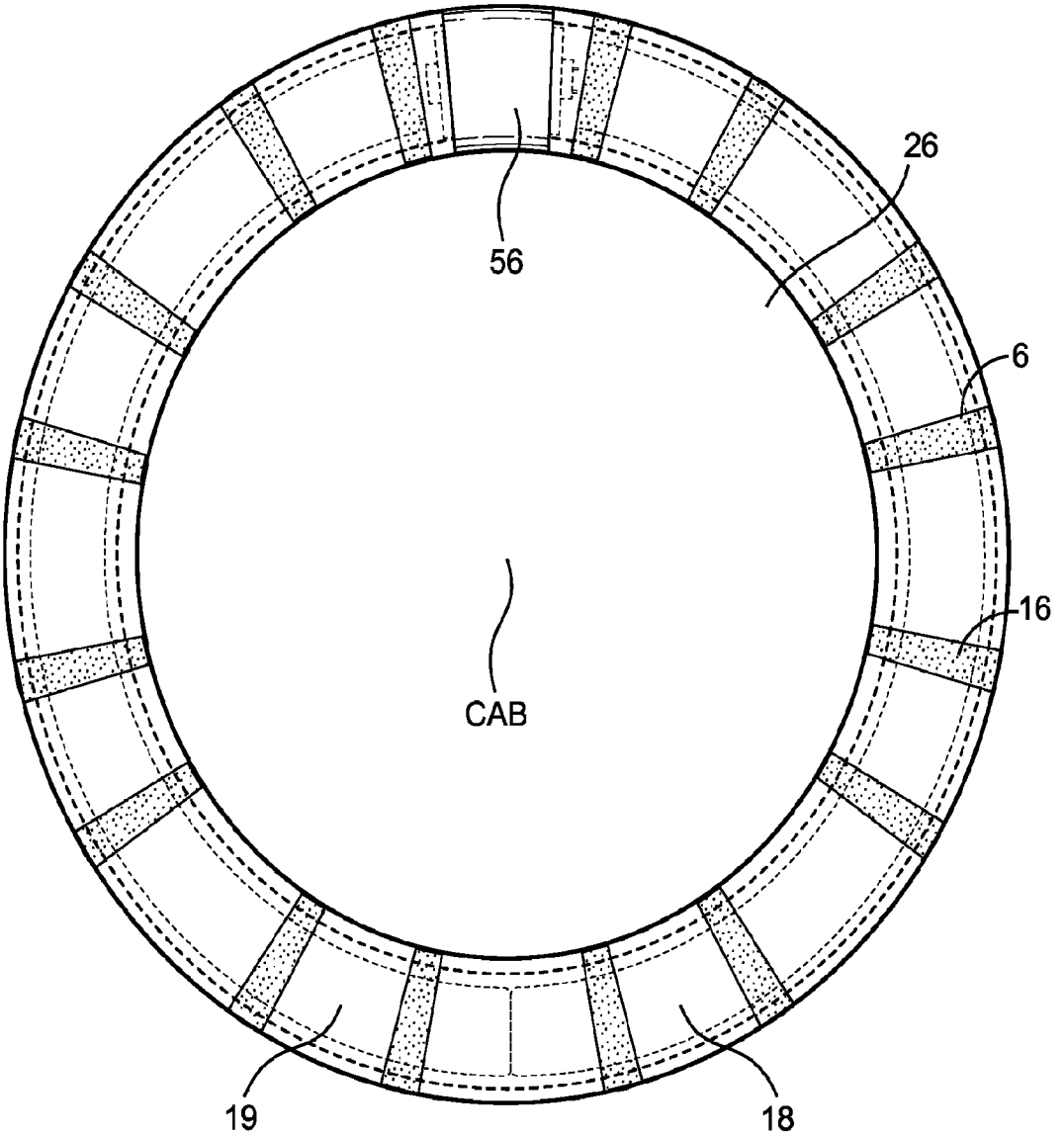


FIG. 8

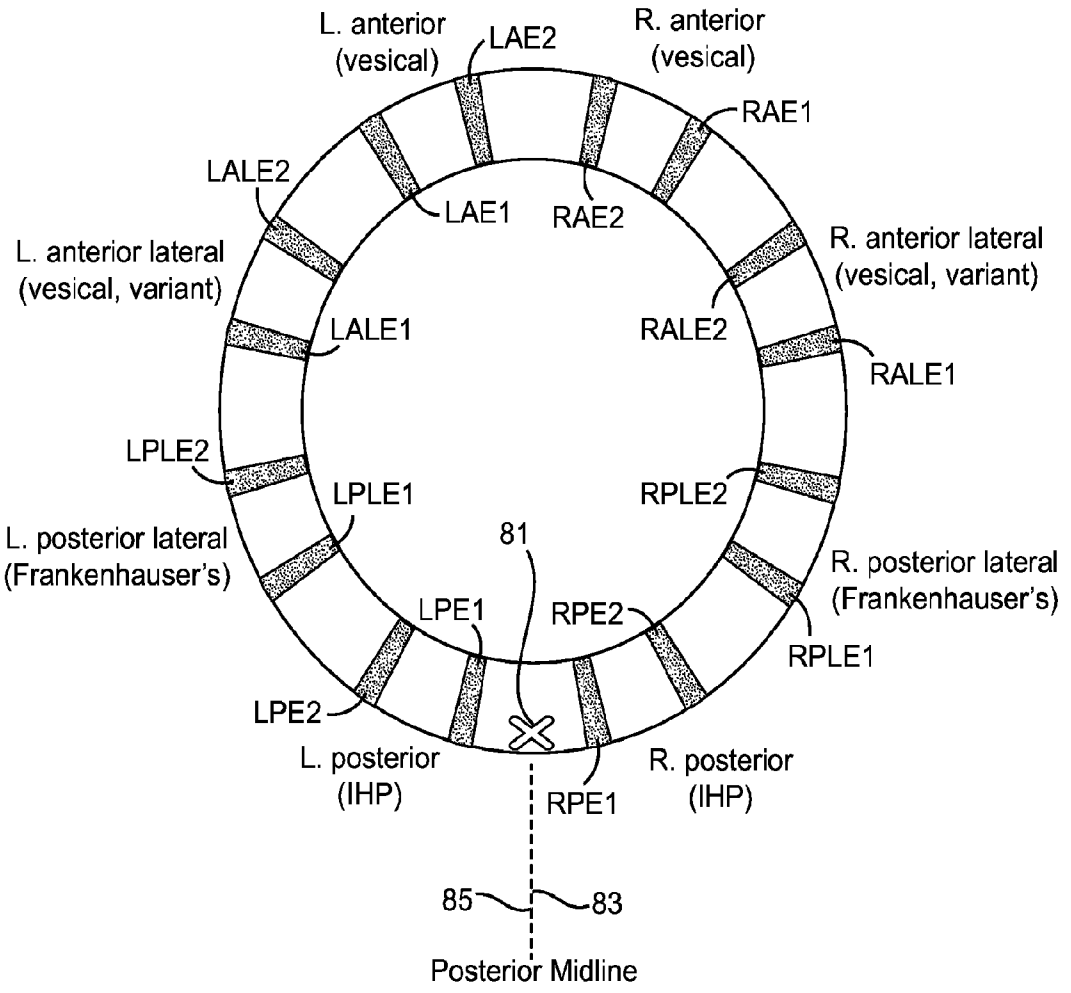

L. anterior
(vesical)
LAE2
R. anterior
(vesical)
RAE1
LALE2
LAE1
RAE2
L. anterior lateral
(vesical, variant)
R. anterior lateral
(vesical, variant)
LALE1
RALE2
RALE1
LPLE2
LPLE1
RPLE2
L. posterior lateral
(Frankenhauser's)
81
R. posterior lateral
(Frankenhauser's)
LPE1
RPE2
RPLE1
LPE2
L. posterior
(IHP)
R. posterior
(IHP)
RPE1
85
83
Posterior Midline

FIG. 9

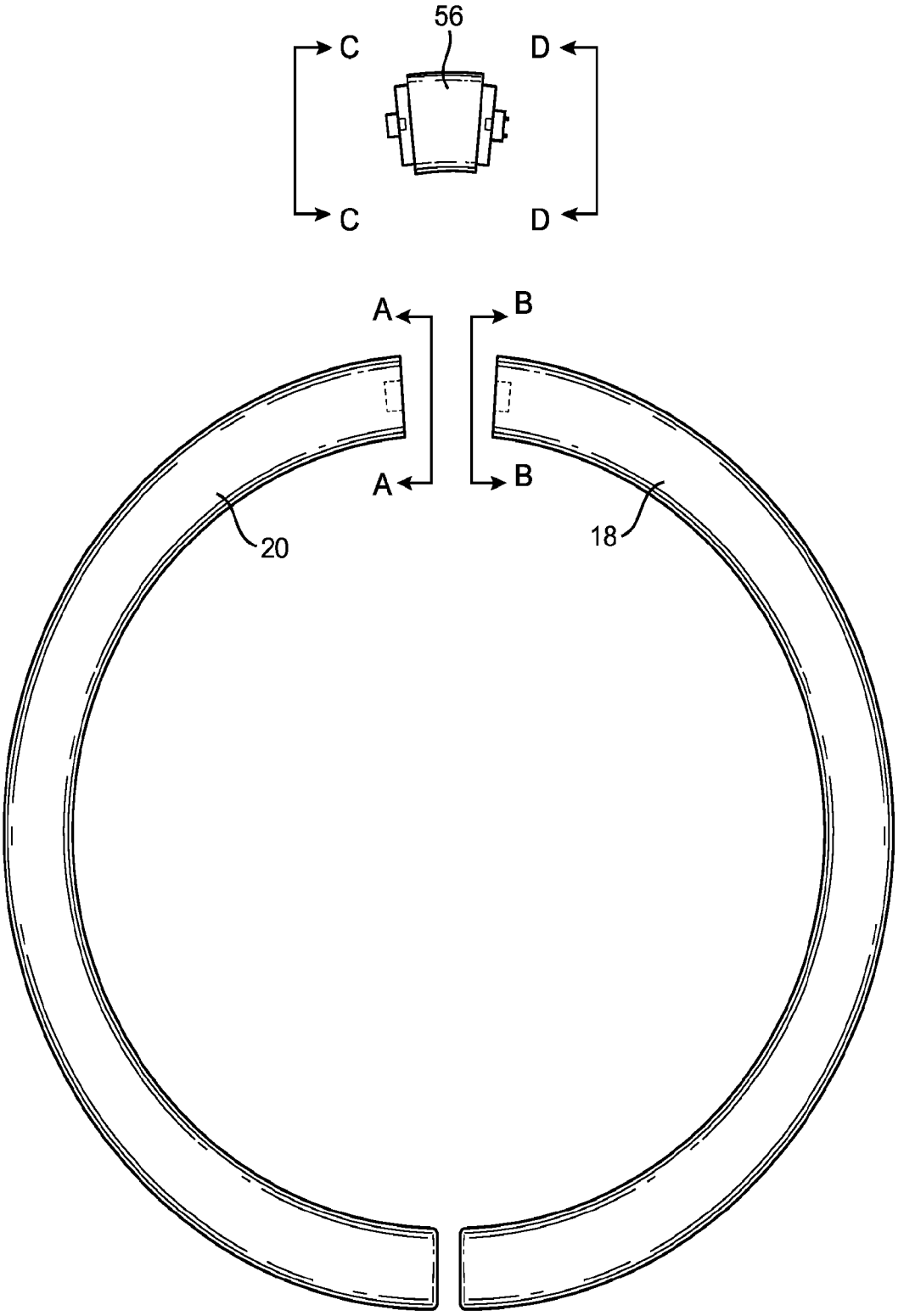


FIG. 10

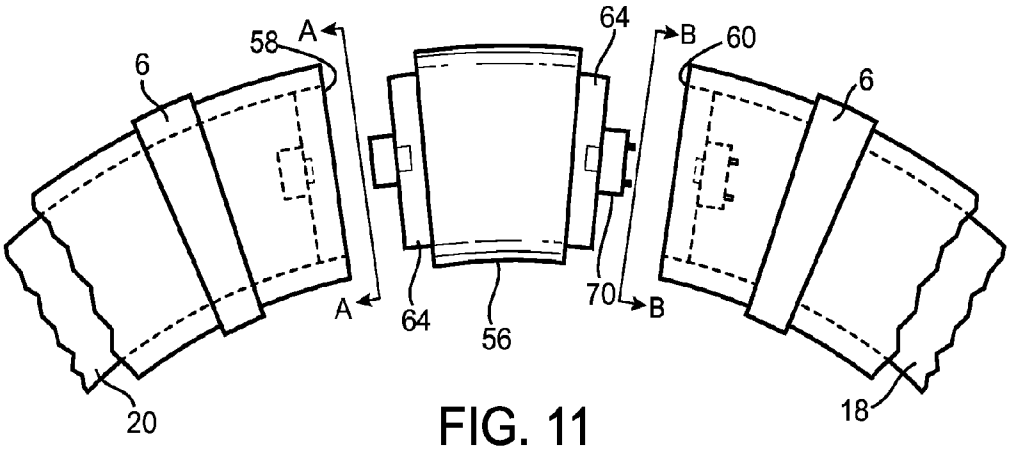


FIG. 11

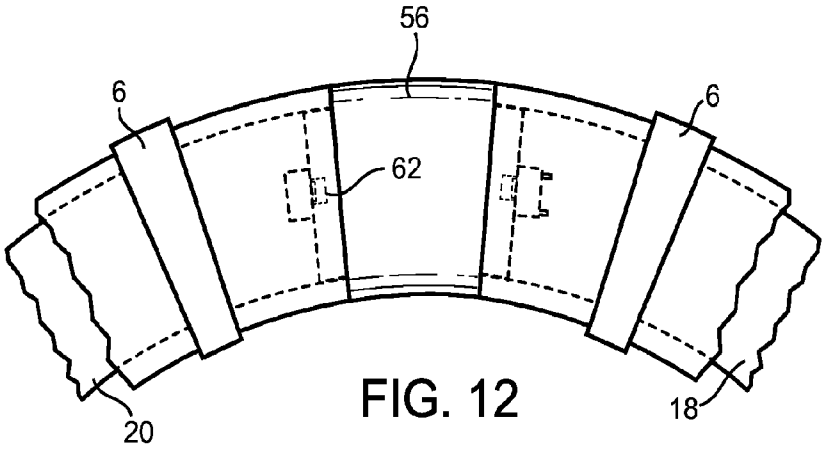


FIG. 12

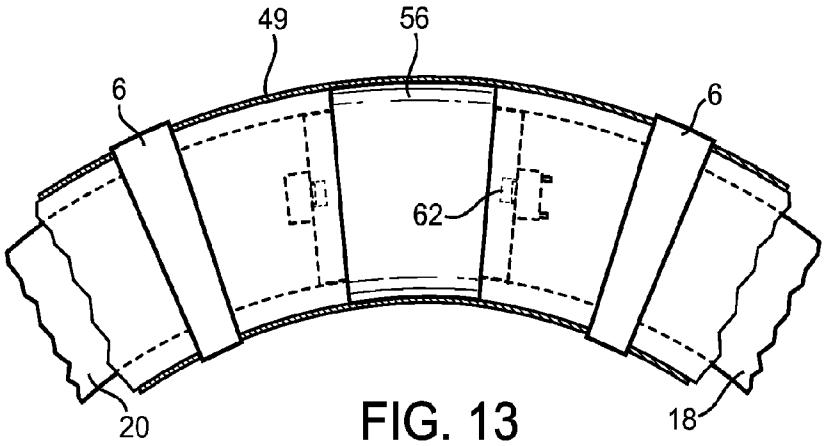


FIG. 13

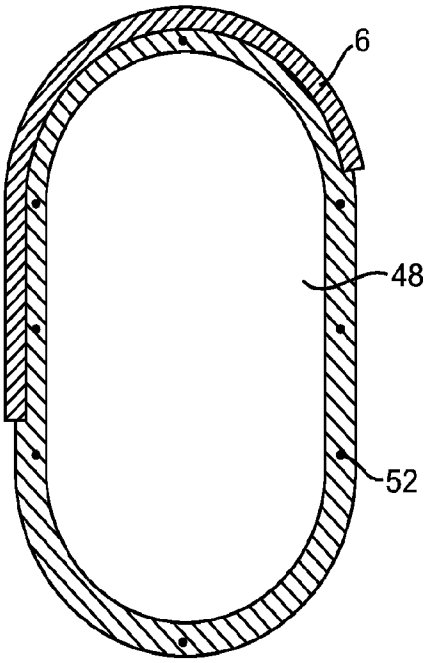


FIG. 14A

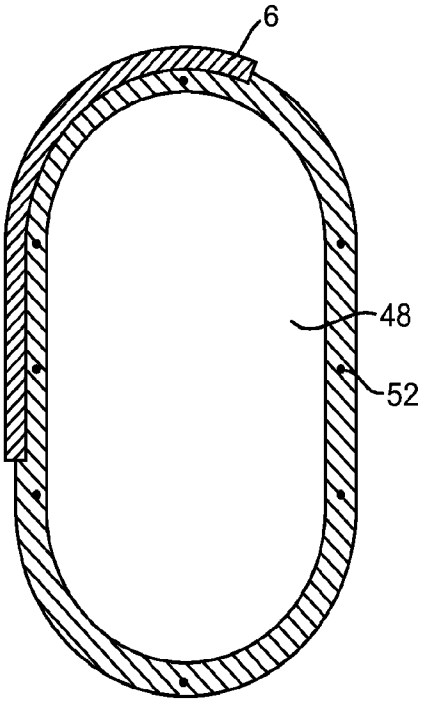


FIG. 14B

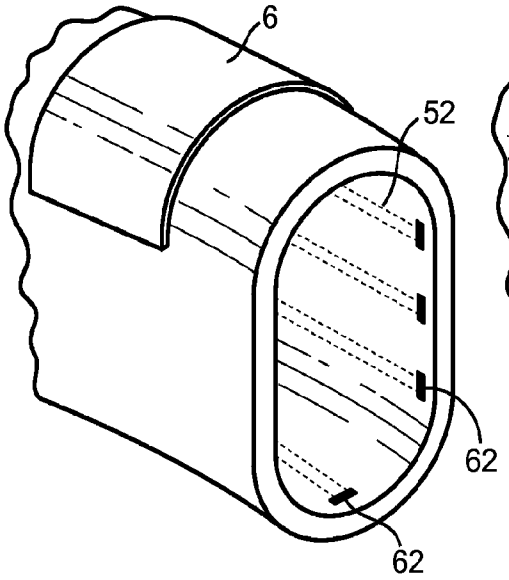


FIG. 15A

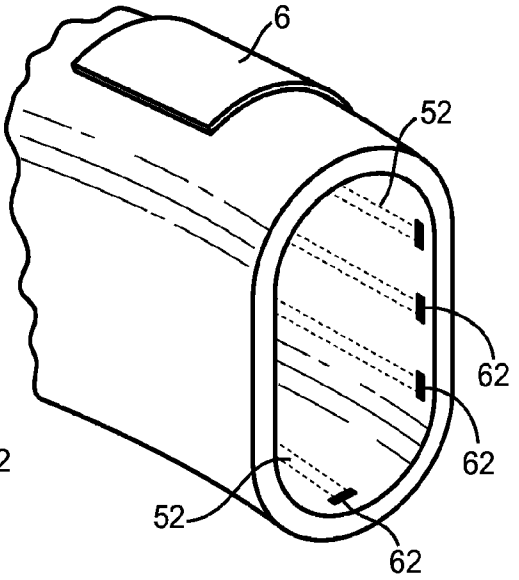


FIG. 15B

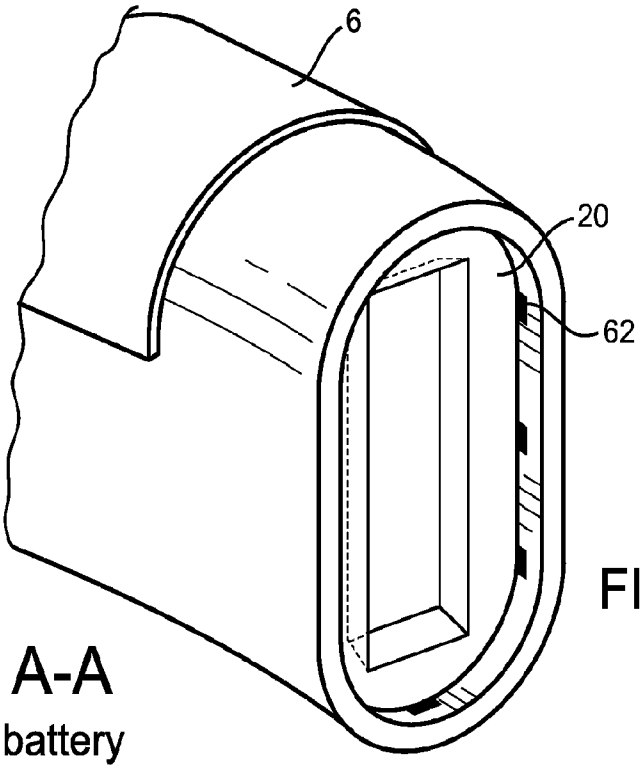


FIG. 16

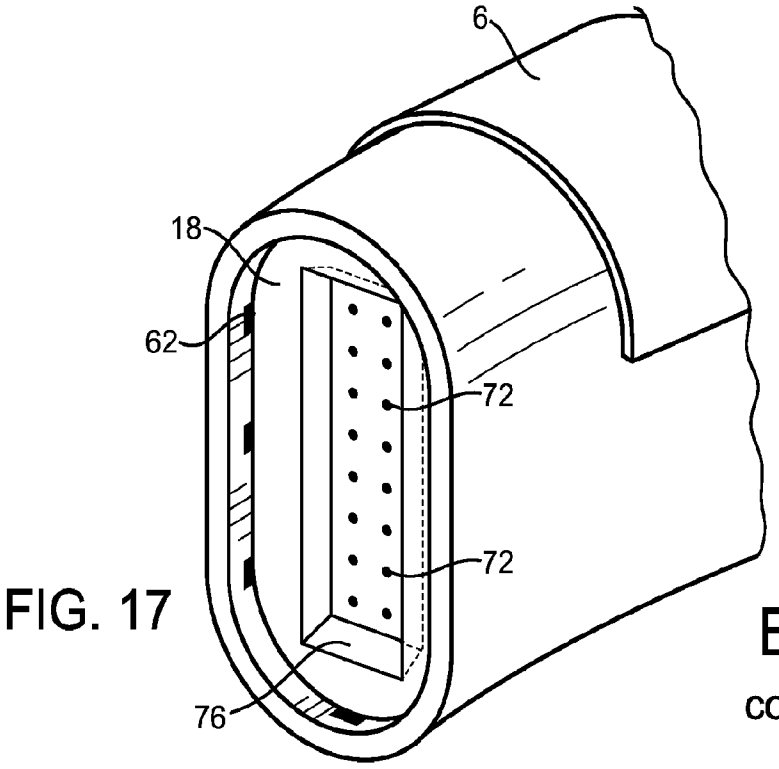


FIG. 17

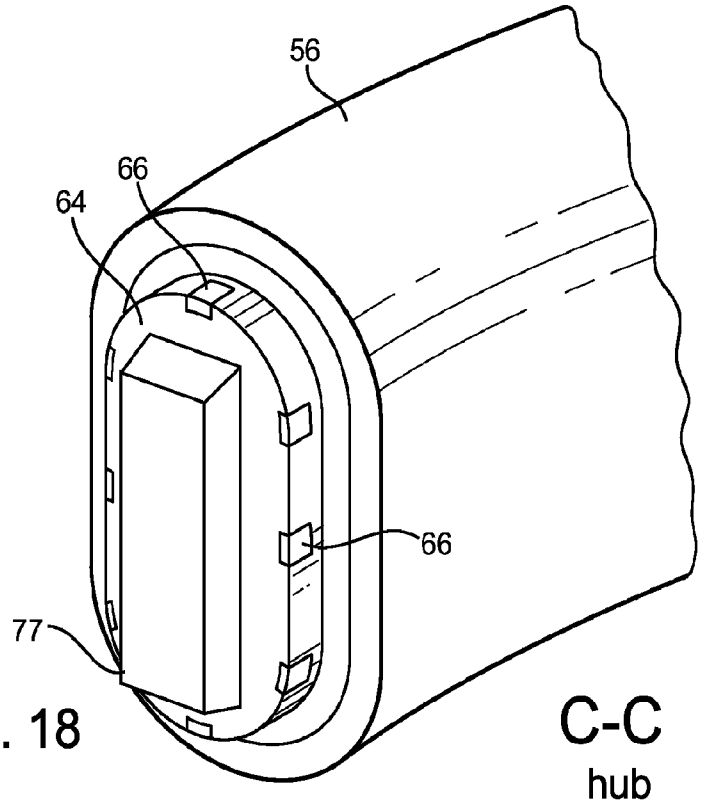


FIG. 18

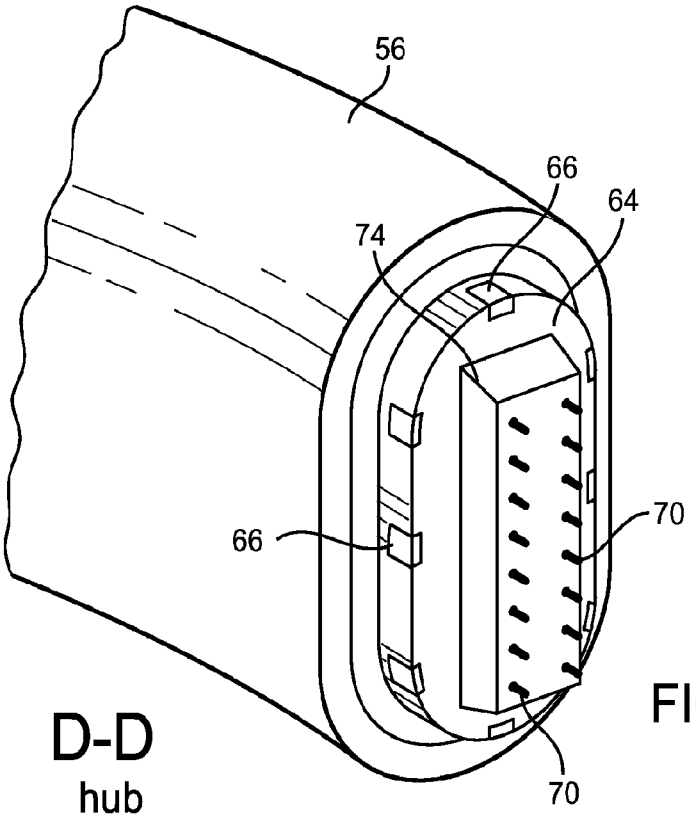


FIG. 19

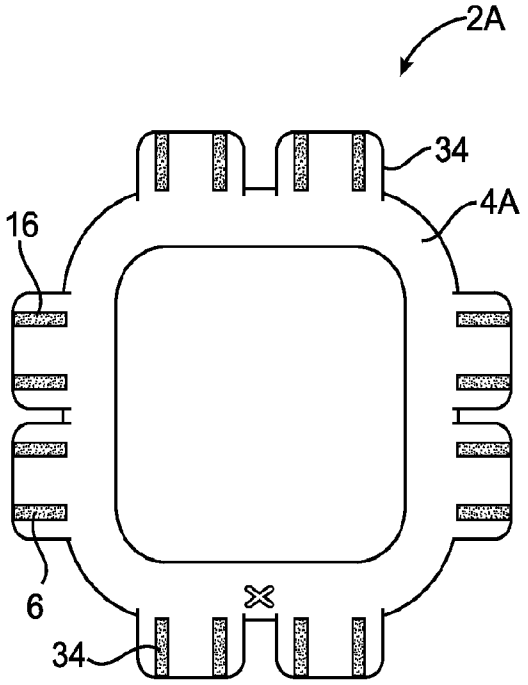


FIG. 20

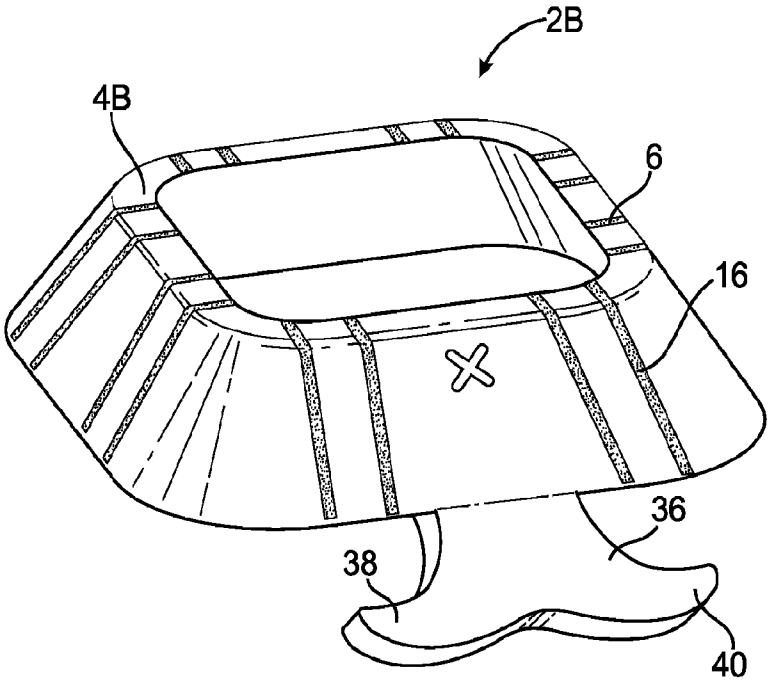


FIG. 21

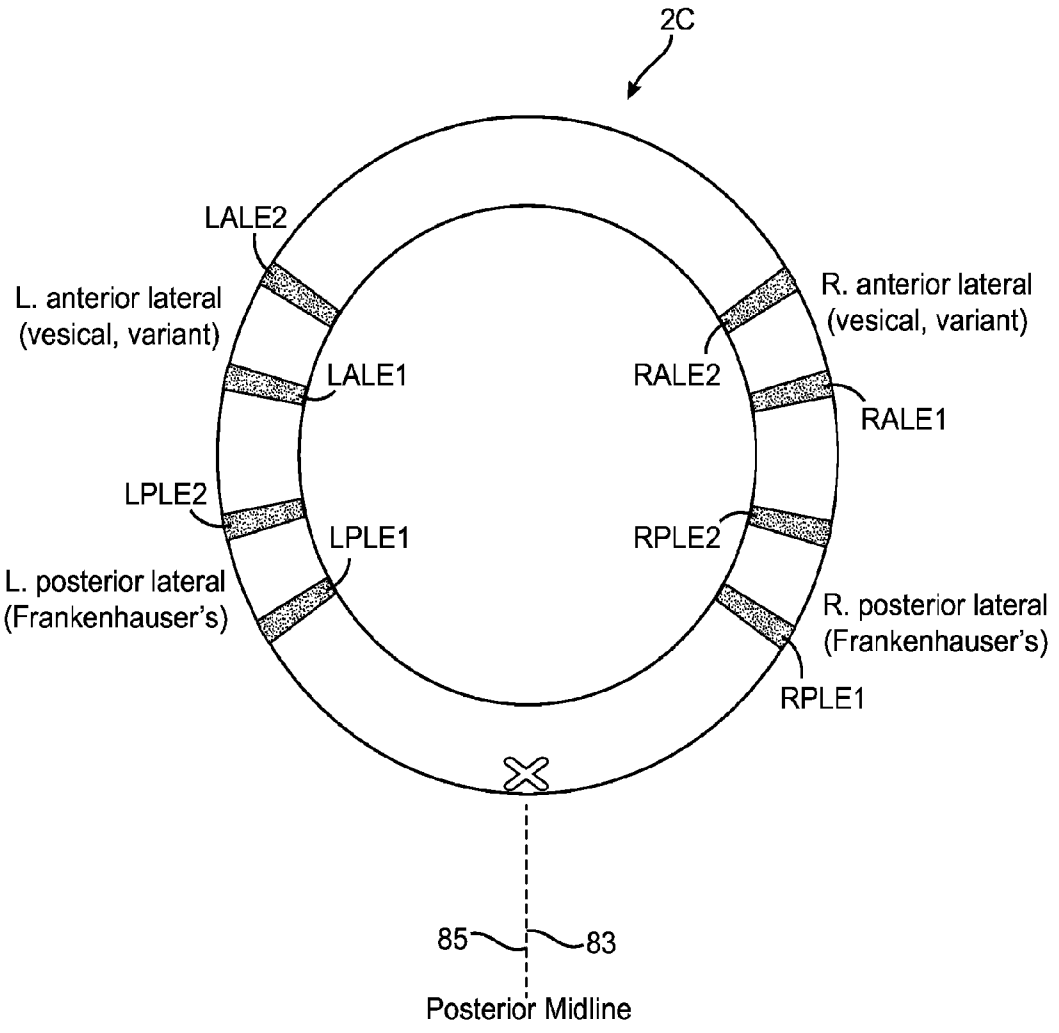

2C
LALE2
L. anterior lateral
(vesical, variant)
LALE1
LPLE2
LPLE1
L. posterior lateral
(Frankenhauser's)
R. anterior lateral
(vesical, variant)
RALE2
RALE1
RPLE2
R. posterior lateral
(Frankenhauser's)
RPLE1
85
83
Posterior Midline

FIG. 22

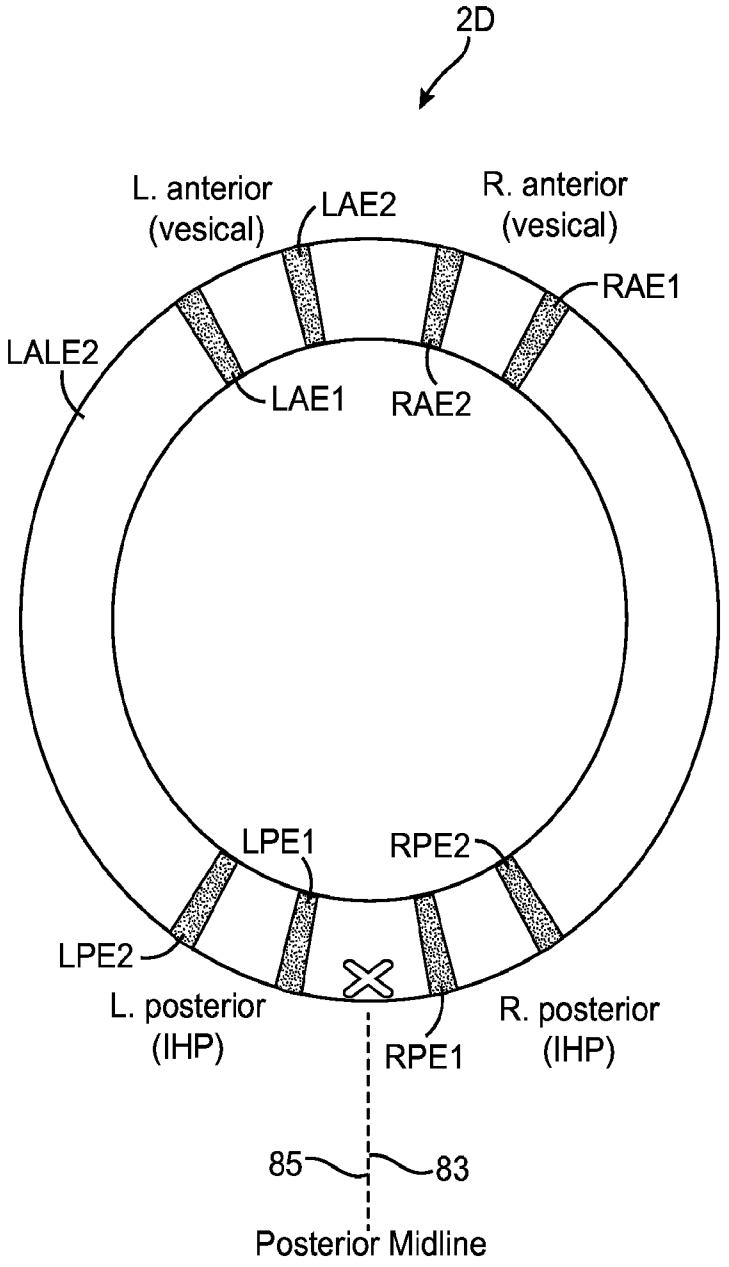

2D
L. anterior
(vesical)
LAE2
R. anterior
(vesical)
RAE1
LALE2
LAE1
RAE2
LPE1
RPE2
LPE2
L. posterior
(IHP)
R. posterior
(IHP)
RPE1
85
83
Posterior Midline

FIG. 23

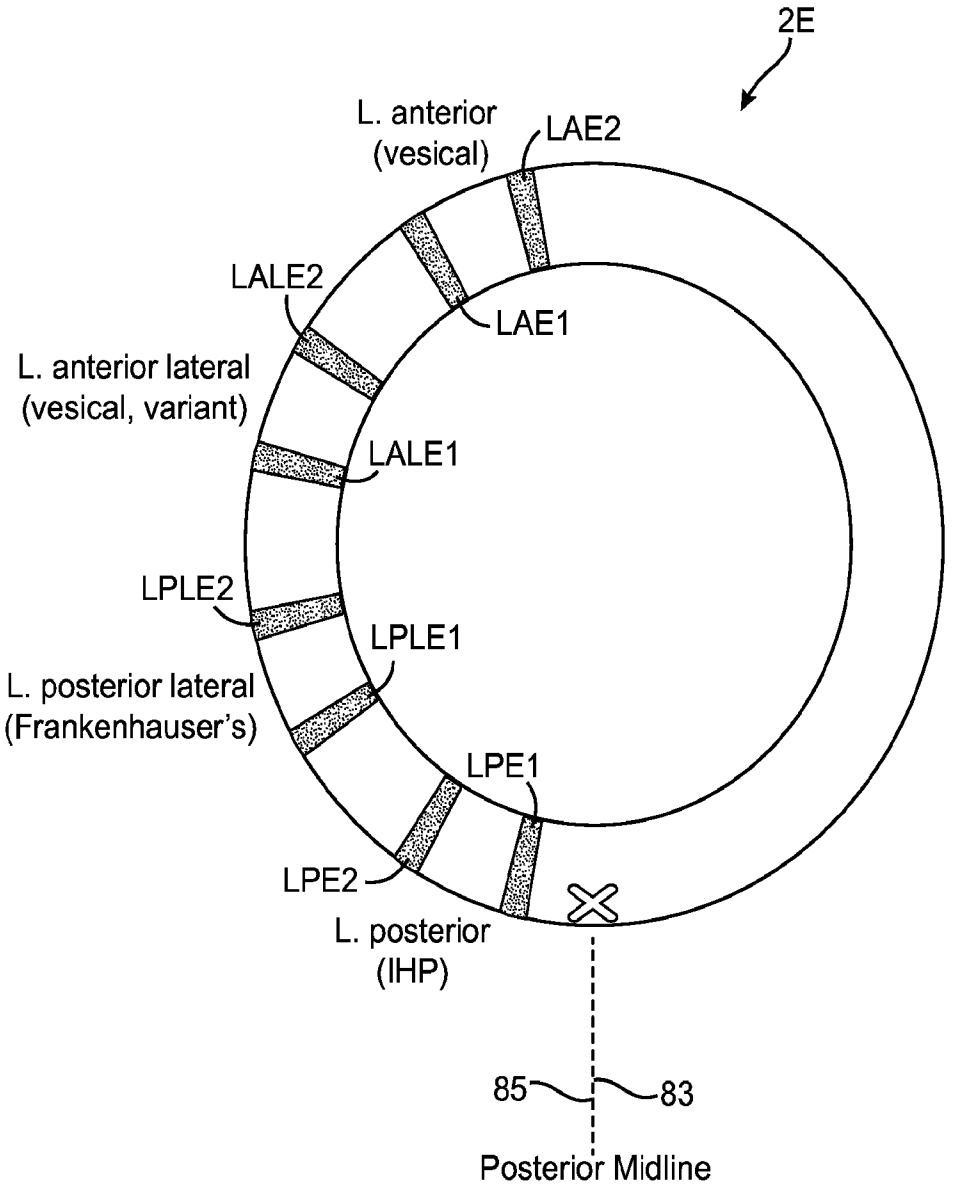

2E
L. anterior
(vesical)
LAE2
LALE2
LAE1
L. anterior lateral
(vesical, variant)
LALE1
LPLE2
LPLE1
L. posterior lateral
(Frankenhauser's)
LPE1
LPE2
L. posterior
(IHP)
85
83
Posterior Midline

FIG. 24

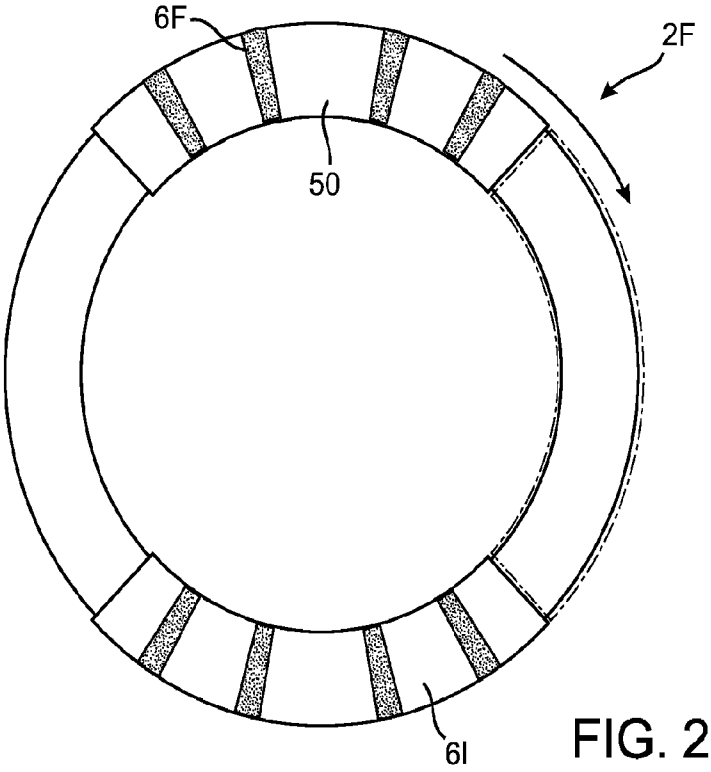


FIG. 25

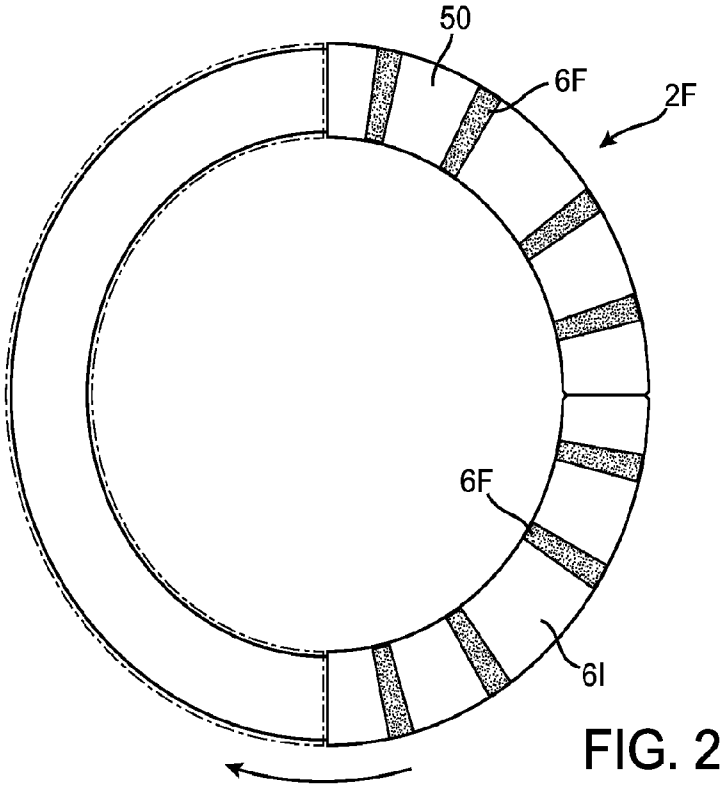


FIG. 26

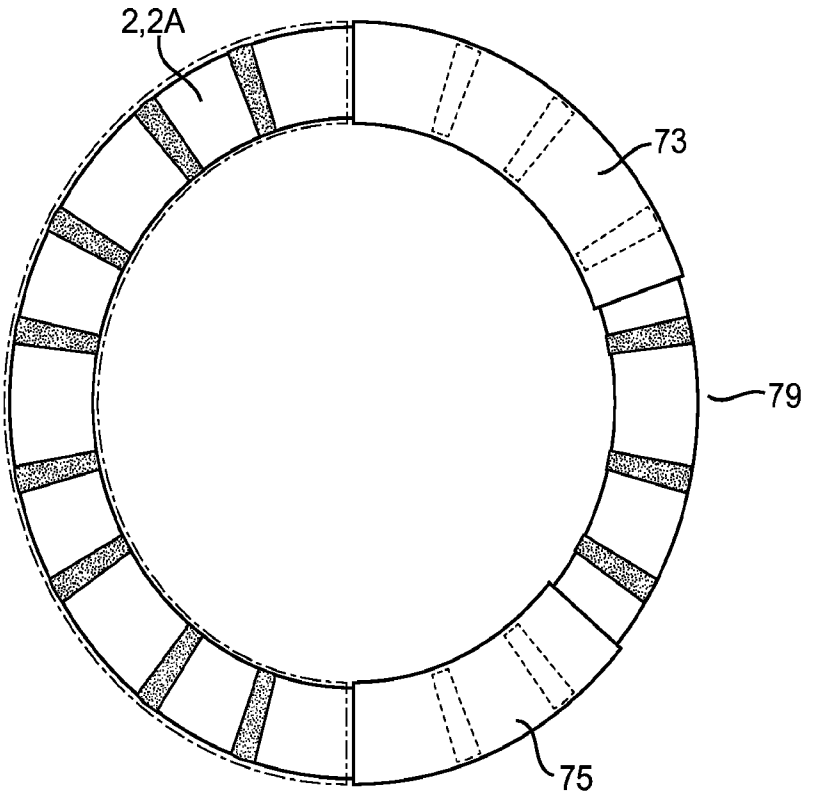


FIG. 27

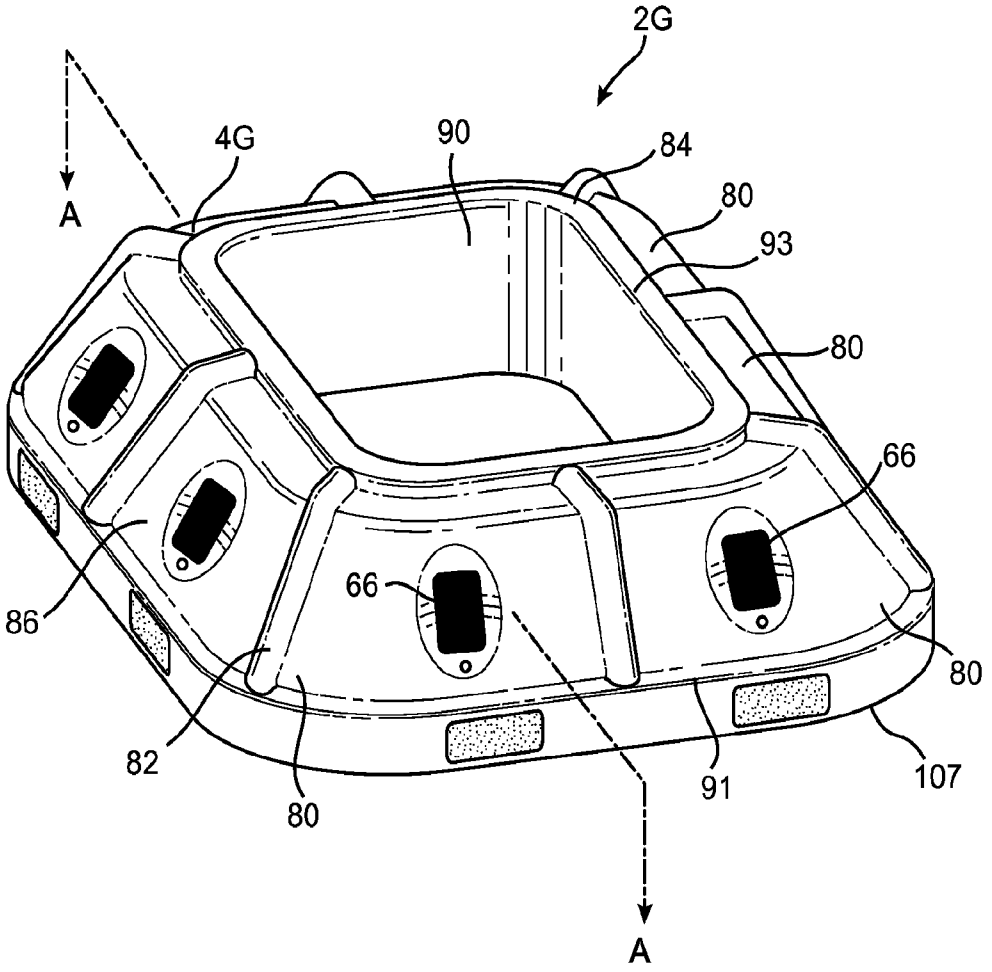
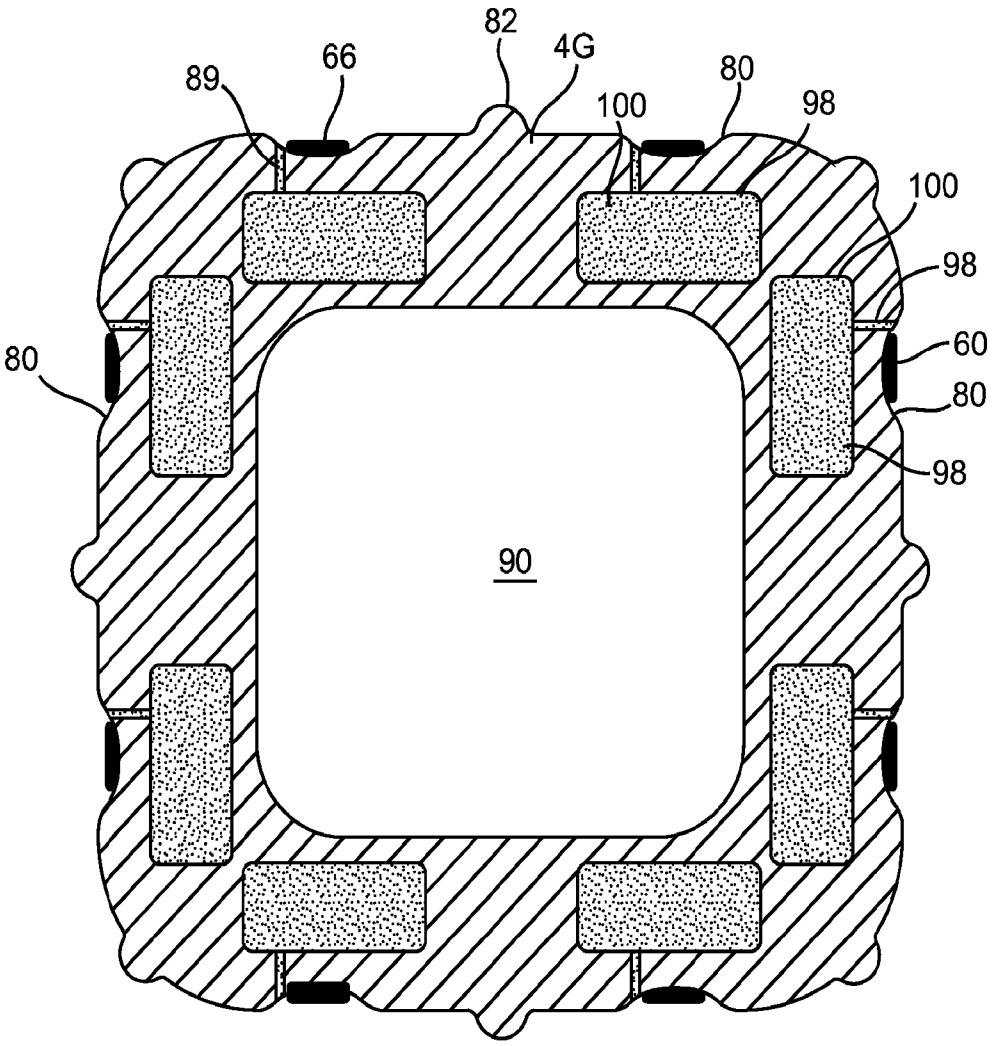


FIG. 28



A-A

FIG. 29

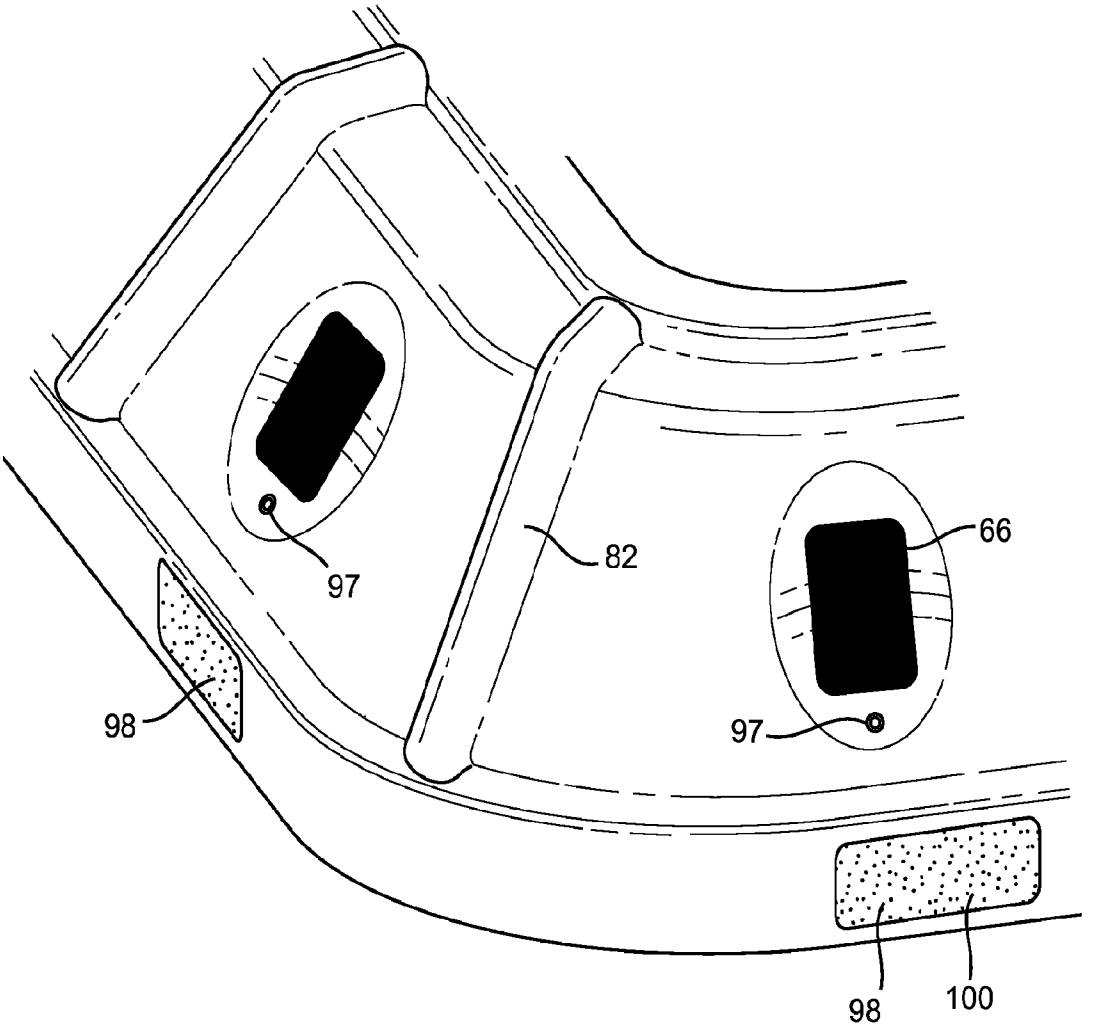


FIG. 30

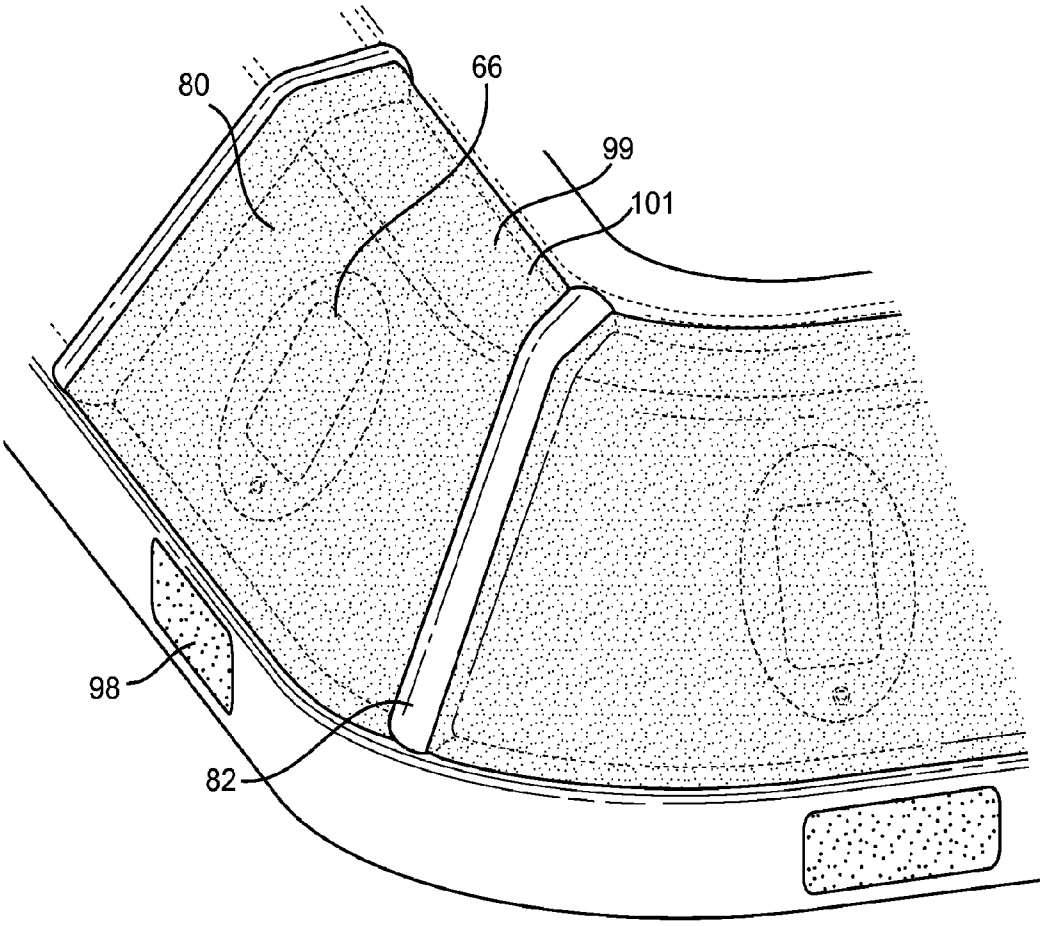


FIG. 31

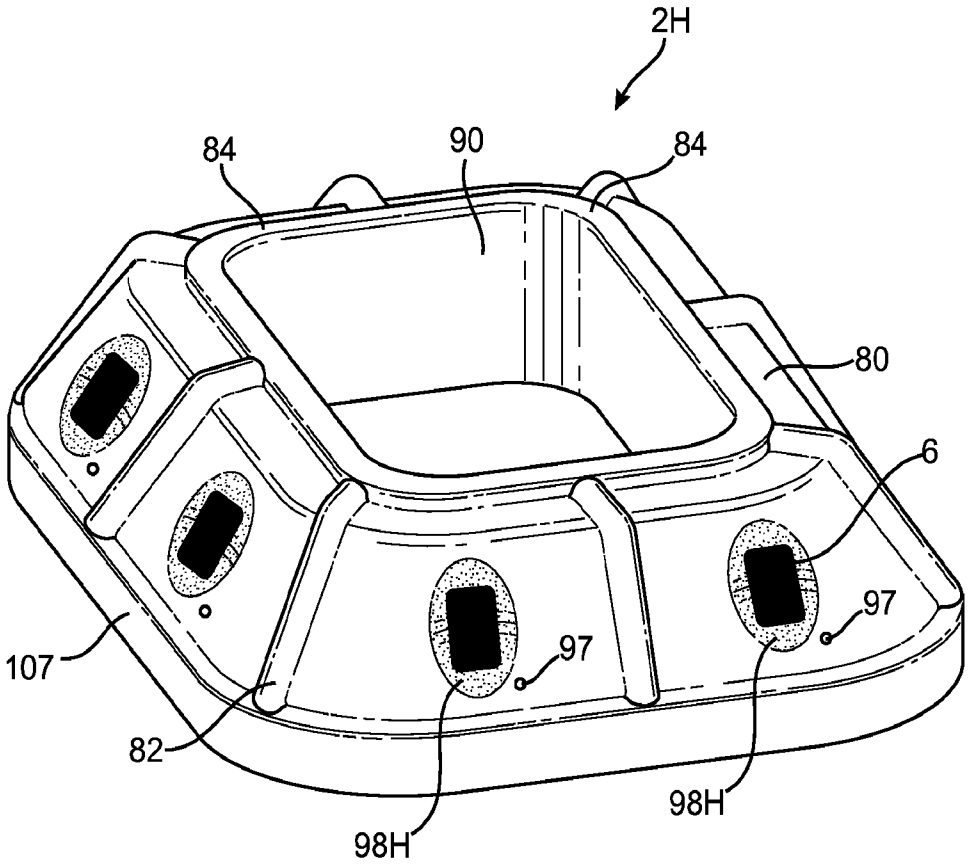


FIG. 32

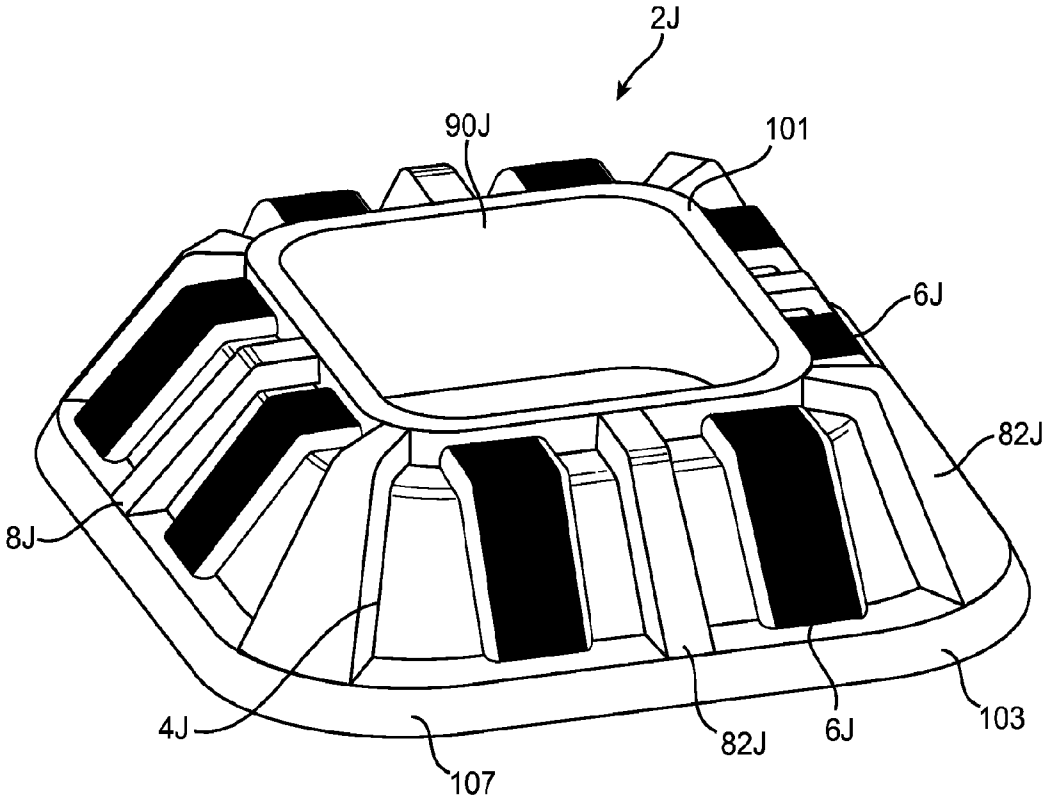


FIG. 33

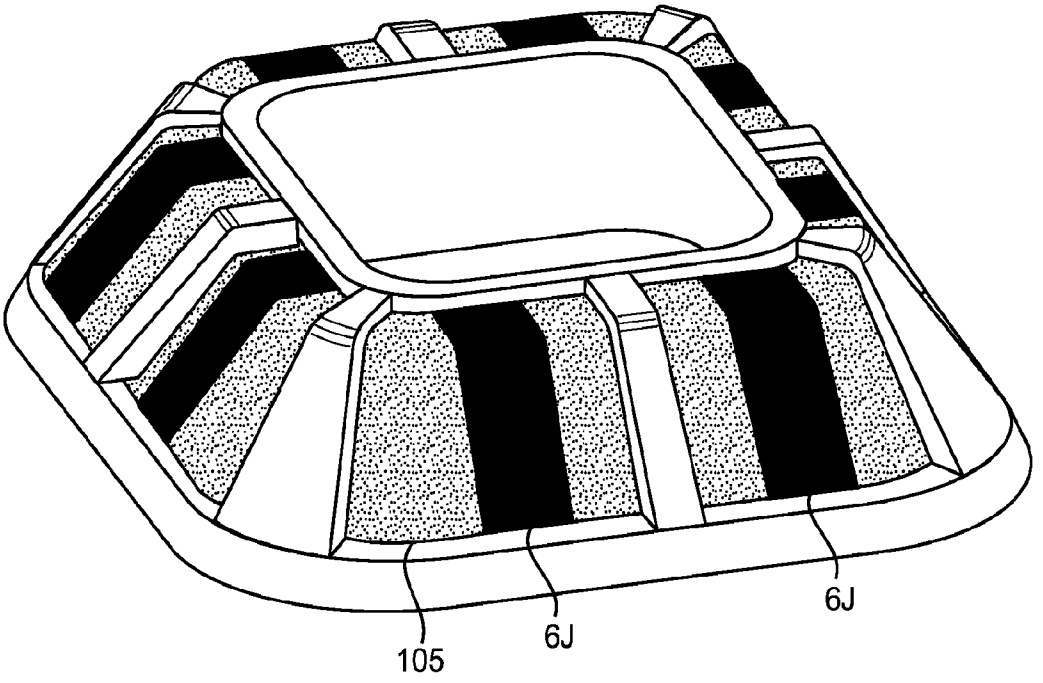


FIG. 34

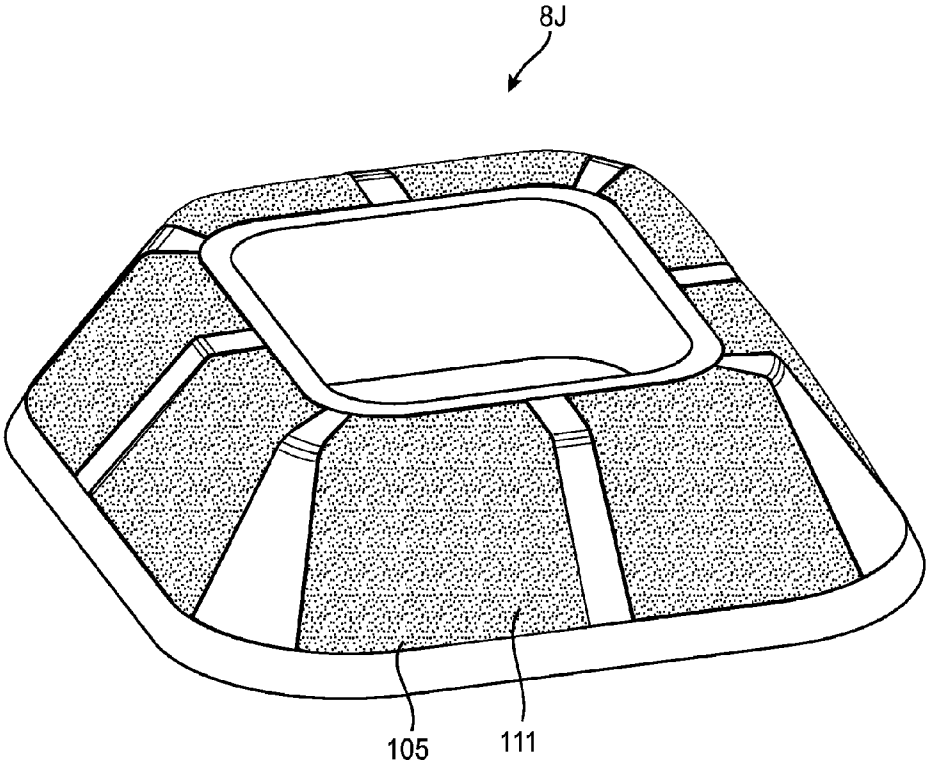


FIG. 35

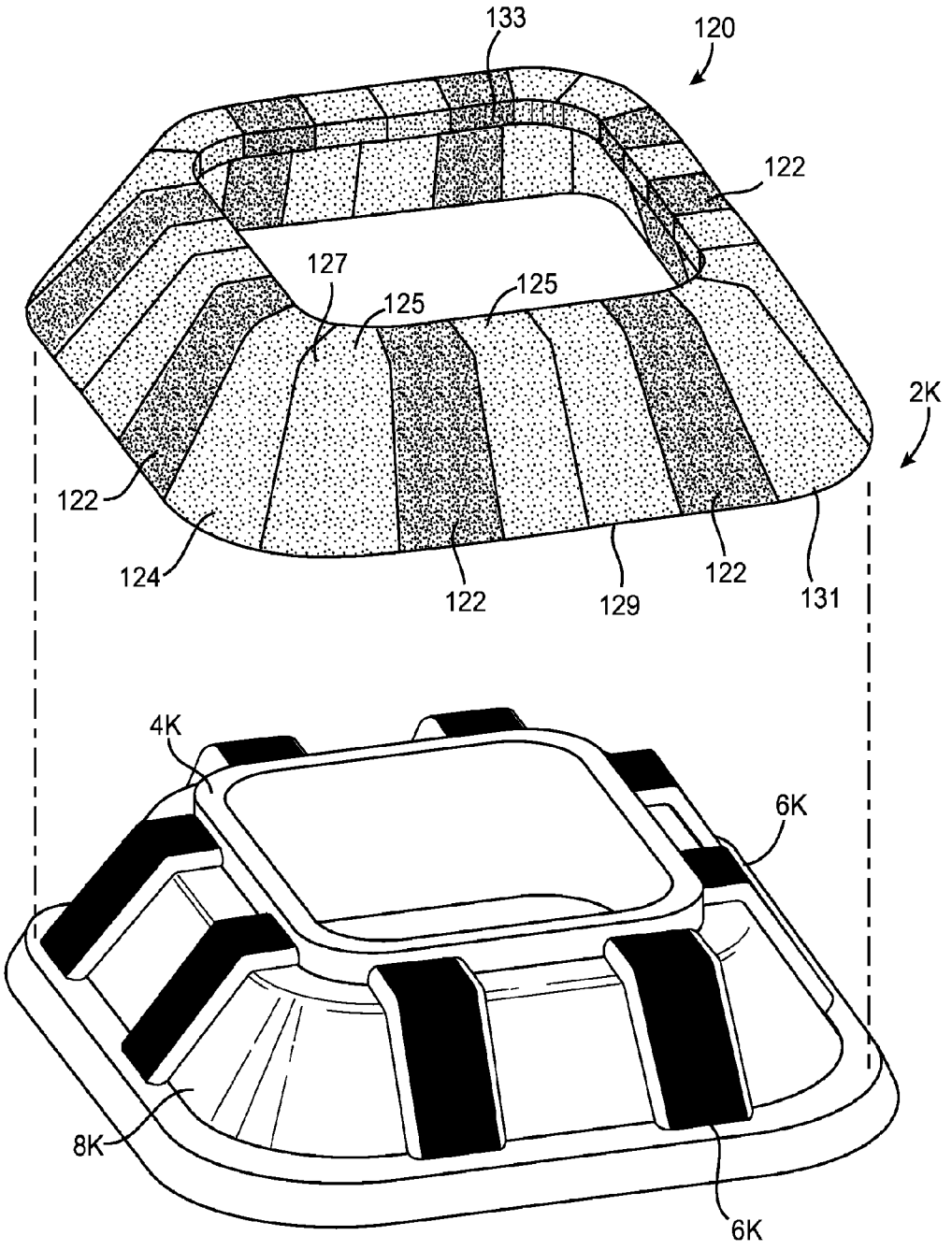


FIG. 36

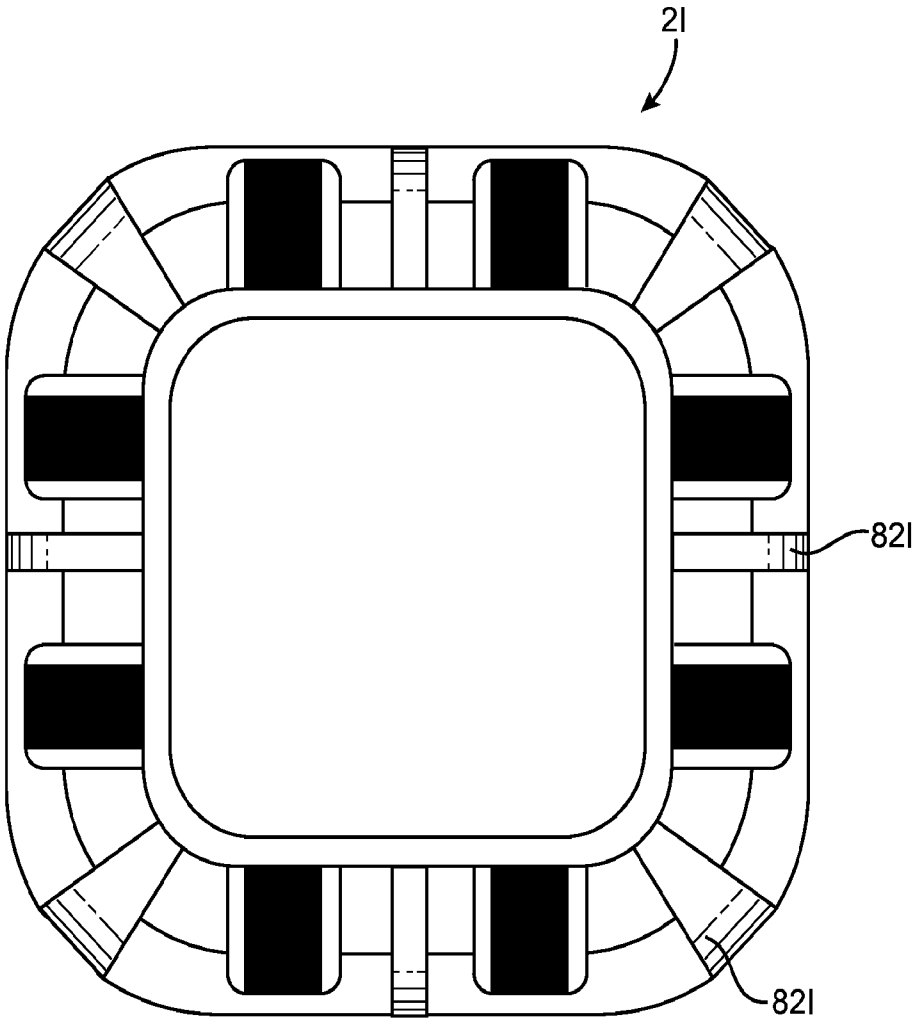


FIG. 37

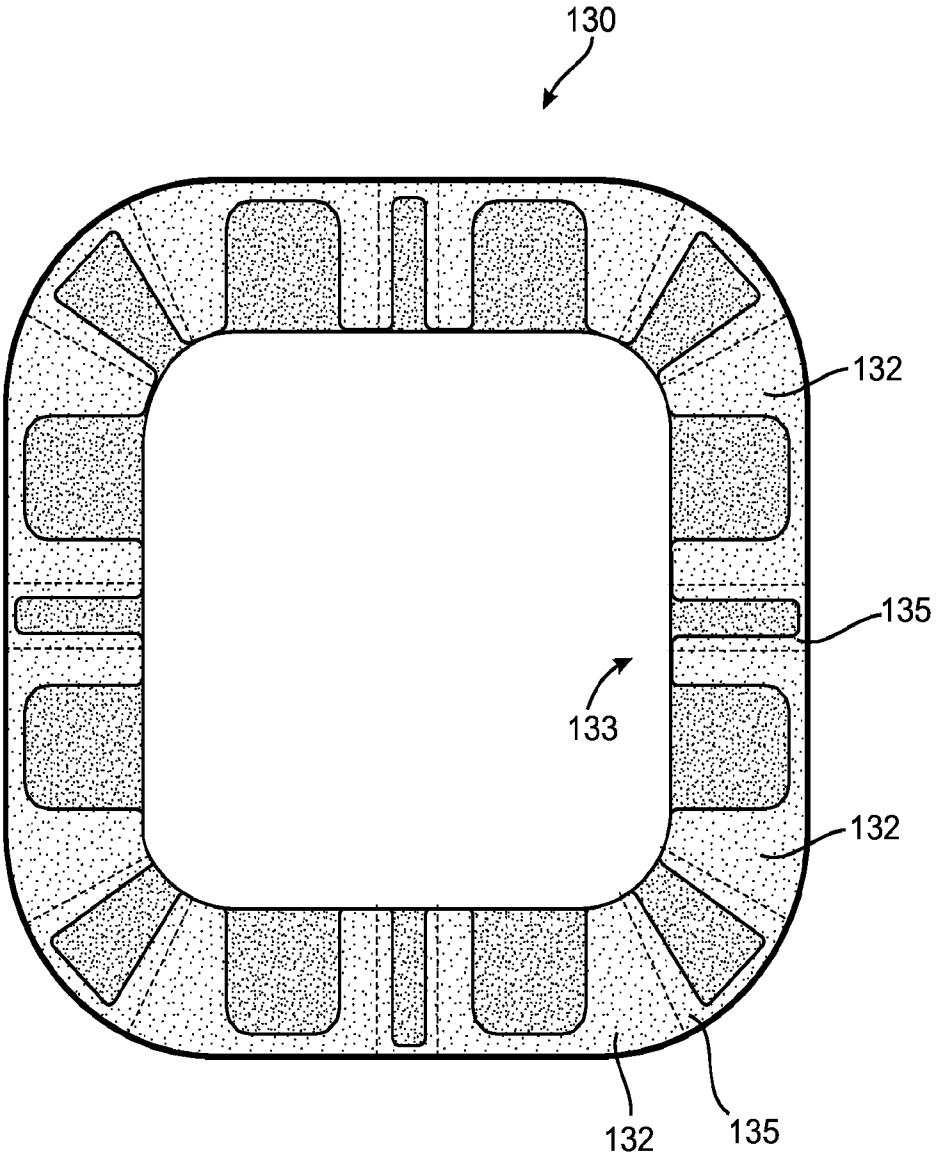


FIG. 38

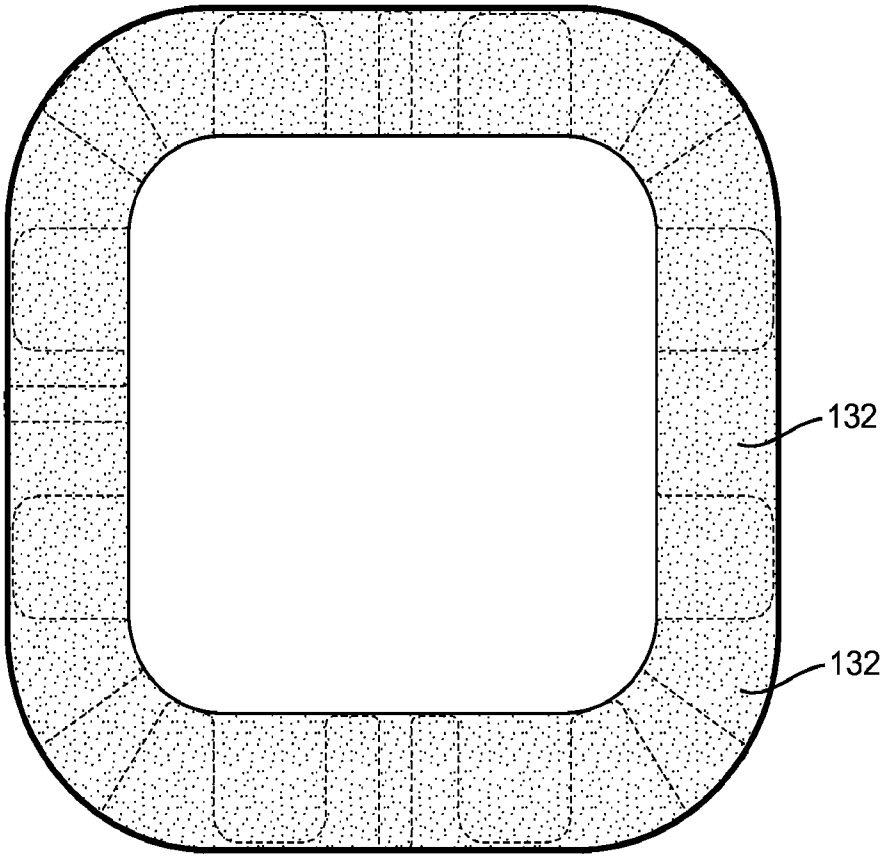


FIG. 39

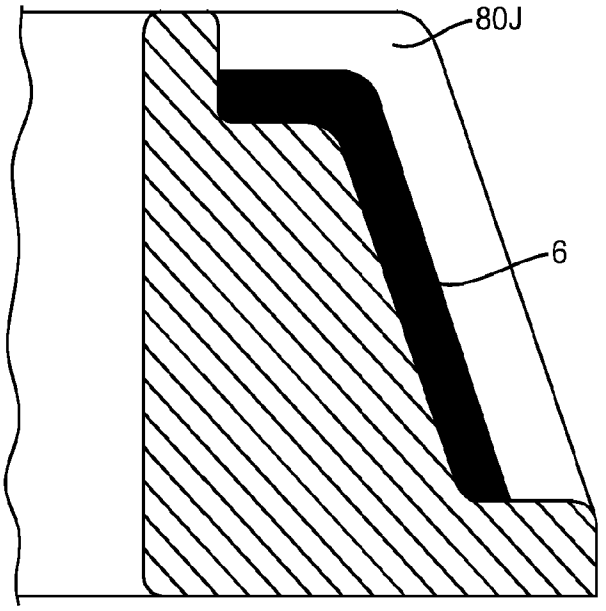


FIG. 40

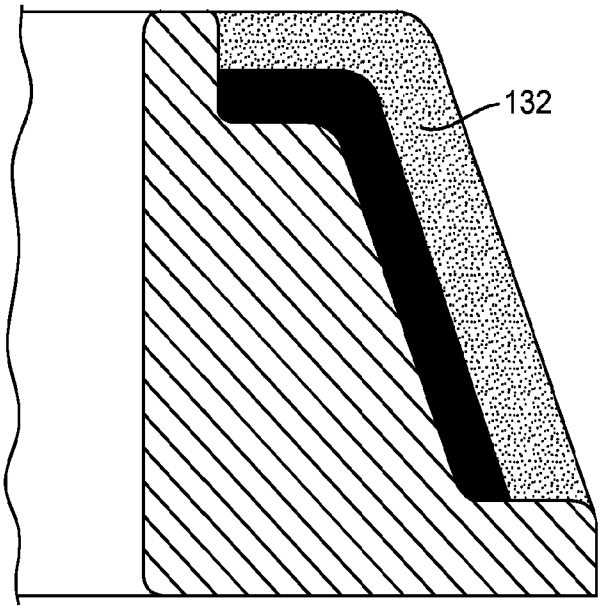


FIG. 41

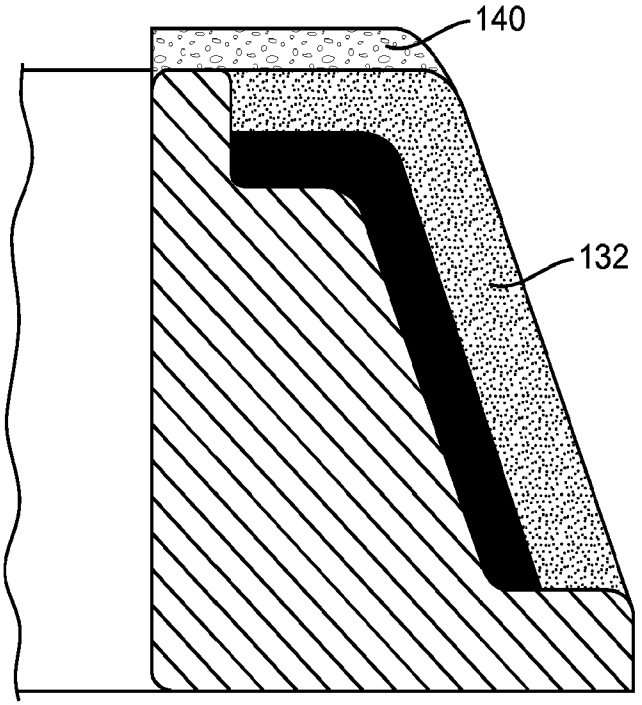


FIG. 42

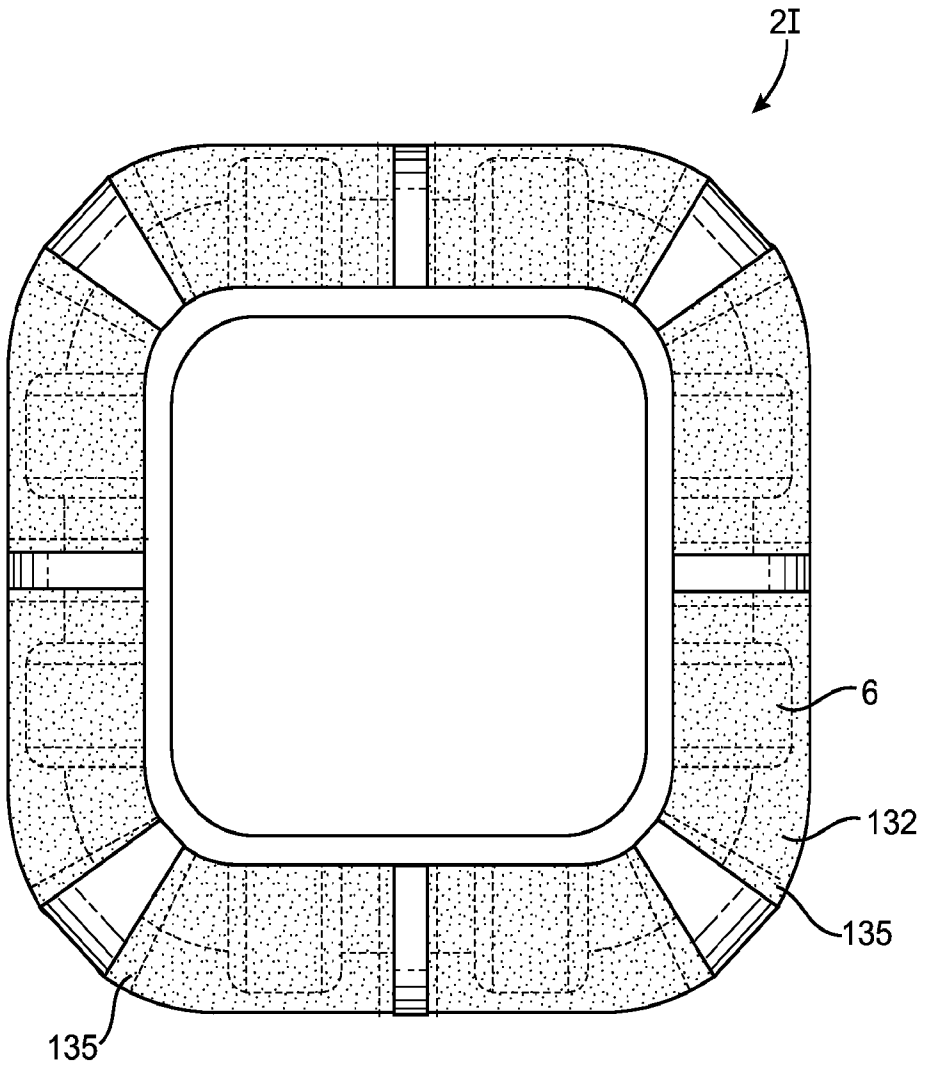


FIG. 43

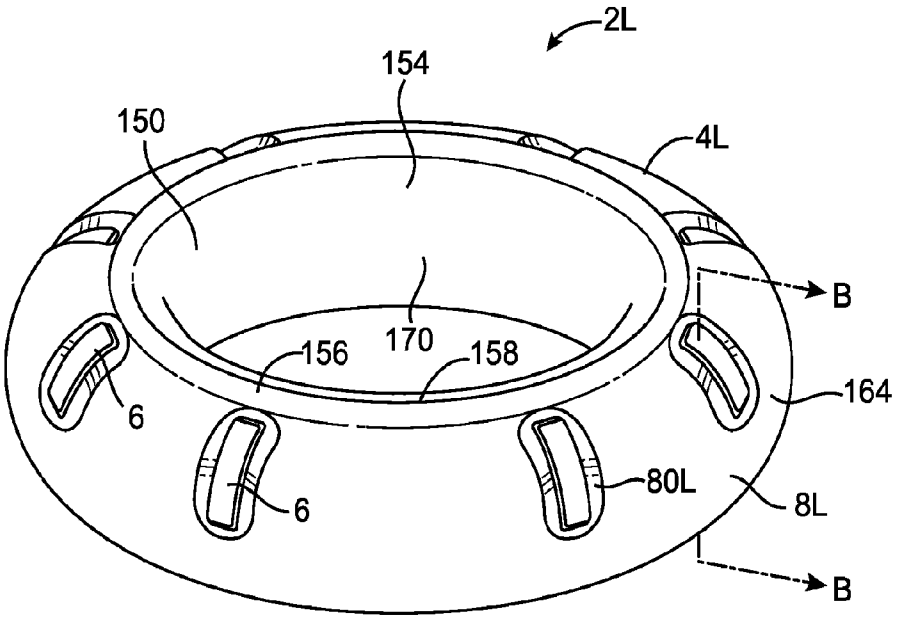


FIG. 44

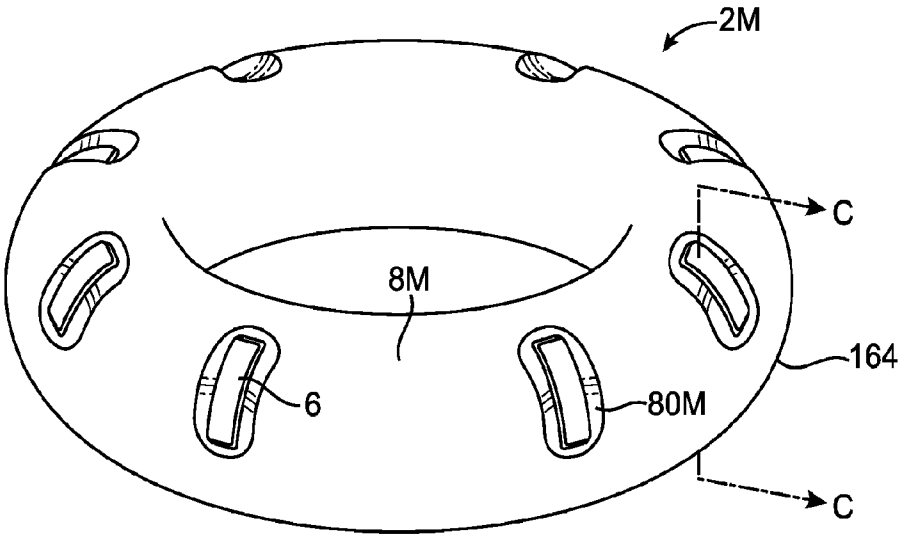
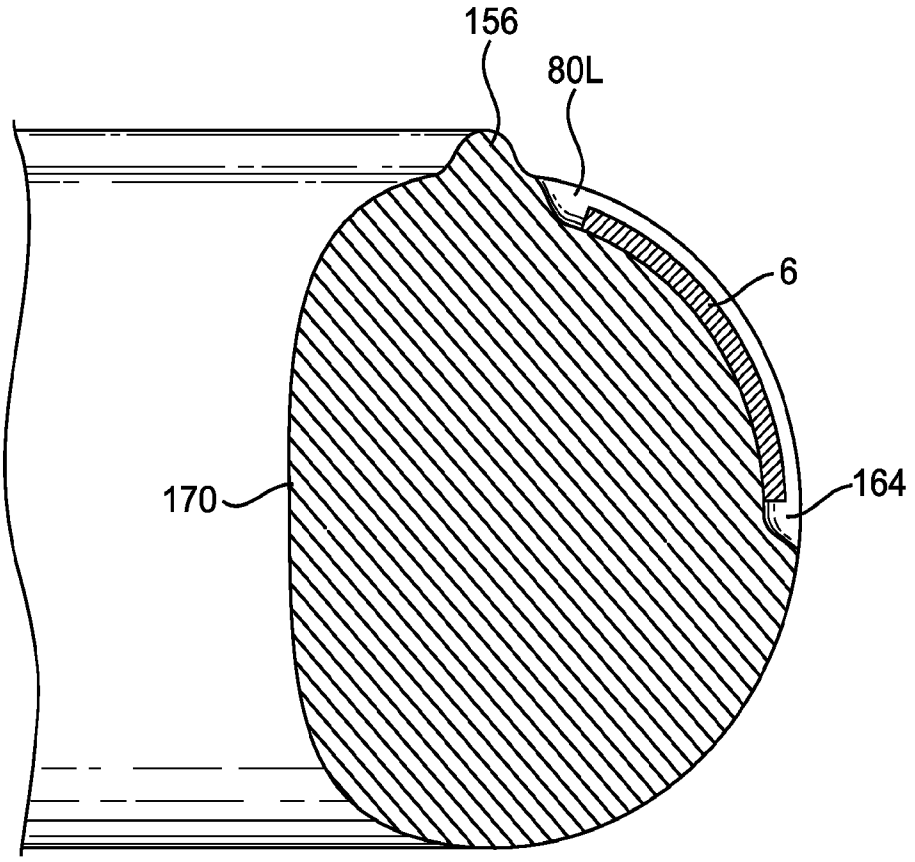
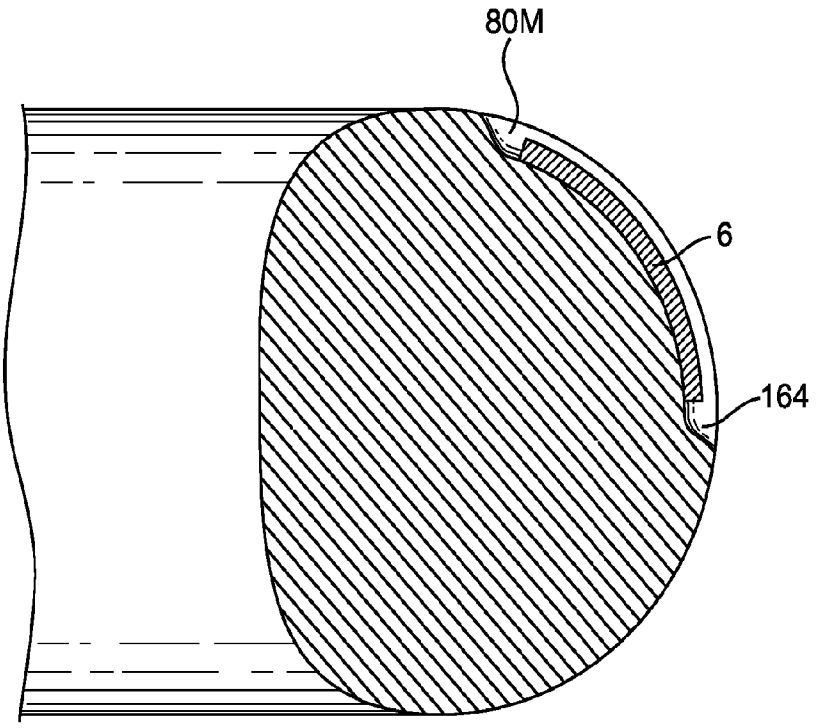


FIG. 45



B-B

FIG. 46



C-C

FIG. 47

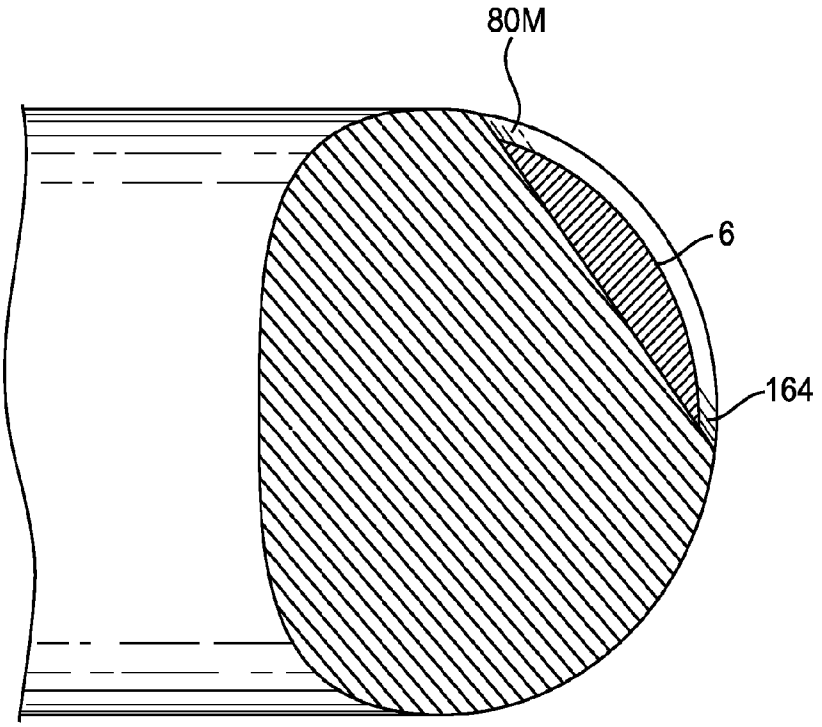


FIG. 48

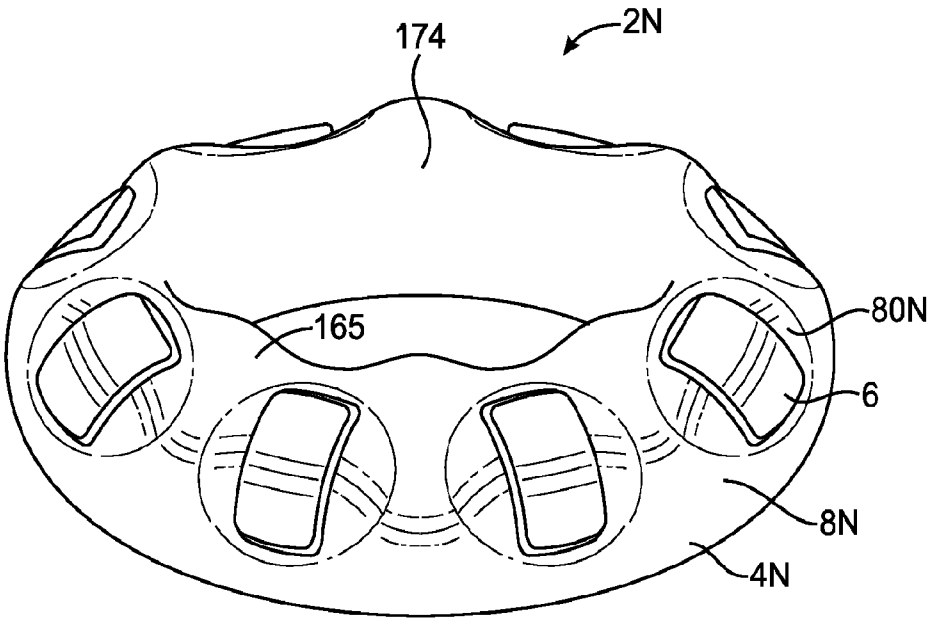


FIG. 49

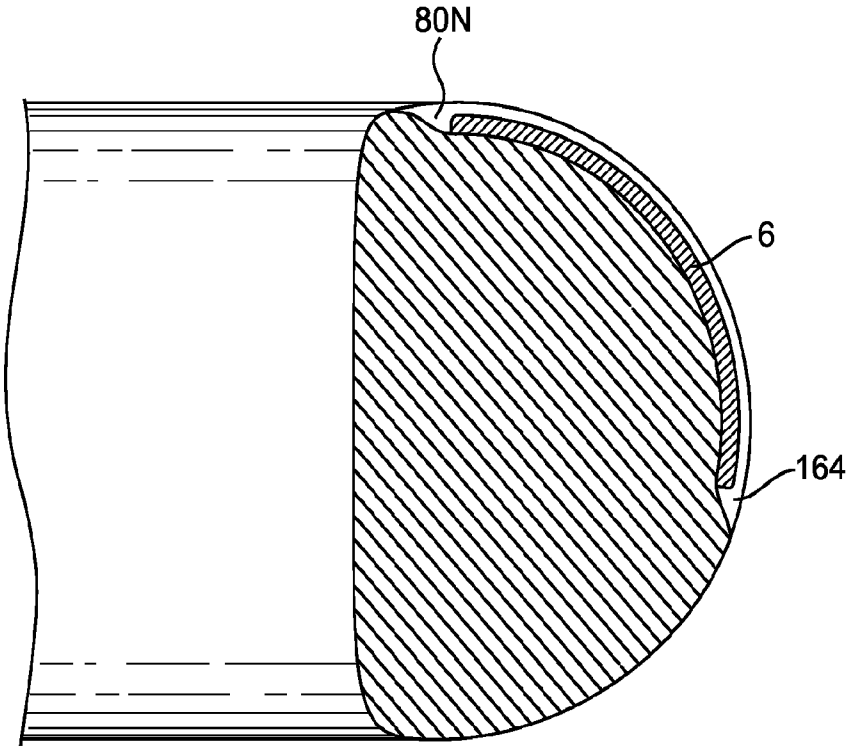


FIG. 50

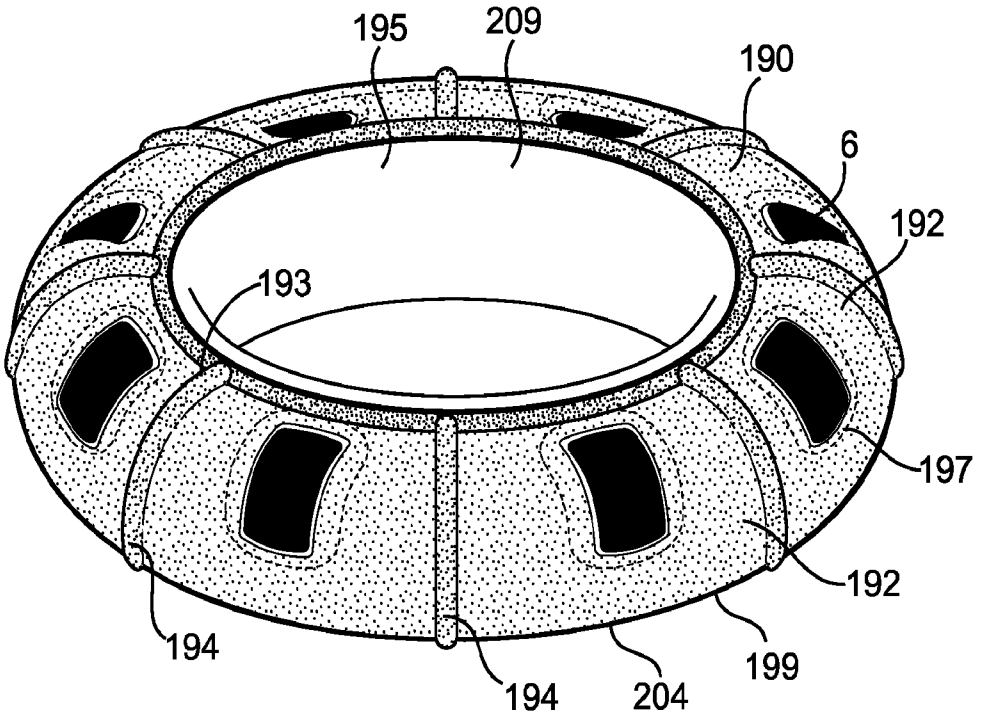


FIG. 51

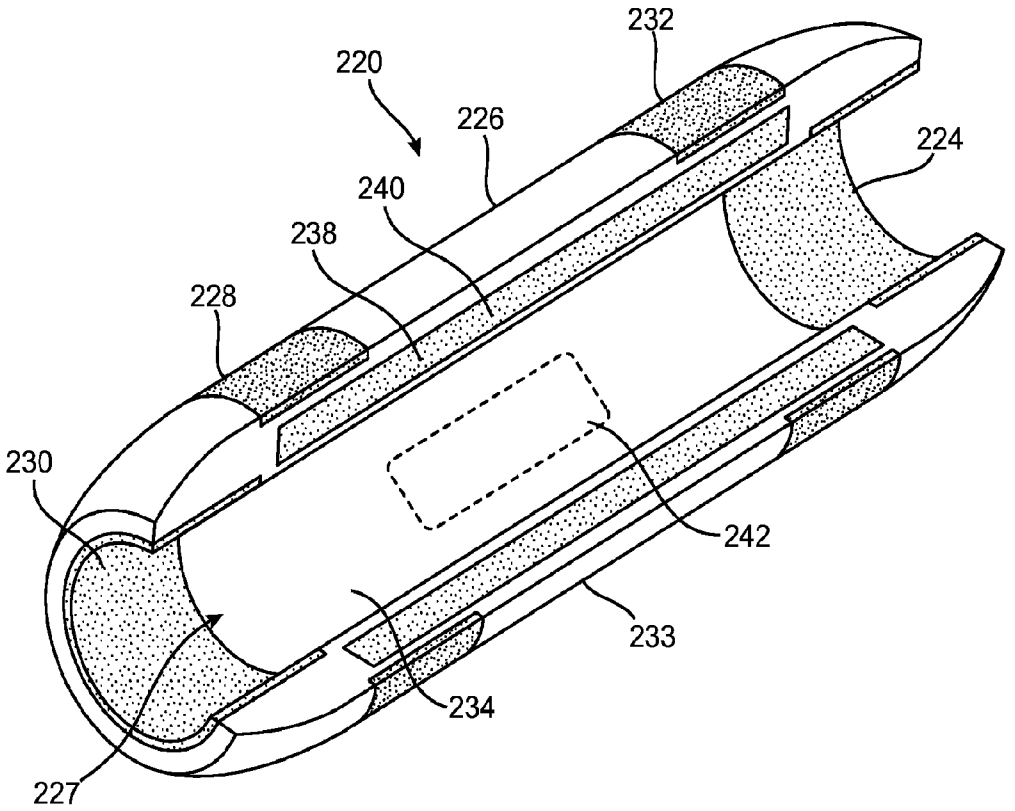


FIG. 52

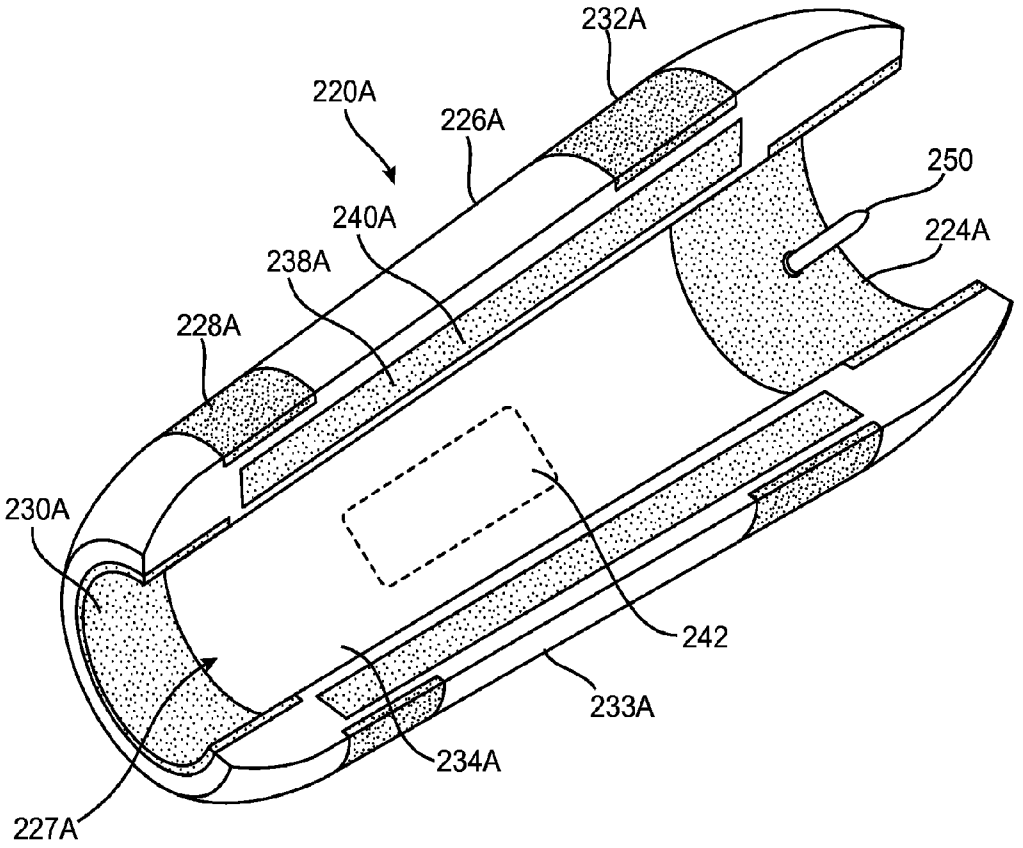

232A
220A
226A
250
240A
224A
238A
228A
230A
242
233A
234A
227A

FIG. 53

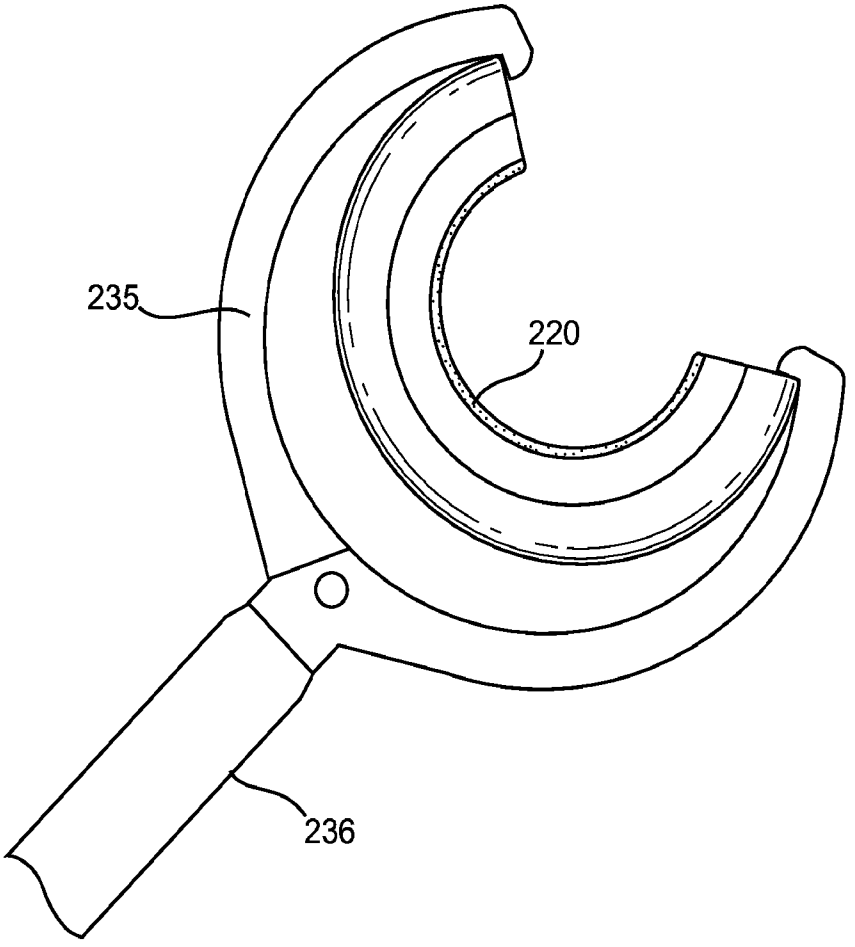


FIG. 54

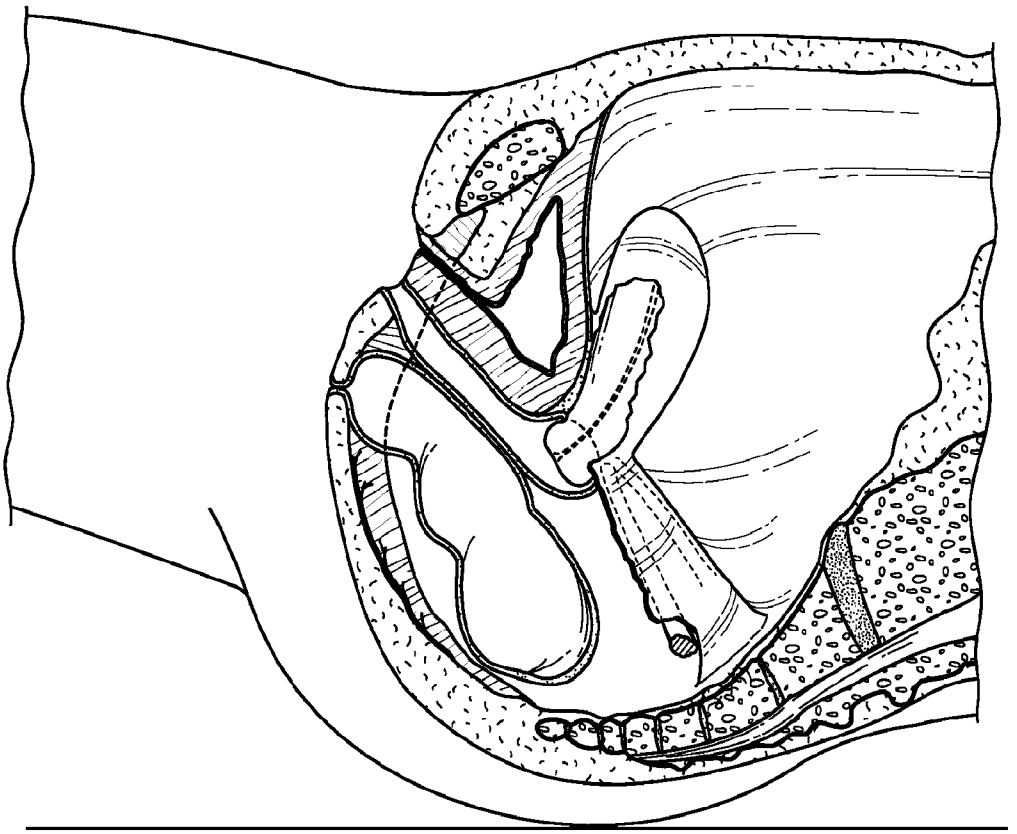


FIG. 55

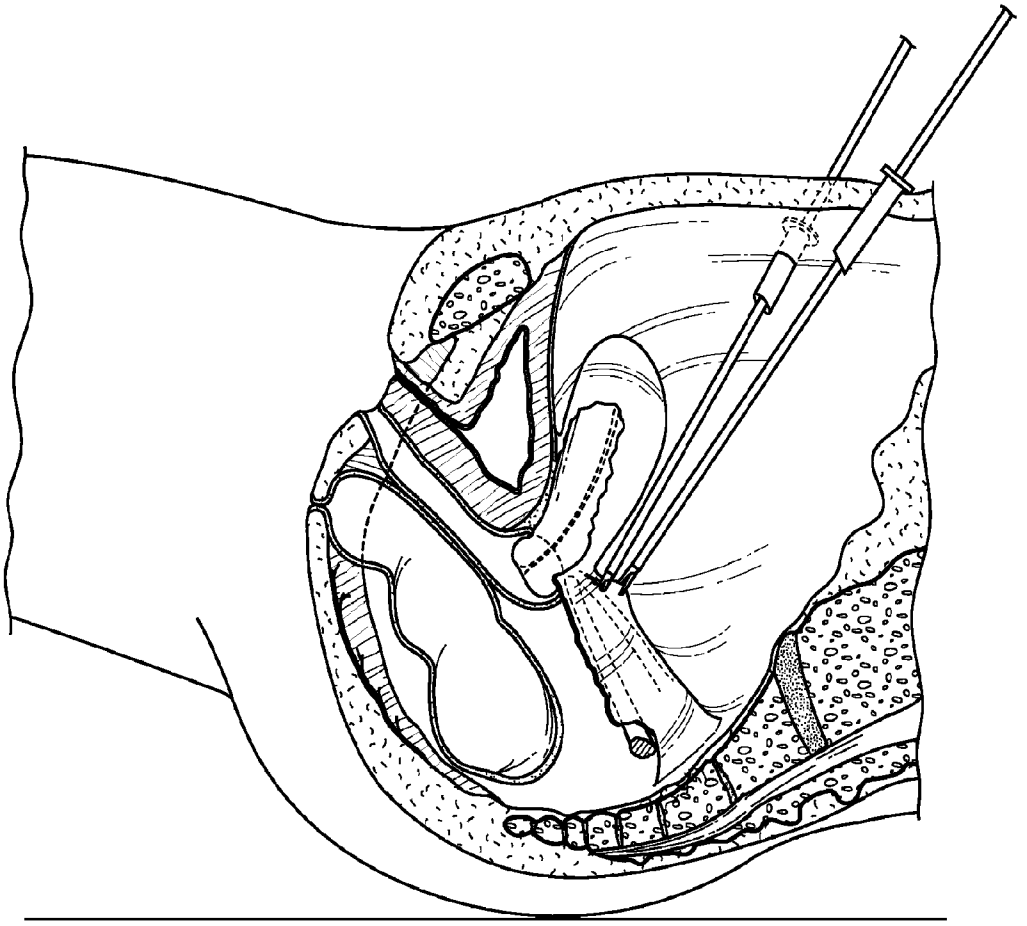


FIG. 56

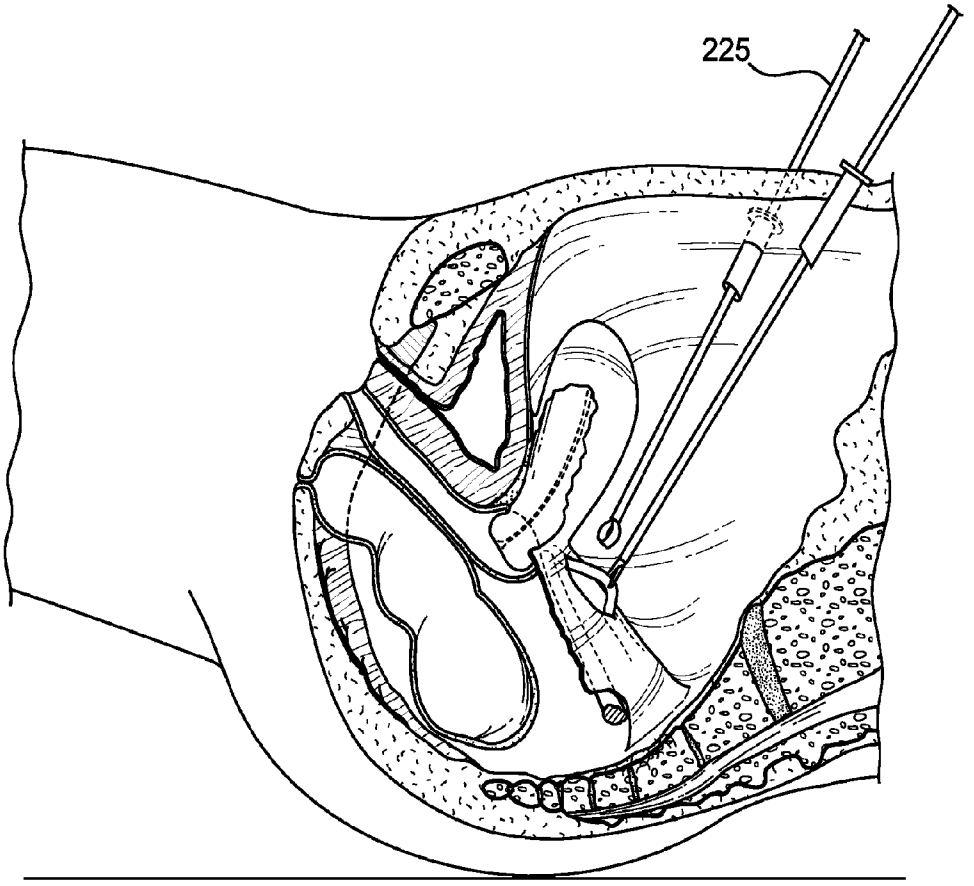


FIG. 57

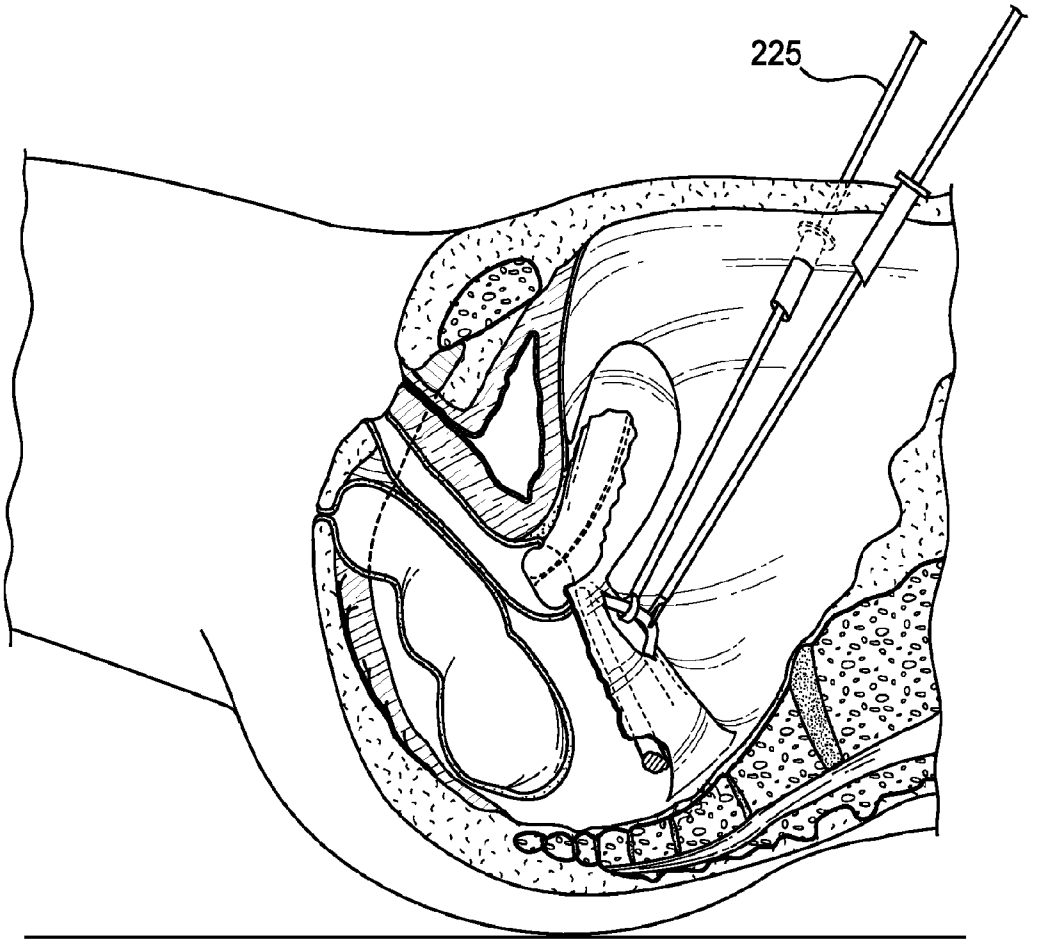


FIG. 58

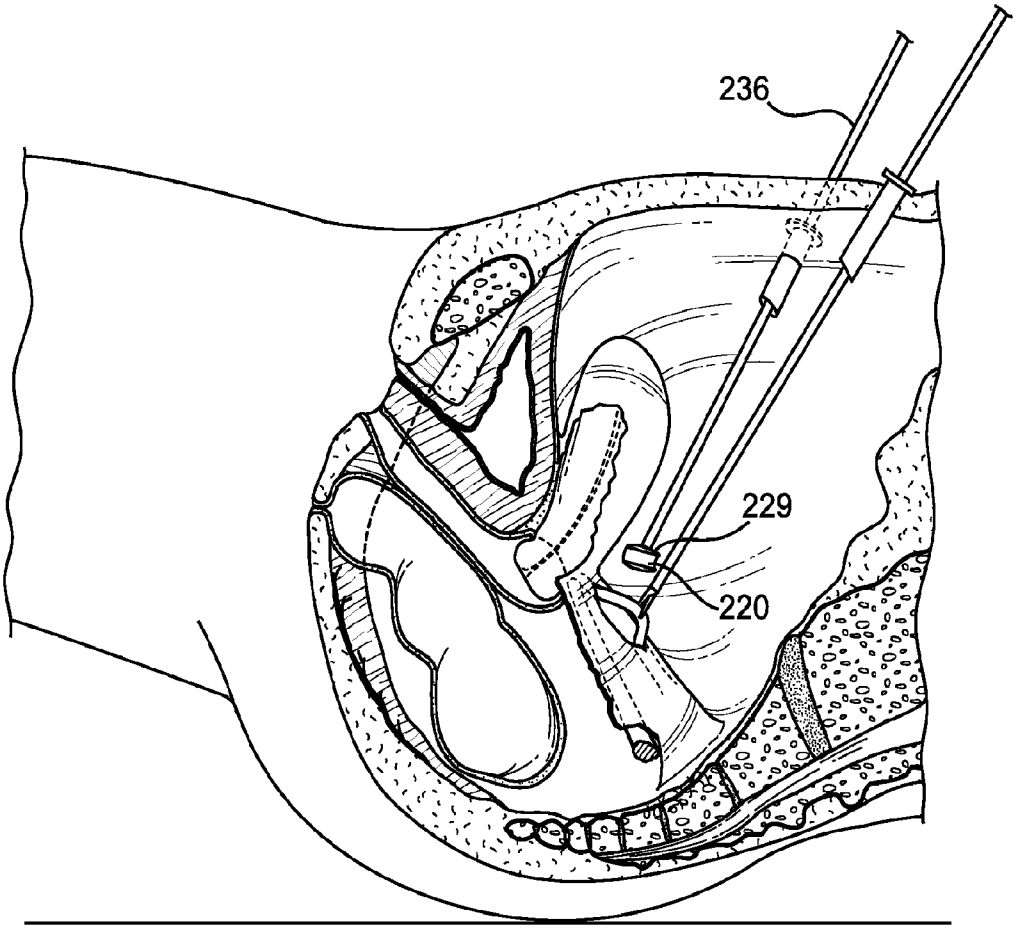


FIG. 59

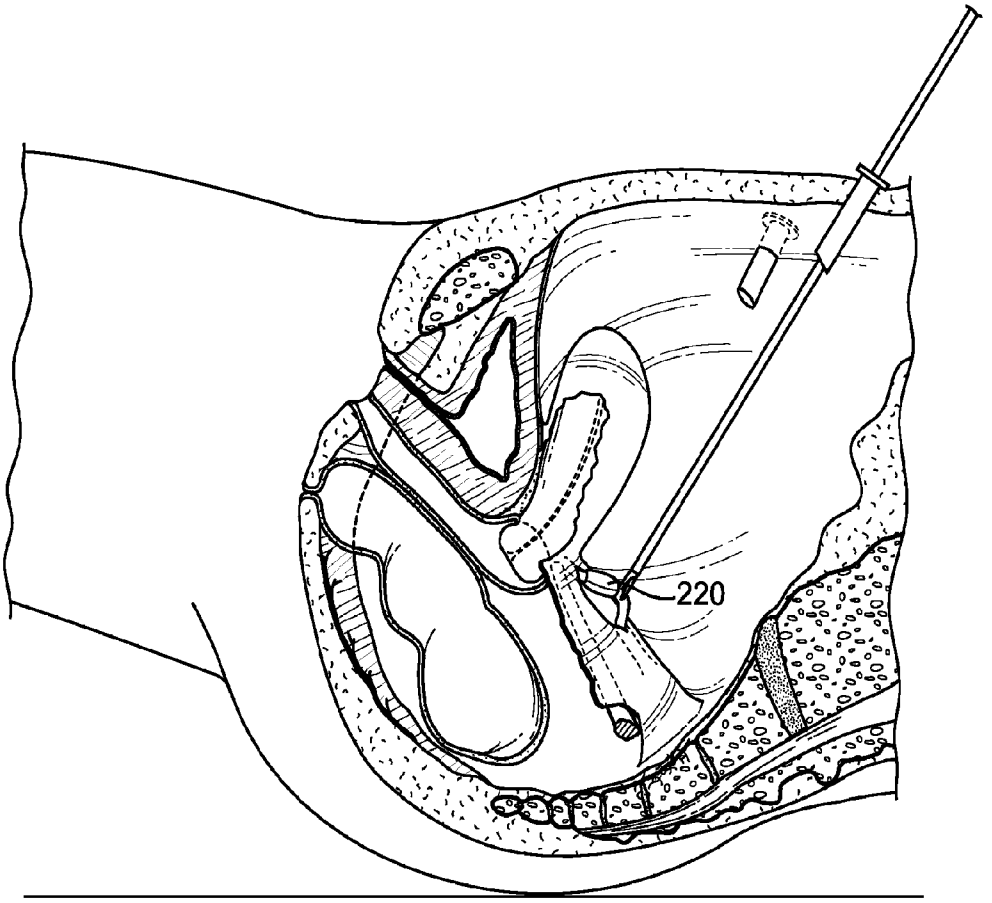


FIG. 60

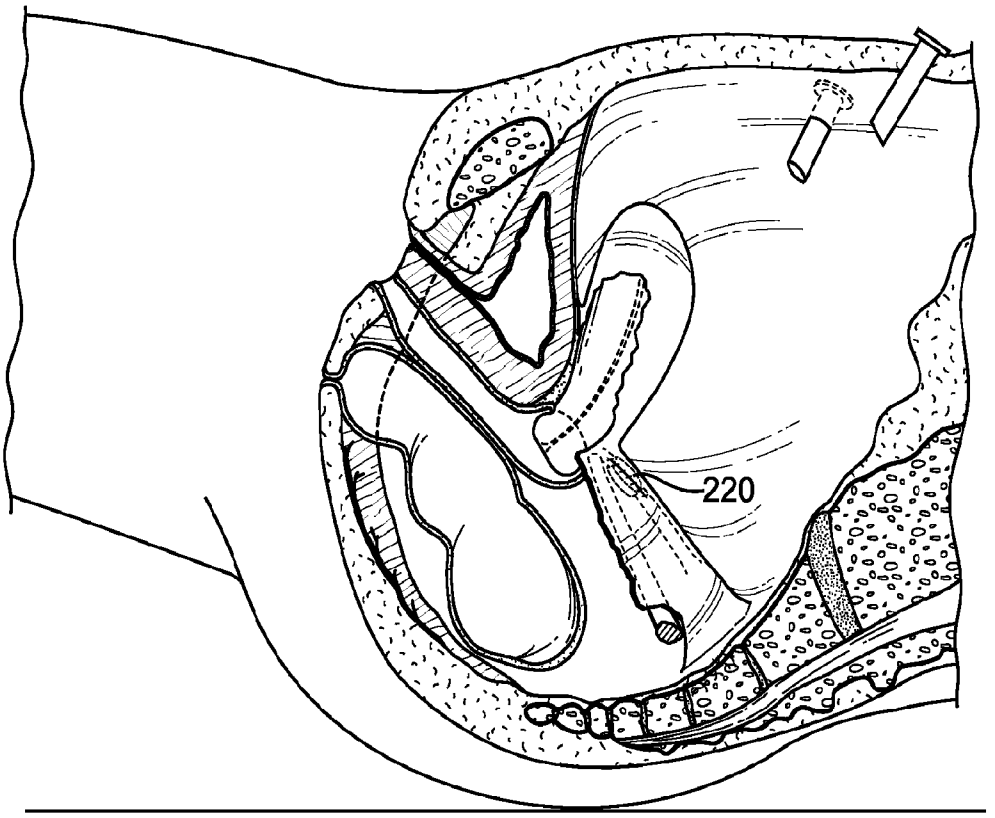


FIG. 61

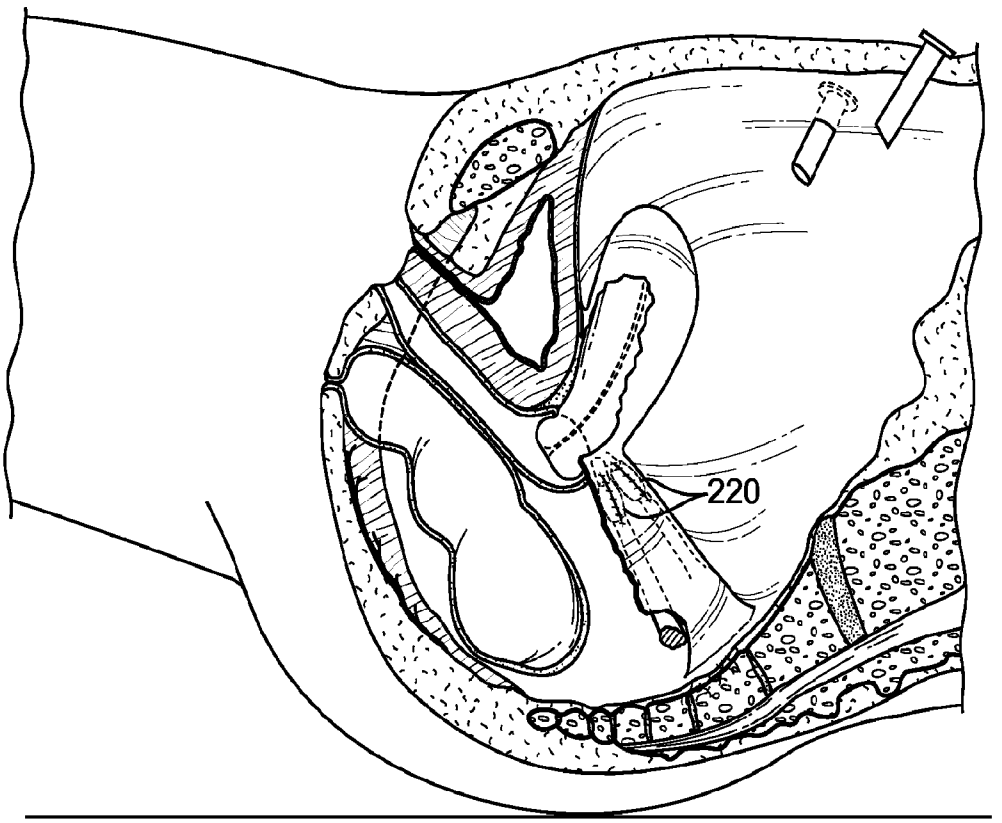


FIG. 62

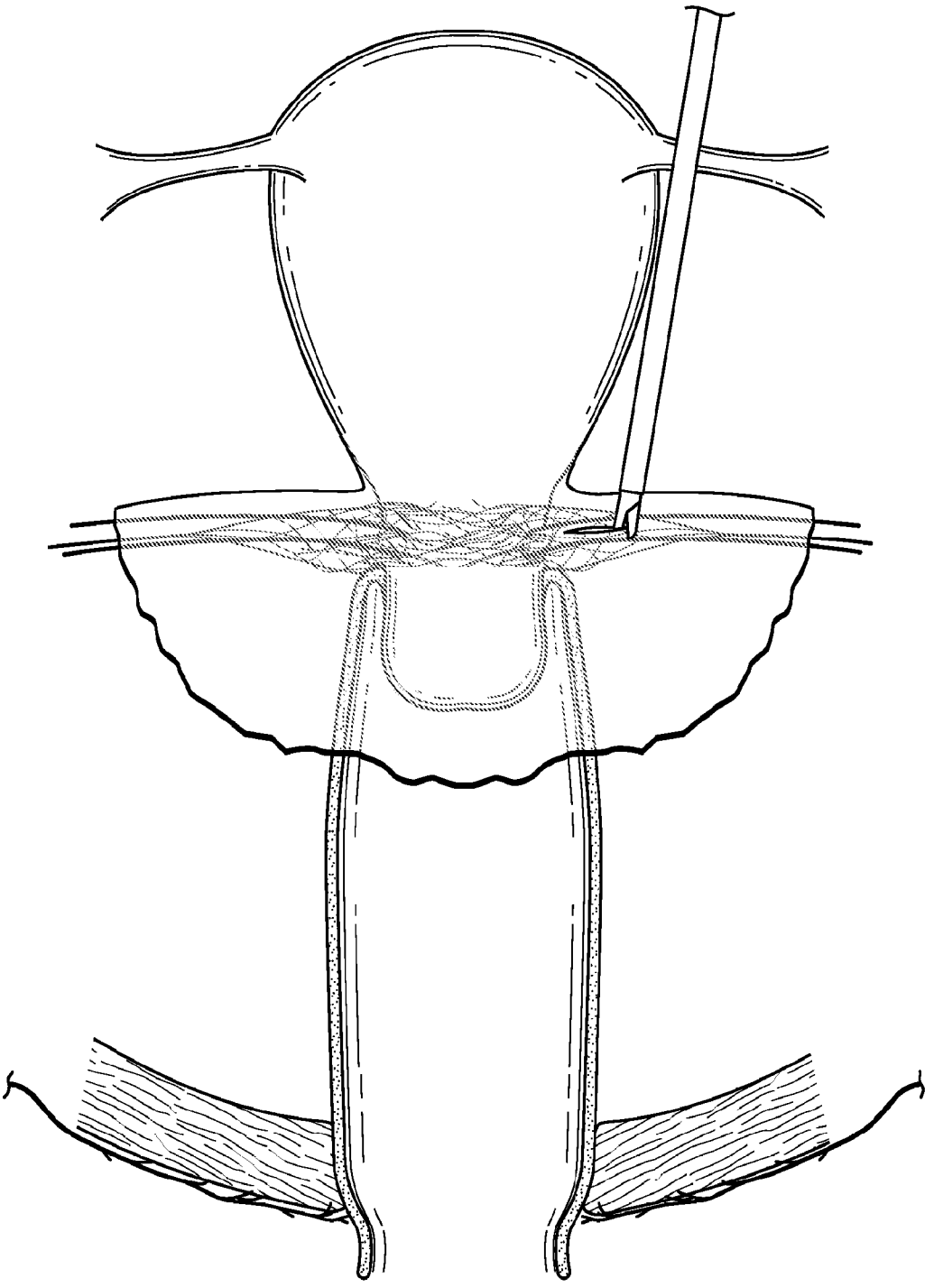


FIG. 63

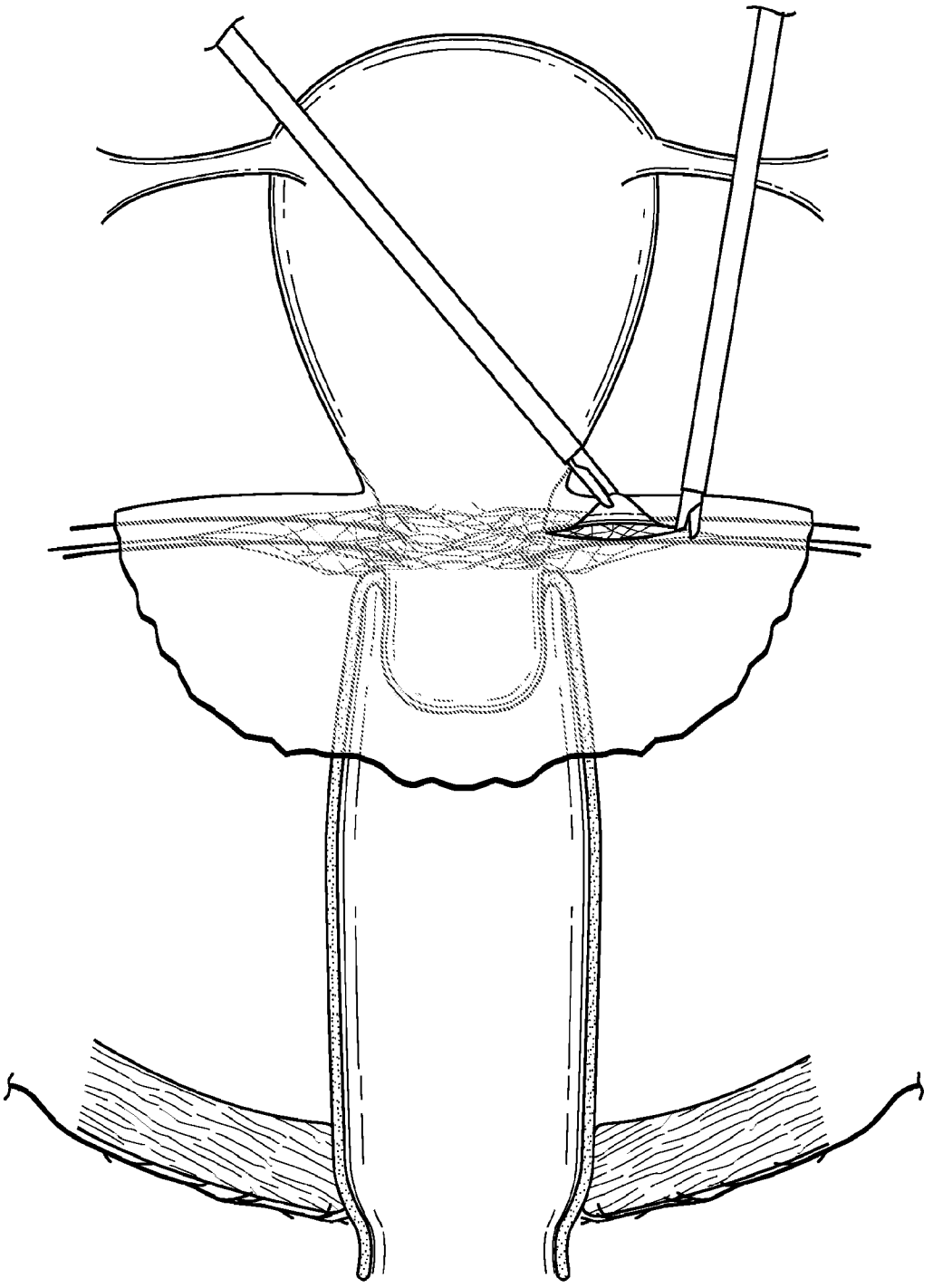


FIG. 64

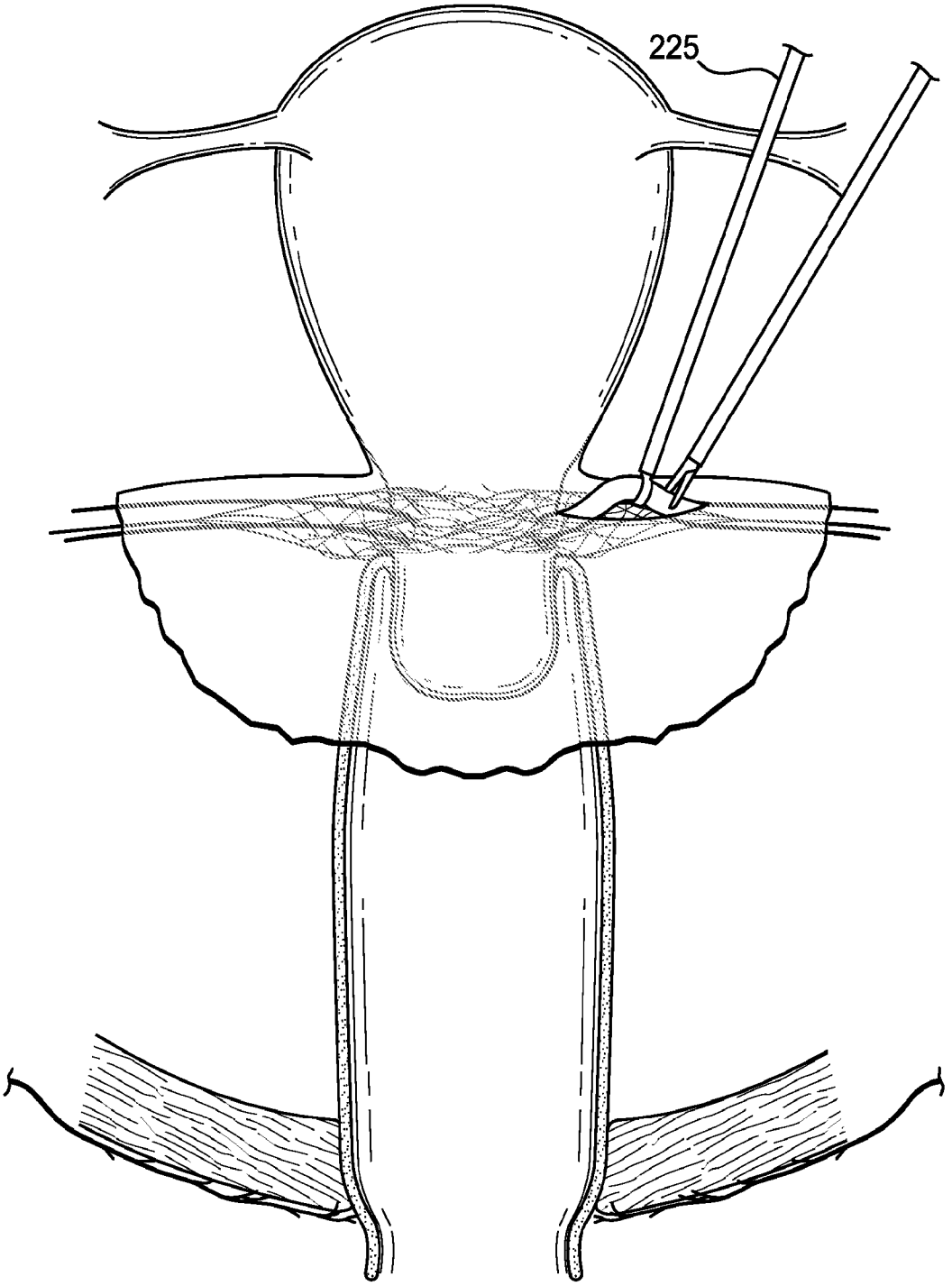


FIG. 65

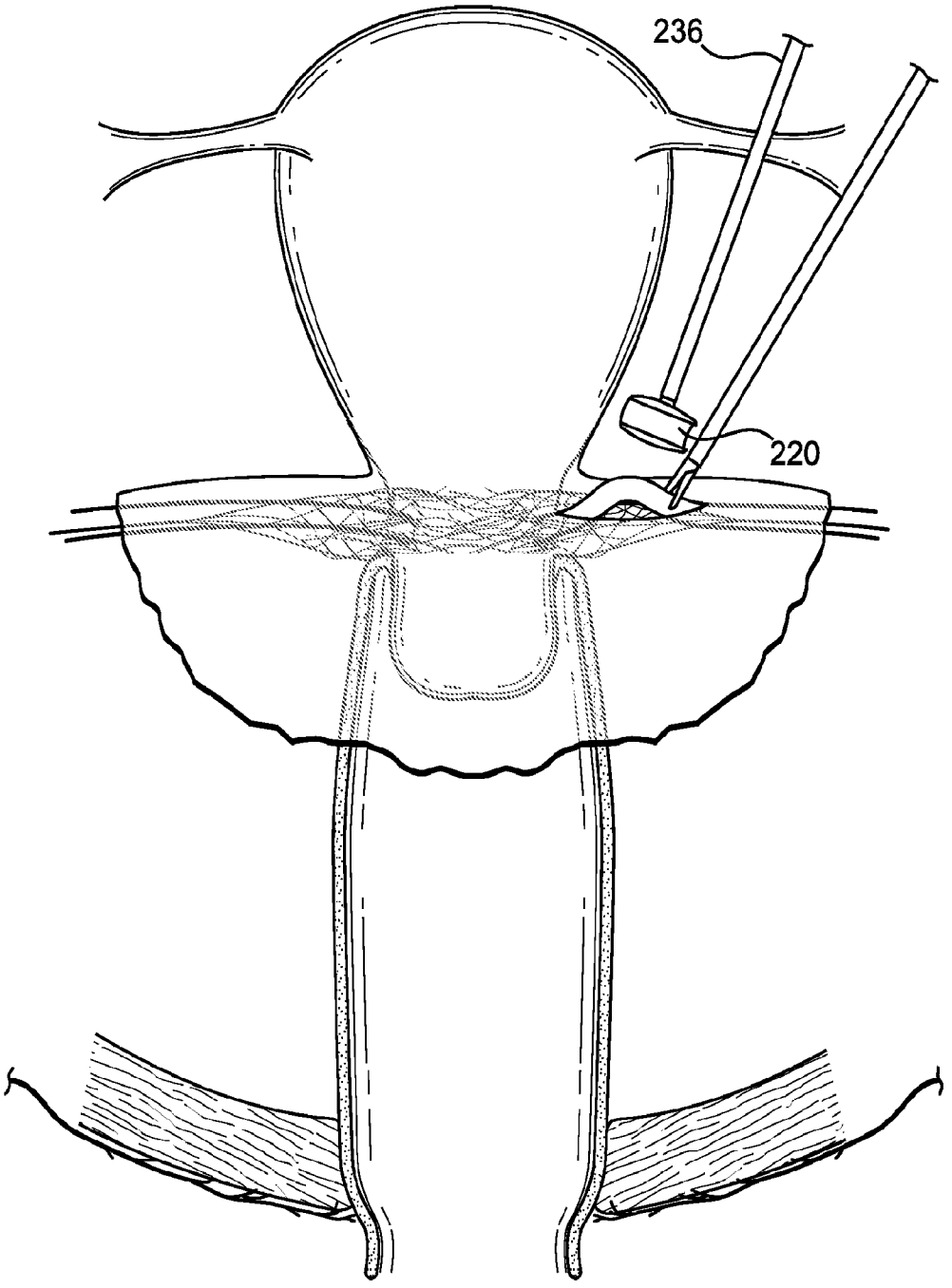


FIG. 66

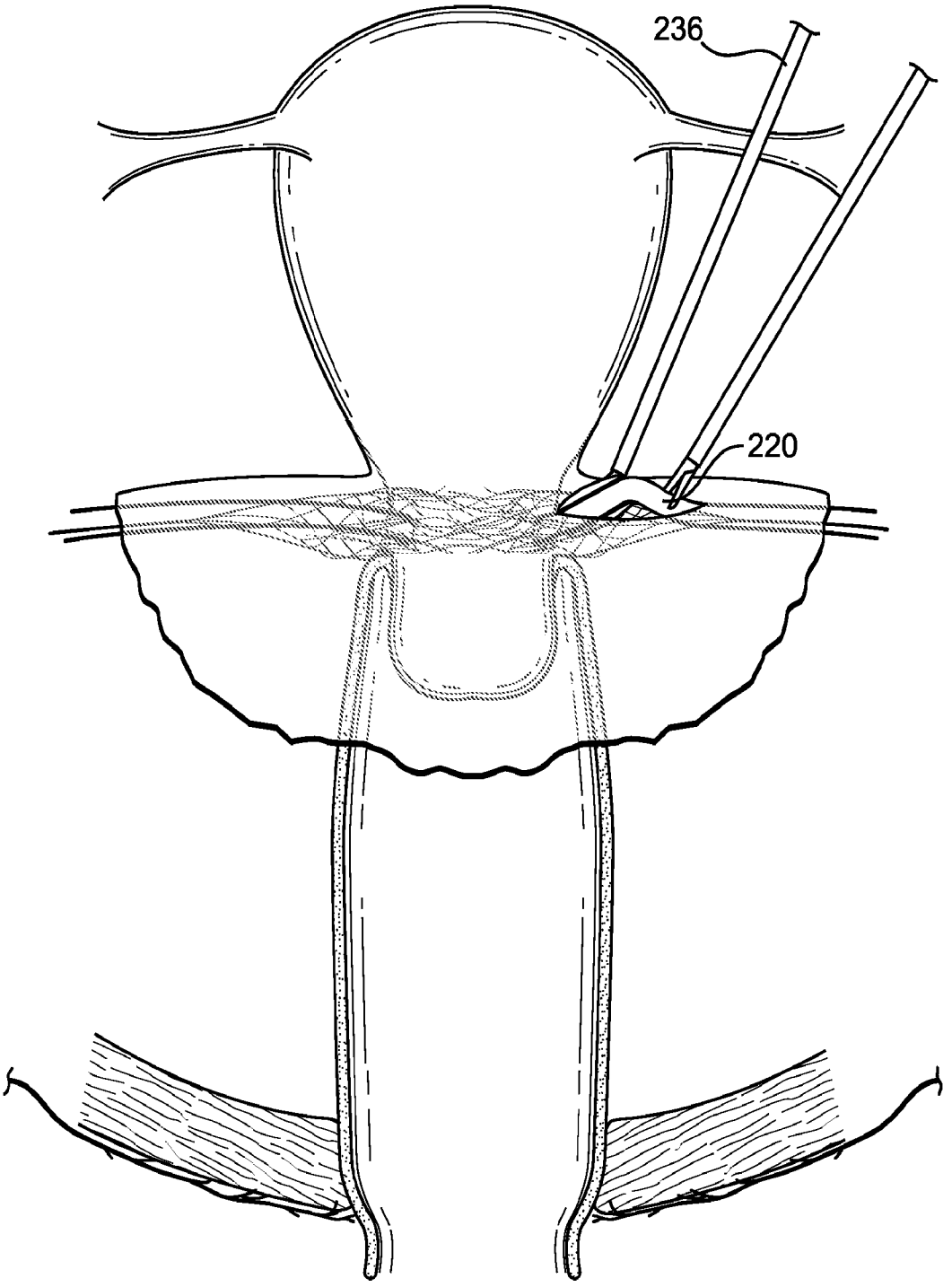


FIG. 67

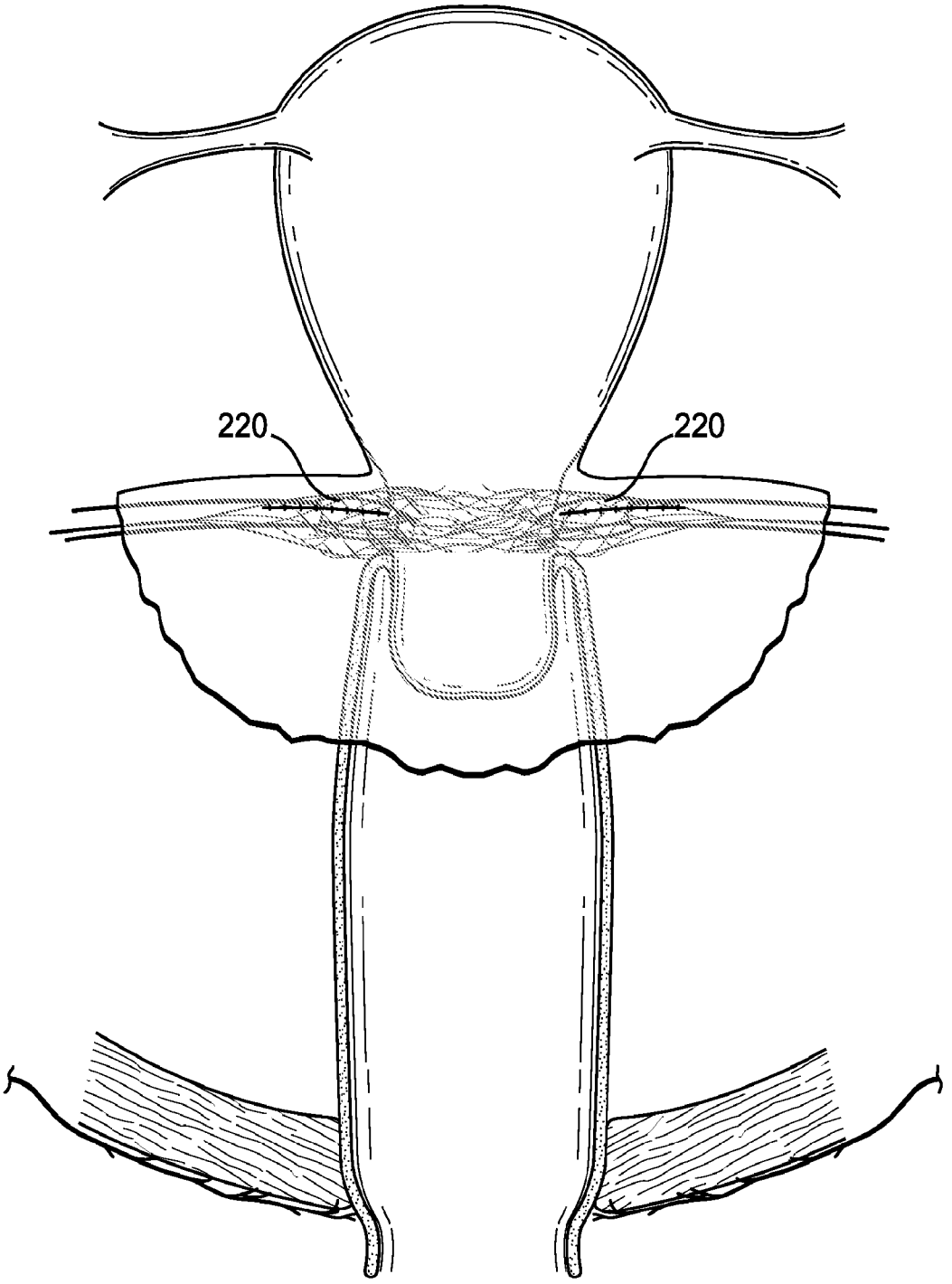


FIG. 68

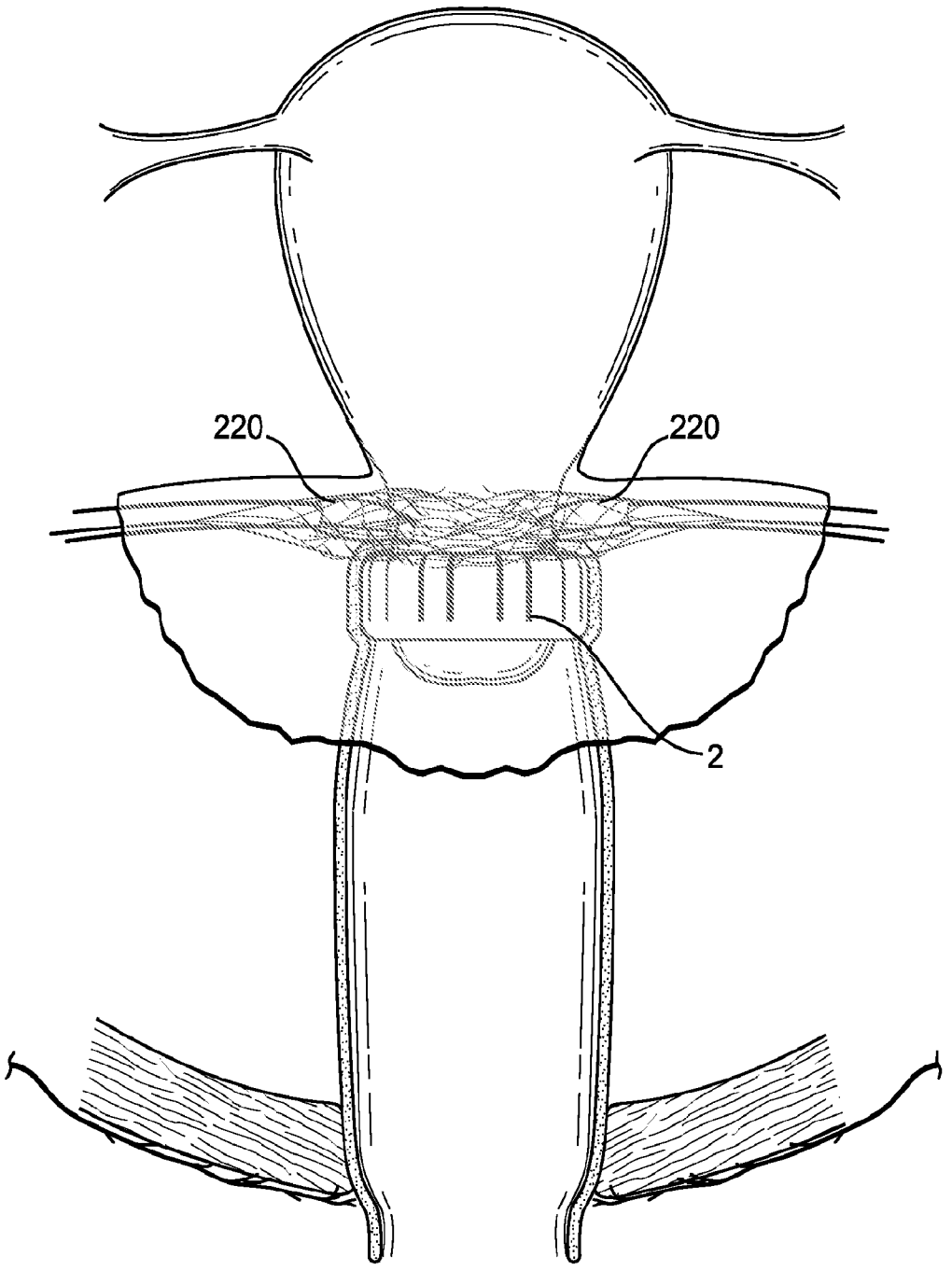


FIG. 69

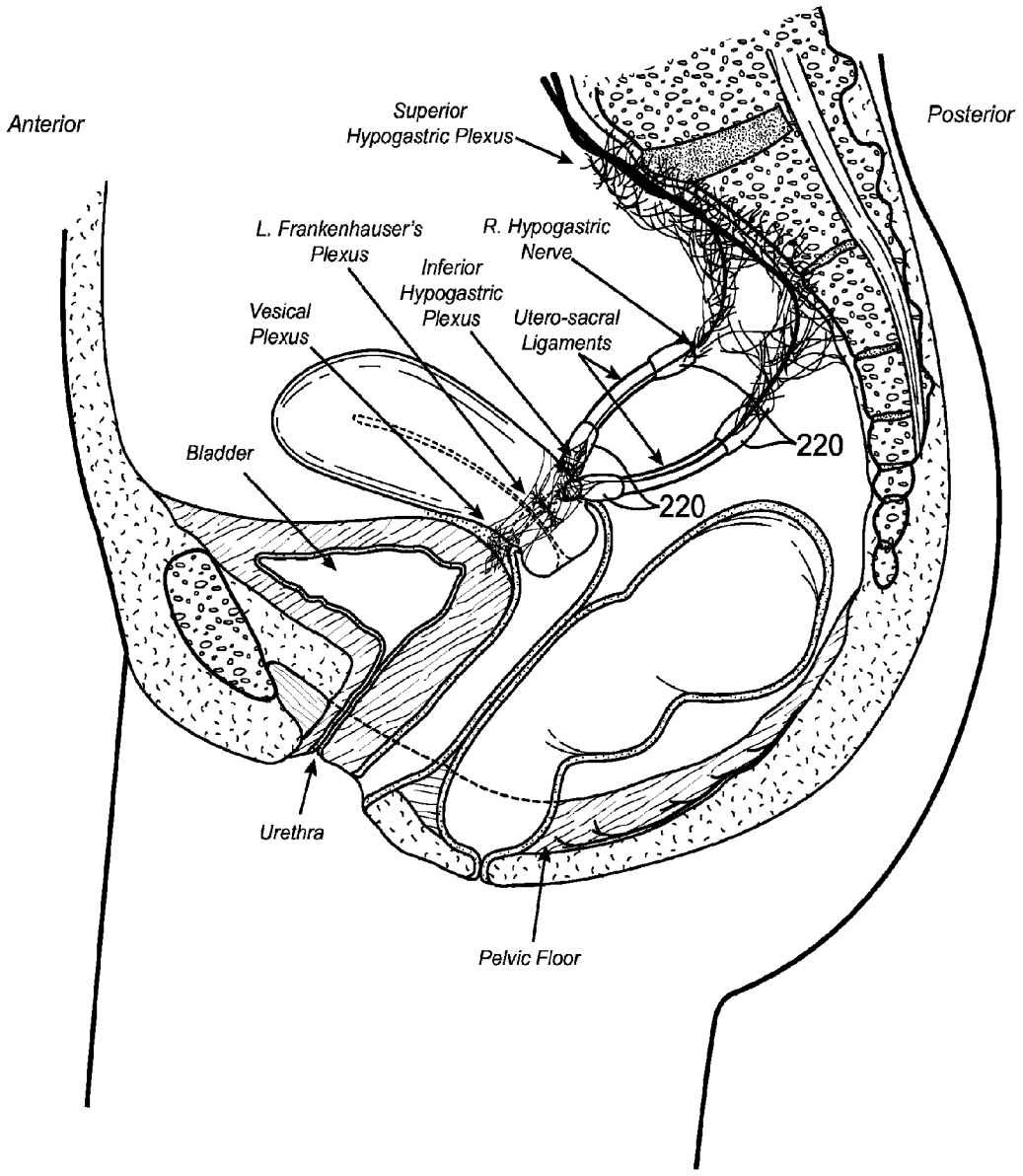

Anterior
Posterior
Superior Hypogastric Plexus
L. Frankenhauser's Plexus
R. Hypogastric Nerve
Inferior Hypogastric Plexus
Vesical Plexus
Utero-sacral Ligaments
220
220
Bladder
Urethra
Pelvic Floor

FIG. 70

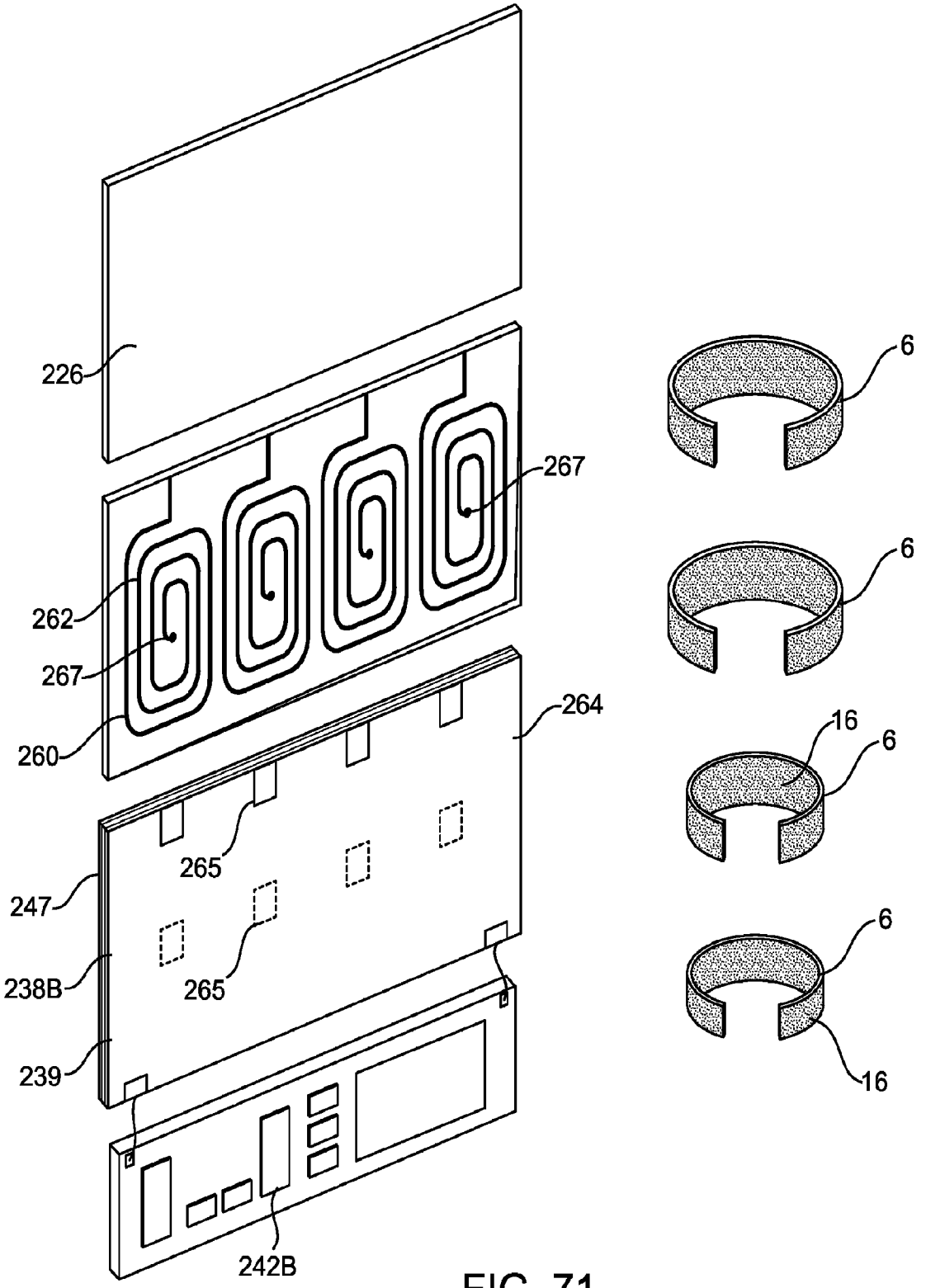


FIG. 71

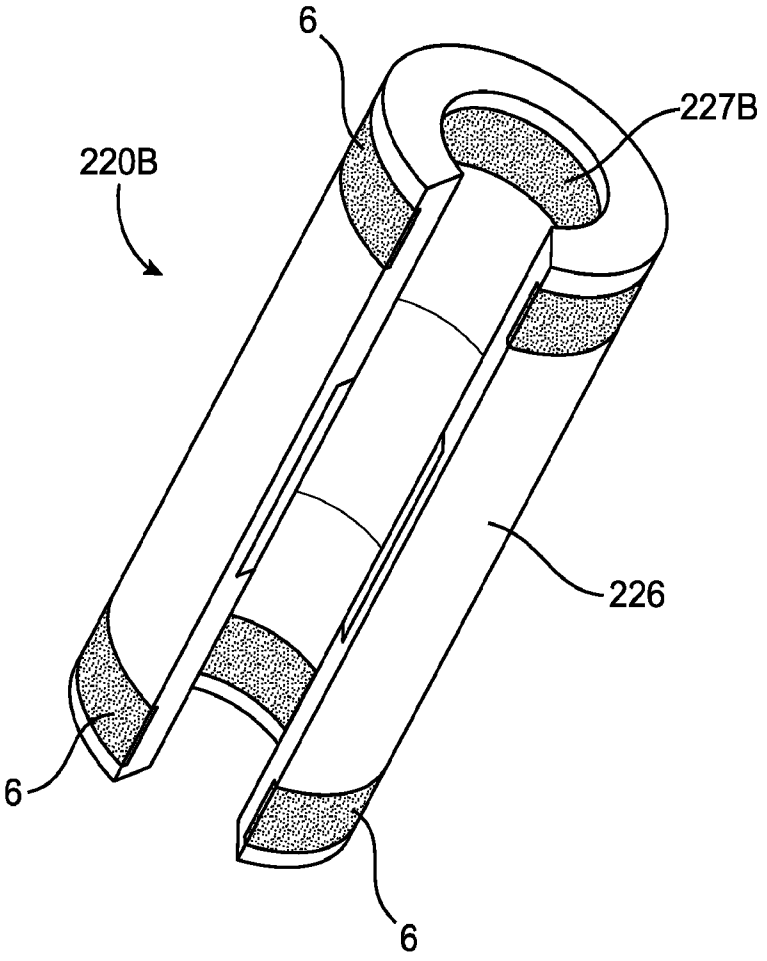


FIG. 72

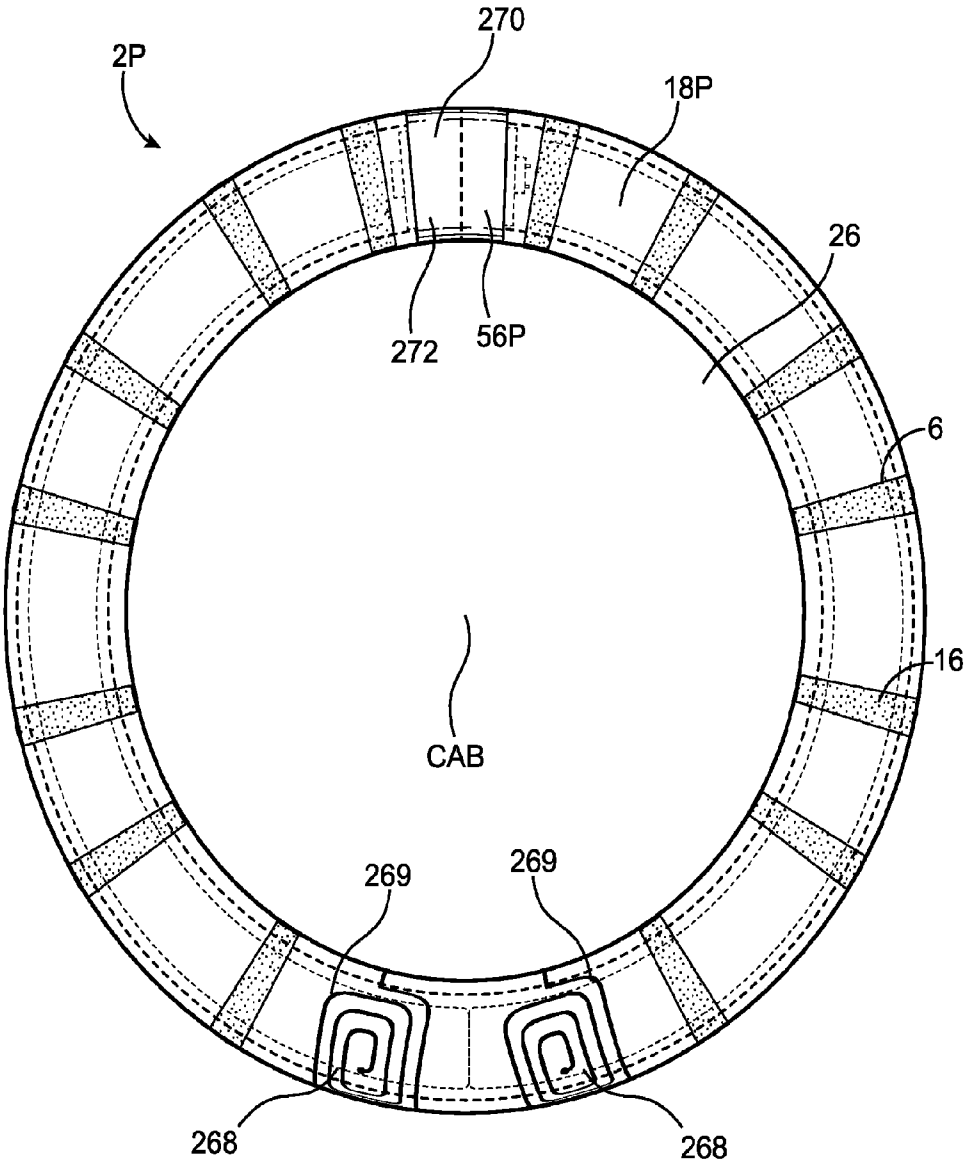


FIG. 73

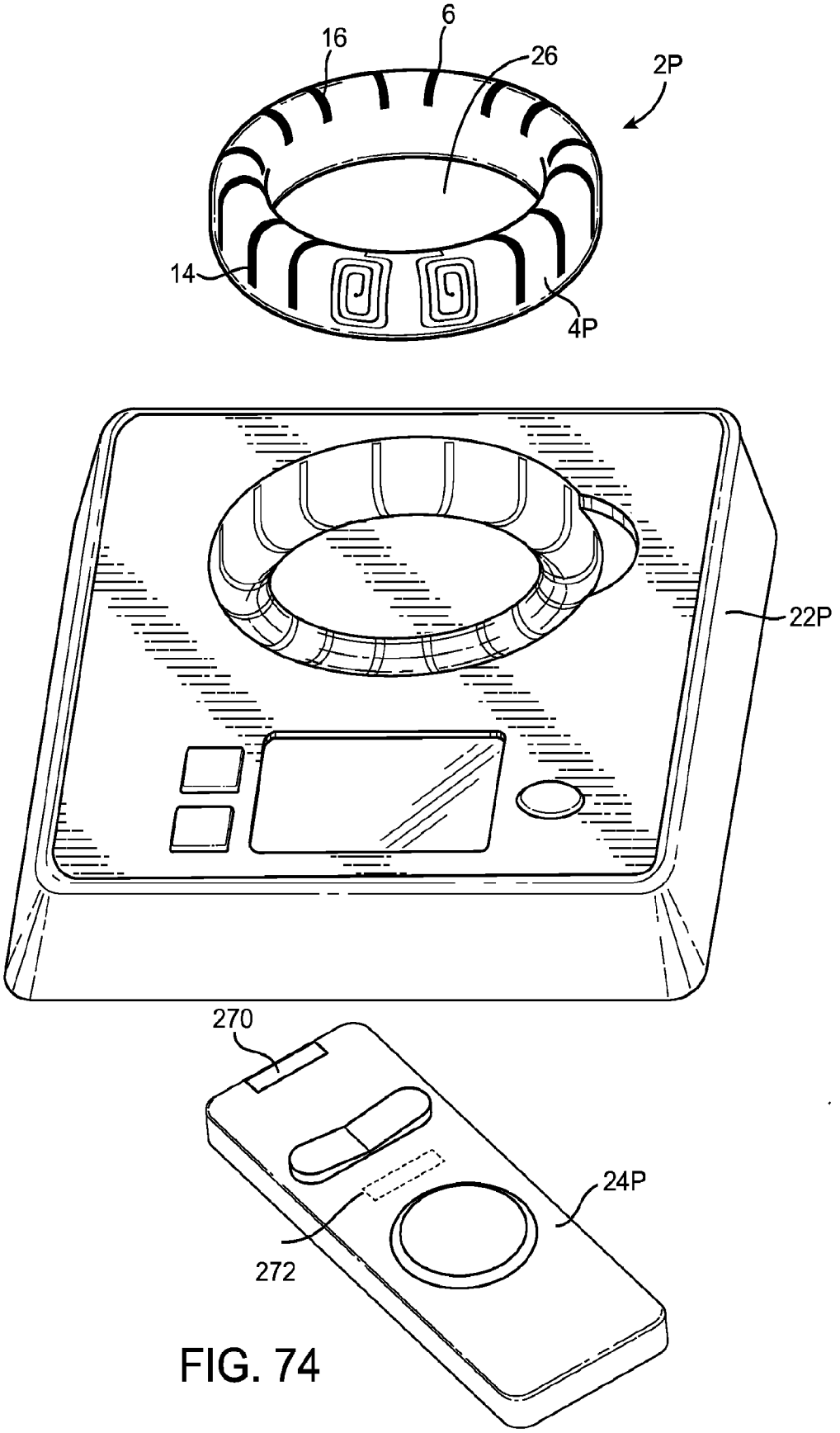


FIG. 74

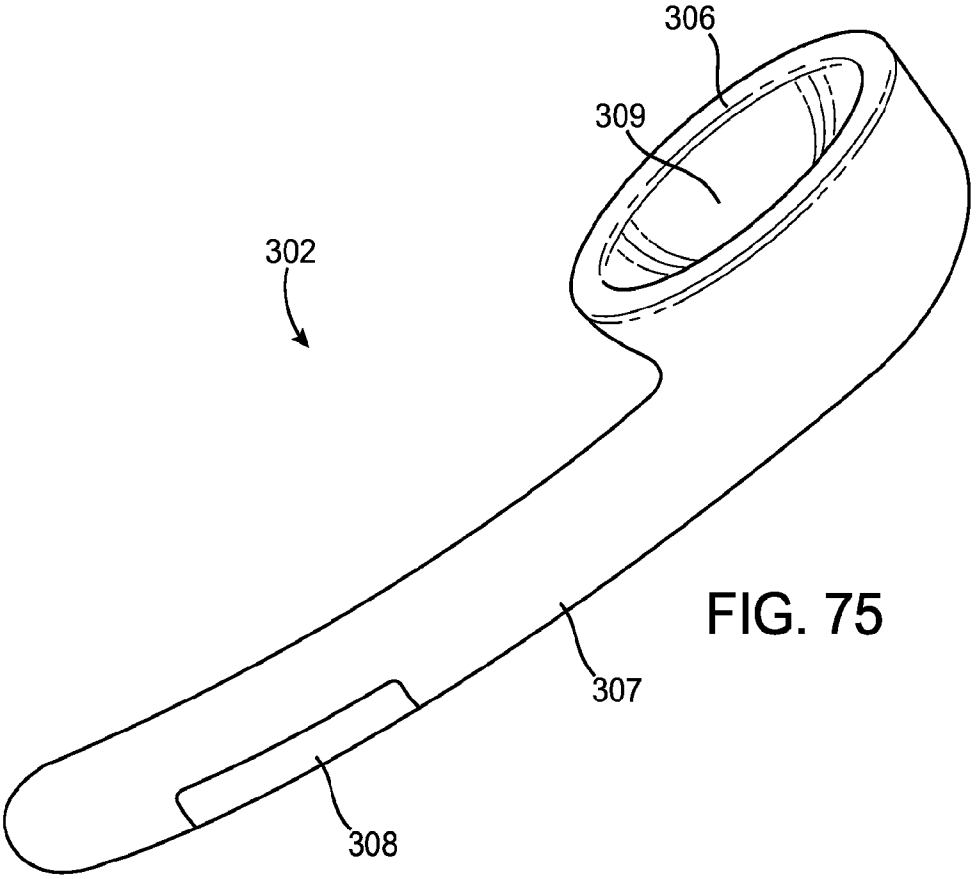


FIG. 75

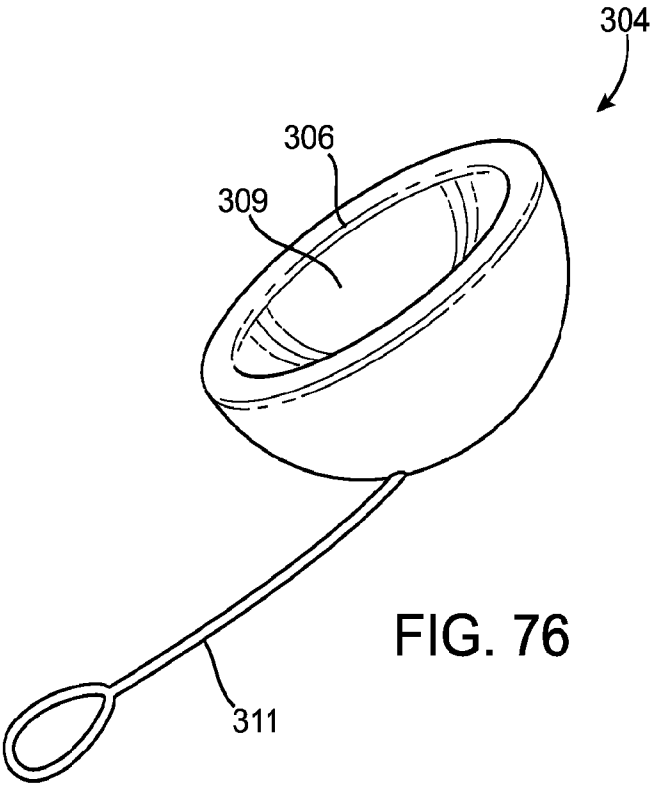


FIG. 76

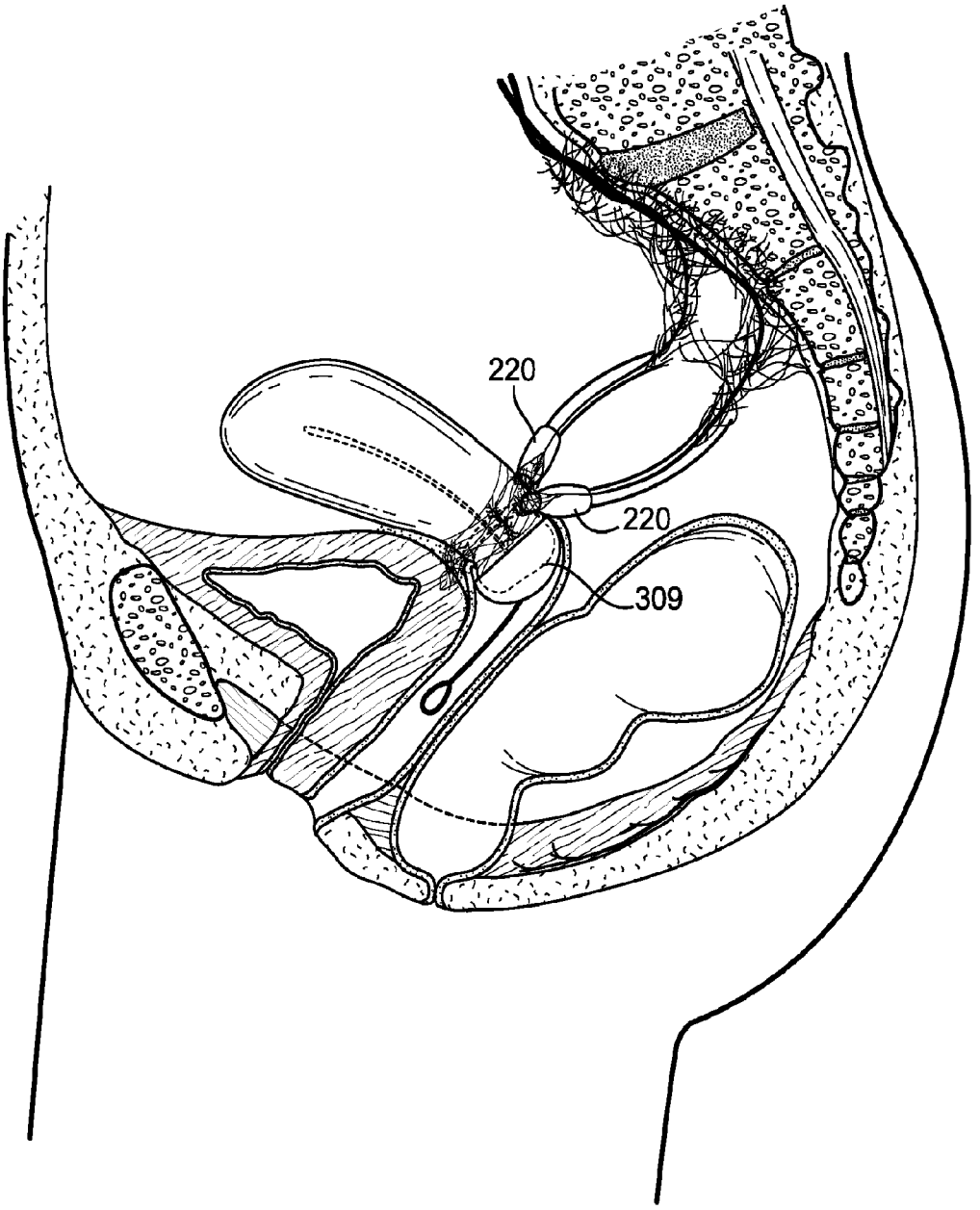


FIG. 77

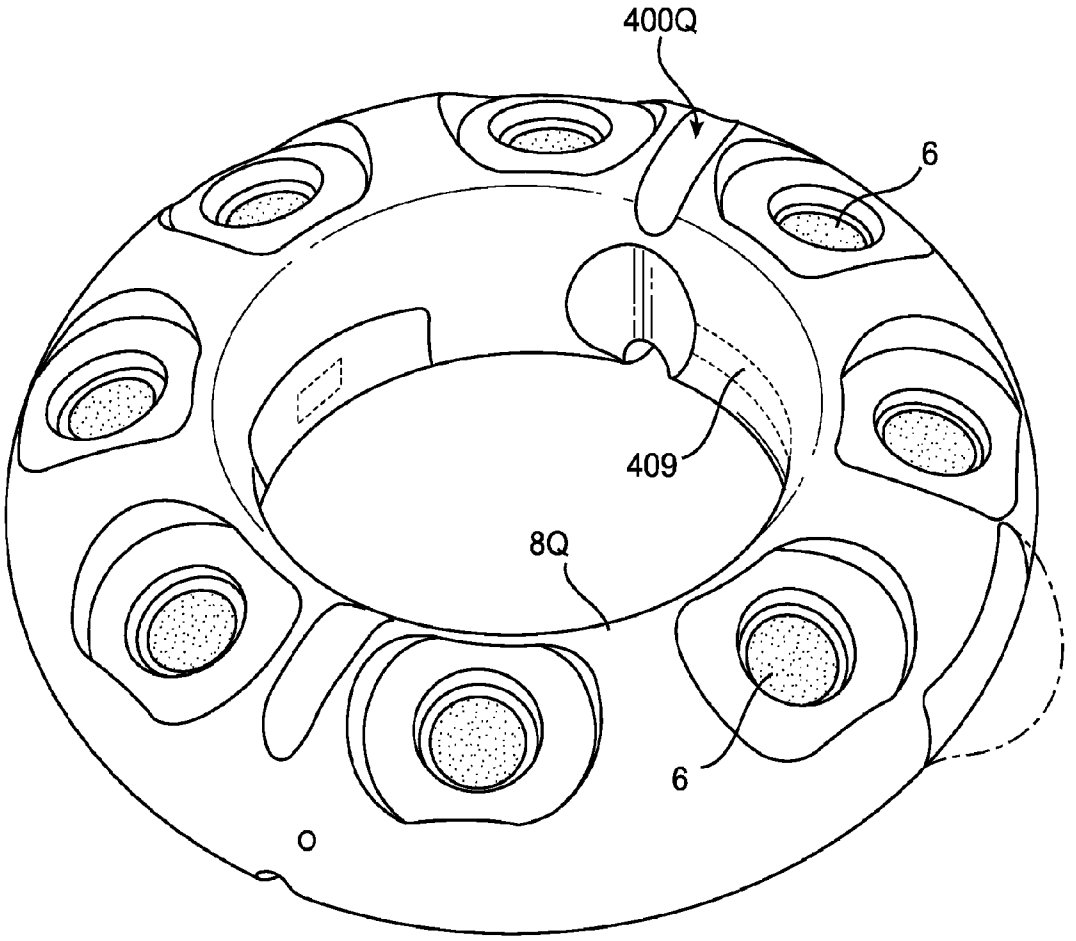


FIG. 78

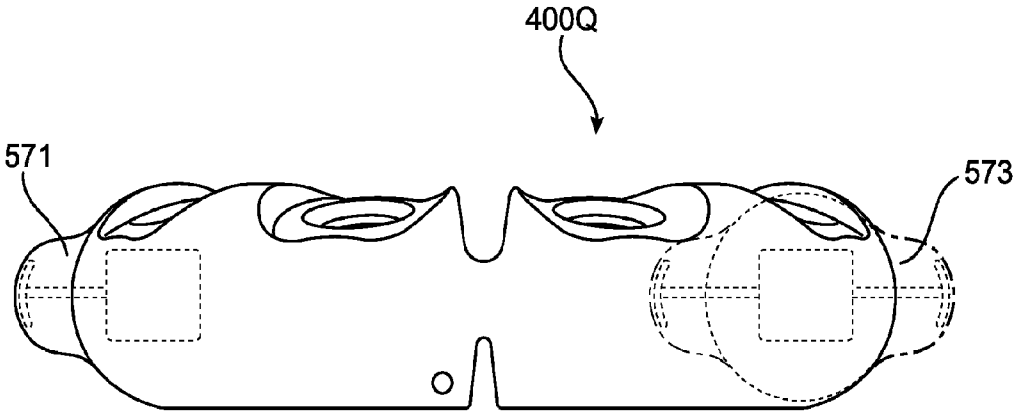

400Q
571
573

FIG. 79

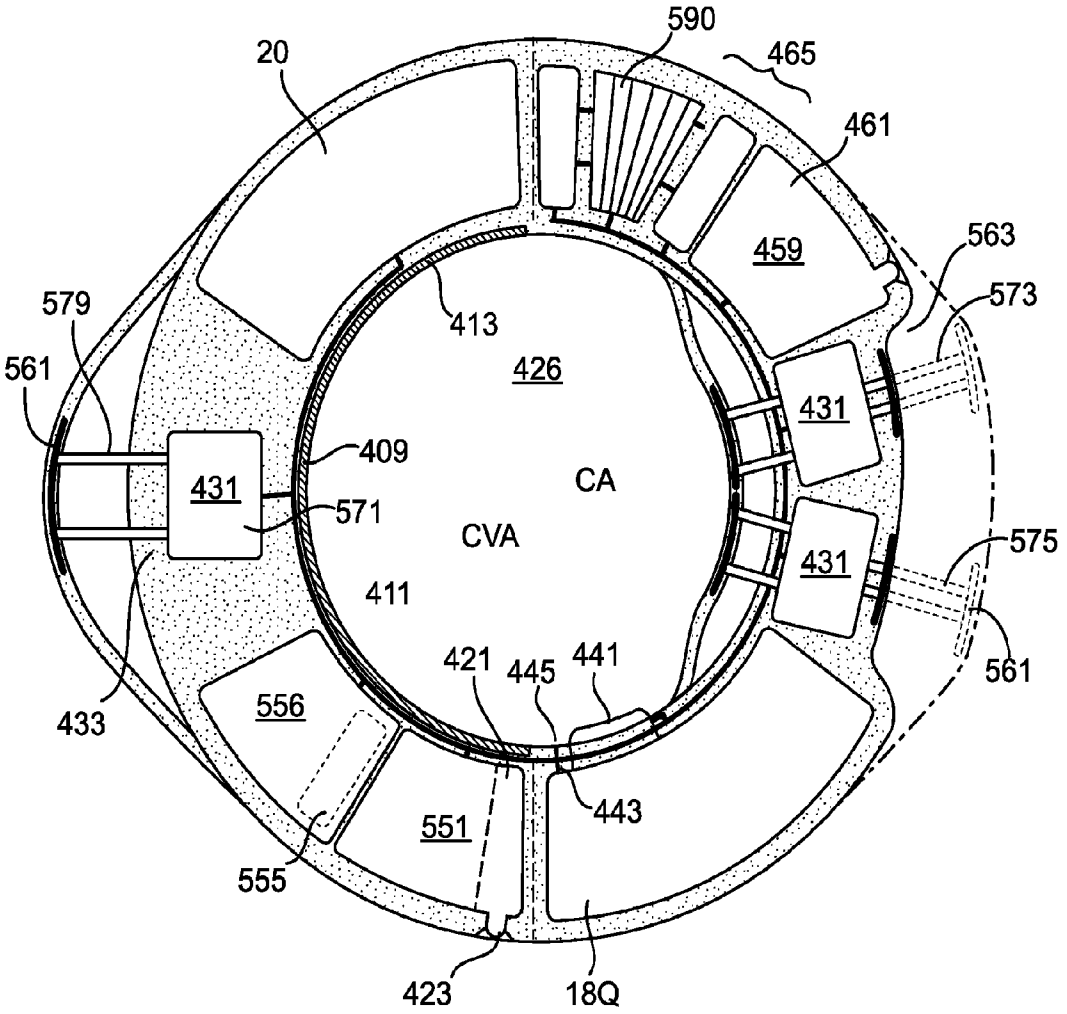

590
20
465
461
459
563
573
579
413
561
426
431
409
CA
431
571
CVA
575
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411
421
445
441
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433
556
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551
555
423
18Q

FIG. 80

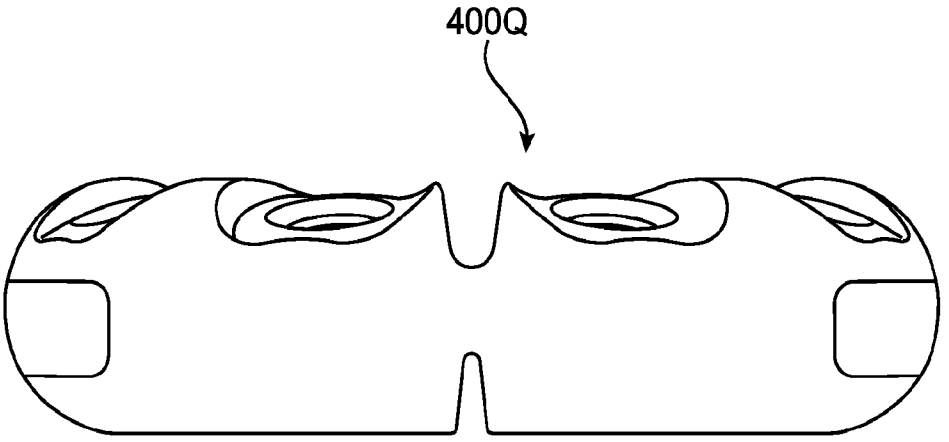


FIG. 81

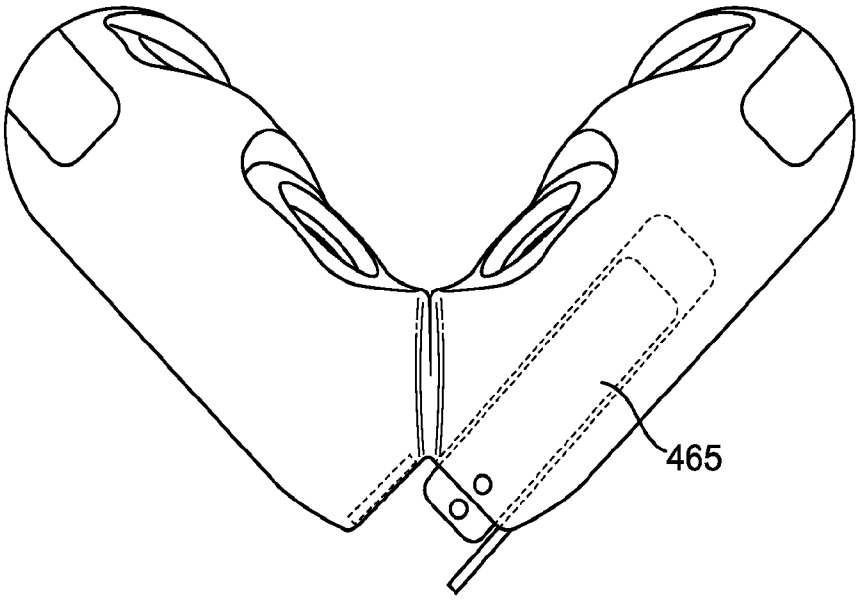


FIG. 82

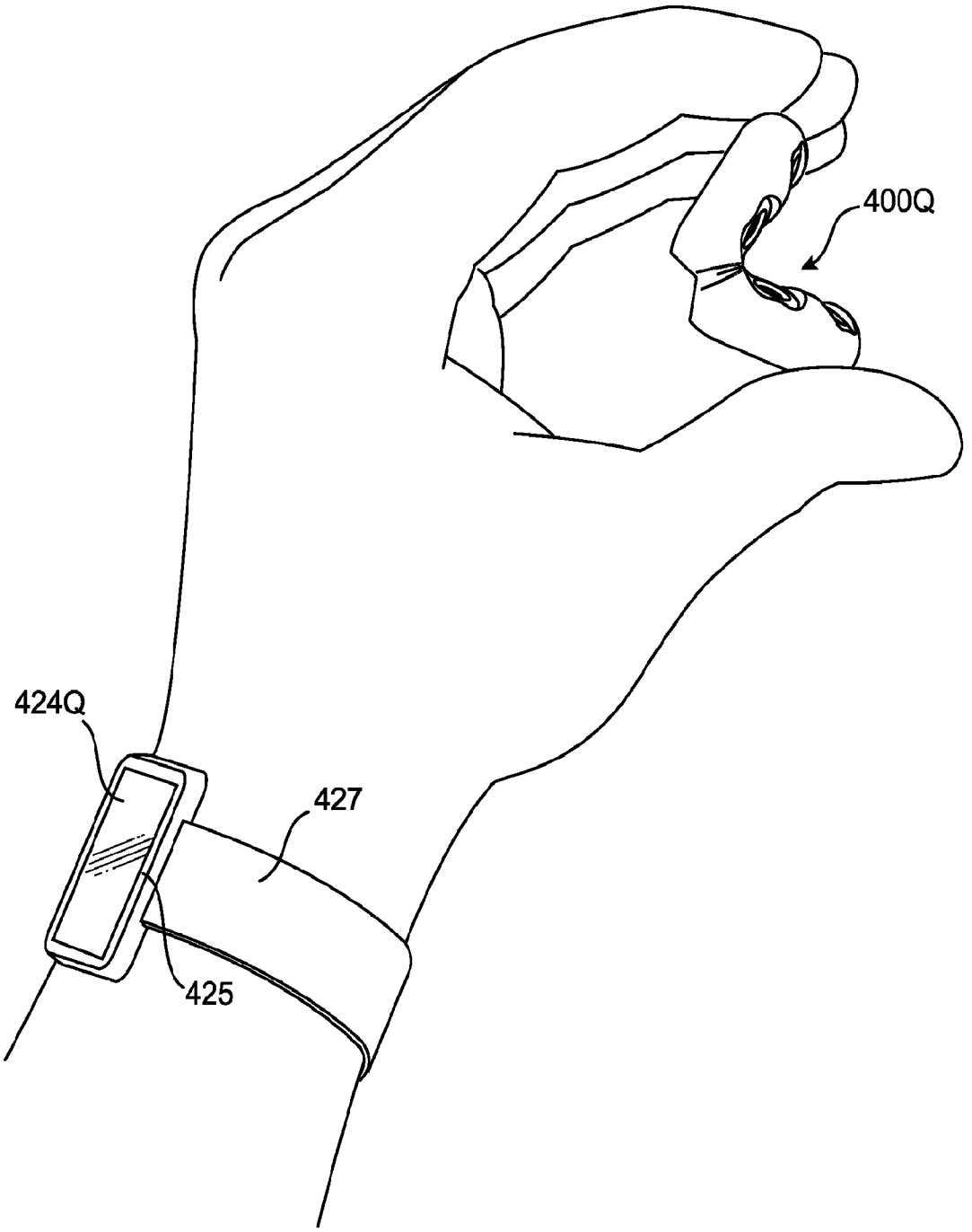


FIG. 83

DEVICES AND METHODS FOR STIMULATING NERVES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation-in-part of U.S. application Ser. No. 14/101,336, filed Dec. 9, 2013, which is a continuation-in-part of U.S. application Ser. No. 14/056,937, filed Oct. 17, 2013, which is a continuation-in-part of U.S. application Ser. No. 13/913,390, filed Jun. 8, 2013, which is a continuation-in-part of U.S. application Ser. No. 13/844,472, filed Mar. 15, 2013 (now allowed), which is a continuation-in-part of U.S. application Ser. No. 13/492,855, filed Jun. 9, 2012 (now U.S. Pat. No. 8,788,040 issued on Jul. 22, 2014), which are all hereby incorporated by reference.

BACKGROUND

[0002] Millions of women suffer from increased urinary urgency, frequency, incontinence, incomplete bladder emptying and irritative bladder conditions. There are two main types of incontinence, urge incontinence and stress incontinence, which have different physiological causes and different treatment options. Many women suffer from mixed incontinence, having both conditions.

[0003] Stress incontinence is largely the result of weakened ligaments, pelvic floor tissue and vaginal support, ultimately allowing the urethra to drop open in the setting of increased intraabdominal pressure. The process leading to stress incontinence is primarily mechanical and is associated with supportive tissue under the distal anterior vaginal wall. Strengthening the pelvic floor and supporting the urethra and/or bladder neck are safe and effective treatments for stress incontinence.

[0004] Urinary urgency, frequency, urge incontinence, incomplete bladder emptying, and nocturia represent a more complex process that is greatly neurologically mediated. Urinary urgency is marked by a strong, and often uncomfortable, urge to void that is difficult to suppress. Urge incontinence is defined by involuntary leakage of urine in the setting of urgency. The conditions noted above and other irritative bladder conditions may result from abnormal sensitivity of autonomic bladder nerves that prematurely communicate "fullness" to the central nervous system. These conditions may also result from erroneous nerve function in the central nervous system that allows the bladder to empty at inappropriate times. The underlying cause of these problems may be multifactorial. Ultimately, it is the autonomic nervous system that communicates bladder sensation, discomfort, or "fullness" and coordinates bladder filling and emptying.

[0005] Incomplete bladder emptying or urinary retention may result from inappropriate autonomic nerve signaling to the urethra and/or bladder. Some medical treatments are aimed at altering autonomic signal to the urethra, such that urethral tone is lessened. Others work by increasing bladder muscle tone by activating autonomic receptors in the bladder to cause a bladder contraction.

[0006] Many treatments of irritative bladder conditions are aimed at modifying nerve signaling between the bladder and the central nervous system. The goal is to affect both the afferent signals to the central nervous system that signal irritation, urgency, pressure or a sense of fullness and/or the efferent nerve signal that can trigger a rise in bladder pressure, cause discomfort, or leakage. Autonomic nerves transmit these signals. Treatment for urinary urgency, frequency, nocturia and urge incontinence is multifaceted, attempting to affect nerve signaling with behavioral, dietary, medical and physical therapies.

[0007] Urinary urge incontinence medications attempt to inhibit bladder contractions by disrupting signals between the autonomic nerves and the urinary tract. These drugs are not adequately effective for the majority of patients and also have significant systemic side effects that limit usage. Discontinuation rates at 6 months are well over 50% due to the high cost, lack of adequate effectiveness, and side effects. There are also contraindications to use, most of which are conditions affecting the elderly population that desires treatment for lower urinary tract symptoms.

[0008] An aggressive pelvic floor physical therapy regimen incorporating education, lifestyle, and dietary changes along with pelvic floor exercise training can be a reasonably effective treatment for urgency, frequency and urge incontinence in some patients. It is not clear how well exercise alone works to control urge related symptoms, as a large portion of the benefit gained from physical therapy is the result of education, cognitive-behavioral techniques, diet and lifestyle change. Patients are not often compliant beyond the short term, as the regimen can be costly, time consuming and difficult to comply with over time.

[0009] The goal of most pelvic floor exercises is to strengthen the muscles of the pelvic floor and increase nerve "tone." These exercises activate the somatic nerves in order to cause pelvic floor muscle contraction. This is primarily a treatment for stress incontinence. A pelvic floor muscle contraction can secondarily affect autonomic nerves to the bladder via a spinal cord reflex arc. These exercises may dampen the signal to urinate or prevent leakage. They do not necessarily prevent the more common overactive bladder symptoms that occur before one has time to perform a contraction, such as a spontaneous sense of urgency or waking at night to void. It has been shown that urinary urgency alone, without leakage, is more bothersome to patients than urinary leakage alone. Effective treatment needs to prevent the spinal cord from perceiving inappropriate sensations in the first place.

[0010] Neuromodulation of autonomic nerves has become a useful treatment method for lower urinary tract symptoms, such as urgency, frequency, incontinence, incomplete bladder emptying, irritative symptoms, incomplete bladder emptying, fecal incontinence and related conditions. One technique involves an implanted stimulation lead over the S3 nerve root. It can be a successful treatment for patients who have failed other treatments.

[0011] Although use of the surgical implant over the S3 nerve root has been successful, the treatment has drawbacks. The main disadvantage is that the device requires surgical implantation of small electrical leads through a foramen in the sacrum and a stimulator device within the soft tissue above the gluteus maximus. Implantation typically requires two surgical procedures, exposure to radiation, and often requires additional surgery to revise or remove the components. It has also been reported that over 25% of patients will require surgical revision of either the implanted battery or lead to manage complications. Additionally, the current surgical implant often needs to be removed for some types of MRI. The device is also extremely expensive. In general, patients prefer less effective alternative therapies, as they

often do not think bladder symptoms warrant surgery or they are not comfortable with the idea of a surgical implant.

[0012] Another drawback of the conventional surgical implant is that the stimulation occurs at the level of the nerve root, so somatic fibers traveling in the S3 nerve root are also stimulated before they branch off into somatic nerves. These nerves can cause the patients to feel vulvar, vaginal, anal and lower extremity muscle contractions or tingling. Still another limitation of the implantable stimulator is that the same one, or occasionally two, nerve roots are available and subject to all of the stimulation. As a result, the nerve becomes less responsive due to habituation rendering the lead less effective or ineffective. This phenomenon has been well established. Due to these many drawbacks, including risk of surgery, complications associated with the implant, cost, reduced effectiveness over time, and somatic symptoms associated with the implanted S3 sacral nerve modulator, this treatment has not been widely adopted despite its effectiveness.

[0013] The existing non-surgical electrical stimulation therapies include devices that are positioned in the vagina thereby avoiding some drawbacks of the surgical implant. However, these devices are often less effective and have their own drawbacks. Many conventional devices positioned in the vagina direct electrical impulses in the lower or distal vagina and/or adjacent to the pelvic floor. Electrical signals are sent through the vagina to paravaginal tissue, targeting nerves adjacent the pelvic floor muscles or the muscles themselves. The goal suggested by these conventional methods is generally to stimulate nerves adjacent the pelvic floor and to increase pelvic floor tension. Many of these therapies attempt to treat stress incontinence and/or simulate pelvic floor exercises. Yet, bladder filling, emptying and sensation are mediated by autonomic nerves, not somatic nerves. The inventor believes that these devices and therapies are often not as effective at treating urinary urgency, incontinence, nocturia, incomplete bladder emptying or other lower urinary tract symptoms as an implanted sacral nerve modulator because they do not sufficiently isolate stimulation to autonomic nerves.

[0014] A major limitation of these vaginal stimulation devices for treating most irritative urinary tract symptoms is that they indiscriminately send electrical impulses to both somatic and some distal autonomic nerve fibers adjacent to the lower and mid-vagina. They also often target somatic nerves, such as the pudendal nerve and its distal branches. The somatic nerves do not directly control bladder filling, emptying, or sensation. Activation of somatic nerves can cause increased pelvic floor tension, discomfort, and pain associated with pudendal nerve activation. Such conditions may actually contribute to urinary urgency, frequency and voiding dysfunction. Somatic nerves are quite sensitive, so the electrical impulses can be perceived even at low intensity, thereby limiting the full range of treatment protocols or precluding therapy altogether.

[0015] Thus, the inventor believes that the problem with present neuromodulation treatment methods is that they either require surgical implantation or, for vaginally inserted devices, the stimulation does not adequately target important autonomic nerve structures yet influences muscles and somatic nerves in the lower vagina providing less effective therapy for autonomically mediated urinary tract symptoms and contributing to undesirable side effects. Furthermore, the conventional implanted sacral nerve root therapies stimulate somatic nerves (although there are also autonomic—parasympathetic fibers near this location) and provide therapy to a very focal portion of a nerve, thereby contributing to habituation. These factors may provide less effective therapy for autonomically mediated urinary tract symptoms and contribute to undesirable side effects. Thus, optimal therapy would stimulate the autonomic nerves that mediate signal between the urinary tract and the central nervous system and/or end organ while avoiding activation of the pelvic floor and associated somatic nerves. Optimally, neuromodulation would be delivered directly to the autonomic nerves at the "gateway" between the urinary tract and the spinal cord while avoiding pelvic floor muscle and nerve activation.

[0016] The present invention is also directed to systems and methods for altering and improving (reducing) sympathetic tone. The autonomic nervous system maintains homeostasis and functional control of most organs in the body. The sympathetic arm of the system mediates the "fight or flight" response associated with a stress state, generally via norepinephrine, otherwise known as "adrenaline." The sympathetic system is responsible for preparing animals for immediate action. The parasympathetic arm maintains organ function at rest. It is theorized that survival of early organisms was quite dependent on the ability to quickly adjust from rest (grazing) to extreme physical activity (fleeing a predator). This transition requires immediate coordination of many organs, glands and nerves that increase cardiac output, optimize respiratory function, increase skeletal muscle contractility, alter blood flow distribution, adjust visual depth perception, and trigger rapid-fire thinking. When the sympathetic tone is high, organs are operating at an extreme capacity, which is not healthy over time.

[0017] Outside of acute stress, organisms need to maintain a fine balance between the sympathetic and parasympathetic tone. In modern times humans are not often fleeing life-threatening danger. However, we tend to live in a chronic state of stress. Naturally, the sympathetic nervous output is upregulated in a chronic stress state. Chronic stress contributes to persistently elevated sympathetic tone, which has deleterious effects on most organs of the body. For example, the heart is very sensitive to even modest increases in circulating epinephrine. Chronic exposure to increased epinephrine levels results in a rise of blood pressure and heart rate that can contribute to many forms of heart disease, including arrhythmias, coronary artery disease, valvular dysfunction and heart failure. Alterations in cerebral blood flow resulting from stress, influenced by the sympathetic nervous system, can result in migraine headaches.

[0018] Metabolism is greatly affected by increased sympathetic tone, via increased release of cortisol. Cortisol is an adrenal hormone that alters metabolism of glucose, bone, muscle, adipose (fat) cells and connective tissue. Cortisol acts locally and systemically to mobilize metabolic resources for a stress response related action. Chronically elevated circulating cortisol levels can have serious and deleterious consequences including insulin resistance/diabetes, decreased bone formation (osteoporosis), inhibited collagen production (poor tissue quality and wound healing), decreased protein synthesis (atrophy), increased gastric acid secretion (ulcers and gastrointestinal bleeding), altered renal function (electrolyte imbalances), impaired hippocampal function (decreased learning ability and dampened memory retrieval), along with increased epinephrine sensitivity in blood vessels (hyperten-

sion). Cortisol also weakens the immune response by inhibiting T cell proliferation, which results in vulnerability to infection and cancer.

[0019] Stress and elevated sympathetic tone is also associated with increases in circulating inflammatory mediators, mainly Interleukin-6, which promote systemic inflammation. Inflammation is responsible for autoimmune conditions affecting nearly every organ in the body. Examples include dermatologic conditions (eczema), atherosclerosis (coronary artery disease and stroke), gastrointestinal (ulcerative coltis or Crohn's disease), lupus, arthritis, allergic reactions, pericarditis, myocytis, cataracts, pain conditions, interstitial cystitis, vasculitis, glomerulopathies, multiple sclerosis, iritis, asthma, and cancer. Pain is associated with inflammation and stress. Increased mortality has been associated with chronic exposure to increased stress and Interleukin-6 levels.

[0020] Many people simply maintain an elevated sympathetic tone, regardless of their stress level. Normal blood pressure and heart rate in healthy and relaxed people varies within a normal range, for example. Central obesity contributes to increased sympathetic output, regardless of stress level or cardiovascular health.

[0021] The role of autonomic imbalance in leading to poor cardiovascular health, and in causing heart failure, is increasingly being recognized. Research shows elevated inflammation in heart failure patients, with inflammation linked to left ventricular dysfunction. Poor autonomic tone is related to arrhythmia and increased heart rate.

[0022] The current approaches to delivering autonomic modulation are based on implanted devices. Even monitoring devices for recording heart rhythms that do not deliver stimulation, are often implanted under the skin, requiring a procedure. By contrast, the present invention provides for both monitoring of heart rhythms (rate and waveform) and delivery of autonomic neuromodulation by vaginally-inserted and self-retained systems and methods, complemented by wireless transmission of data from a user's existing personal device which may act as a controller.

[0023] Ultimately, lowering sympathetic tone can improve specific disease states and overall health. Current approaches to decrease sympathetic tone include exercise, weight loss, relaxation techniques, meditation and cognitive behavioral therapies. These approaches are not always effective, achievable or sustainable.

[0024] The present invention is directed to improved systems and methods for stimulating nerves. The present invention is also specifically directed to systems and methods for altering sympathetic tone. The present invention allows monitoring and sensing, diagnosis, and/or therapeutic treatment of numerous medical conditions.

SUMMARY

[0025] The present invention provides devices and methods for targeting autonomic nerves while minimizing transmission of stimulus to pelvic floor muscles and non-target nerves, specifically, somatic nerves adjacent to the lower or mid-vagina. The present invention is positioned to stimulate autonomic plexuses and autonomic nerves at the "gateway" between the lower urinary tract and the spinal cord while avoiding pelvic floor muscle and nerve activation. In specific embodiments and methods, the present invention targets the inferior hypogastric plexus (or pelvic plexus), left and right Frankenhauser's plexus (or Lee's plexus) and the vesical plexus. These plexuses may, of course, be called by other names such as Lee's plexus as another name for Frankenhauser's plexus without departing from the invention. Furthermore, the Frankenhauser's plexus refers to both left and right Frankenhauser's plexuses collectively. Unless otherwise specified, use of Frankenhauser's plexus or plexuses shall mean both plexuses.

[0026] In one aspect of the present invention, a device for stimulating nerves is positioned in the upper half of the vagina, and in specific embodiments in the vaginal fornices, so that the stimulus intended for the target nerves does not adversely influence non-target somatic nerves, such as the pudendal nerve or its branches, adjacent to the distal or lower half of the vagina. Reducing side effects and possible urinary tract symptoms due to stimulating somatic nerves are thereby avoided in accordance with the present invention.

[0027] The present invention treats urologic, gynecologic, colorectal and pain conditions in women with neuromodulation of nerves via electrical stimulation (and other modalities) delivered by a unique, self-retained, indwelling vaginal device that resides in the fornices of the vagina (or uppermost portion of the vagina in women without a cervix) and targets specific autonomic plexuses which communicate with associated nerves traveling to and from genitourinary and pelvic structures. The neuromodulation of the present invention stimulates the nerve plexuses to change a signal transmitted by the nerve plexuses to the associated autonomic nerves. The wide range of functions served by these autonomic nerves allows the present invention also to address sympathetic tone, cardiovascular function, sexual dysfunction, and other medical conditions. Similarly, the wide range of communication to and from autonomic nerves allows the present invention to affect organs well beyond the genitourinary and pelvic region itself.

[0028] Referring to FIG. **1**, autonomic nerve signals traveling to and from the bladder, urethra, rectum, vagina, uterus, peritoneum and other pelvic structures travel through the inferior hypogastric plexus IHP, carrying the signal between pelvic structures and the spinal cord. The inferior hypogastric plexus IHP is the gateway between the visceral (bladder, gynecologic, rectum) organs and the central nervous system. The IHP is a coalescence of both sympathetic and parasympathetic autonomic fibers. The sympathetic fibers run between the thoracic nerve roots (T10-L2) and into the superior hypogastric plexus, then travel towards the IHP via the left and right hypogastric nerves LHN, RHN along the uterosacral ligaments USL. In some cases a portion of the sympathetic fibers may enter the IHP along the undersurface of the cardinal ligaments. These fibers facilitate bladder storage. The parasympathetic nerves travel from the sacral spinal nerve roots (S2-4) in the sacral or pelvic splanchnic nerves, or nervi erigentes towards the pelvic organs, often in association with the pelvic nerve. They facilitate bladder emptying. Sympathetic and parasympathetic fibers coalesce in the IHP over the posterior and lateral surfaces of the upper cervix, just above the vaginal insertion.

[0029] Importantly, the vagina terminates at the level of the pericervical ring around the uppermost portion of the cervix, just below the uterosacral ligament USL insertions. The recesses of the most proximal, or uppermost, aspect of the vagina that surround the cervix are called the vaginal fornices VF. The pelvic floor PF surrounds the lower portion of the vagina near the vaginal opening, making the "floor" of the pelvic cavity. The inferior hypogastric plexus IHP is a web-like plexus adjacent to the posterior and lateral cervix at the

level of the uterocervical junction and the uterosacral ligament USL insertions, just proximal to the posterior vaginal fornix. Inferior hypogastric plexus IHP fibers also cover the distal uterosacral ligaments and possibly reside in the lower or under-portion of the cardinal ligament just anterior to the USL. For reference, the IHP is generally referred to as a singular structure in the literature, but anatomic studies suggest significant concentrations of these ganglia may be distributed bilaterally, as described above. For purposes of this description and application the IHP, when used herein, will refer to the IHP and any lateral extensions around the cervix or most proximal aspect of the vagina.

[0030] Autonomic nerve fibers travel from the IHP around the cervix to the vesical plexus, which communicates with autonomic fibers to innervate the bladder. Some autonomic fibers travel from the IHP to the posterior-lateral aspect of the cervix to right and left Frankenhauser's plexuses FP (also known as Lee's or the uterovaginal plexuses). Frankenhauser's or Lee's plexuses send some nerves upward to innervate the uterus and some nerves inferiorly to innervate the vagina, cervix, urethra, and clitoris. Both of these plexuses may be important in controlling urinary tract function. Autonomic fibers travel between the IHP and the middle rectal plexus to innervate the distal rectum.

[0031] Surgical removal of the cervix can result in injury to the hypogastric nerves, IHP, Frankenhauser's plexuses and/or the vesical plexuses. These structures often heal and function well post-operatively. However, they can sustain permanent injury and exhibit chronically altered function resulting in chronic urinary tract conditions and other forms of pelvic organ dysfunction.

[0032] As mentioned above, autonomic nerves and somatic nerves have different functions. Autonomic nerves control visceral, internal organ function and some types of pain. The bladder and urethra are innervated by autonomic nerves. Somatic nerves mediate voluntary muscle activity, body movement, and somatic sensation. The pudendal nerve PN and its distal branches mediate voluntary pelvic floor function and some distal vaginal, urethral, anal and genital sensation. The nerve types also have different distributions. For example, autonomic nerves traveling to and from the pelvic organs enter via a proximal and central approach, just above the top of the posterior vagina in the center of the pelvic cavity. The somatic nerves travel to the pelvic floor from an inferior and lateral approach. A problem with prior art devices placed in the vagina is that they stimulate, usually intentionally, somatic nerves adjacent the pelvic floor such as the pudendal nerve and its branches.

[0033] Autonomic nerves are responsible for signaling visceral organ or peritoneal pain, such as that caused by endometriosis, dysmenorrhea, interstitial cystitis, irritable bowel syndrome, adhesions and other conditions. Autonomic nerves also influence how visceral organs respond to somatic pain and can be a source of referred pain in a somatic distribution. Autonomic sensation may be transmitted by autonomic (or visceral) sensory fibers, not necessarily sympathetic or parasympathetic fibers.

[0034] In an embodiment, the present invention is an indwelling, removable, programmable, stimulation device that is positioned in the fornices of the vagina, thereby optimally targeting autonomic plexuses of the pelvic organs and the distal aspect of the hypogastric nerves. This device will deliver electrical stimulation (and support other therapies, such as application of a magnetic field, medication, or ultrasound) to the plexuses and associated nerves at the autonomic gateway between the pelvic organs and the central nervous system, mainly at the left and right hypogastric nerves, inferior hypogastric plexus, left and right Frankenhauser's plexuses, the vesical plexus and possibly the middle rectal plexuses. Stimulation of these plexuses and distal hypogastric nerves changes a signal sent by these plexuses and nerves to their associated efferent and afferent nerve fibers.

[0035] At this location the neuromodulation signal will have more effect than if it were distributed distal to the plexuses, such as with current devices that stimulate and reside lower in the vagina. With more distally stimulating devices some aberrant nerve signal arising above the stimulation site can travel, for example, between the urinary tract and the plexuses or hypogastric nerve above the stimulation site. The same limitations can hinder the effects of the current devices in treating gynecologic, colorectal and pain conditions as well. The device of the present invention, on the other hand, is positioned in the vaginal fornices or upper-most portion of the vagina thereby optimizing stimulation to the autonomic nerves and plexuses that control the sensation and function of the pelvic organs, including the bladder.

[0036] In a preferred embodiment, a ring-like device with an electrode, or a plurality of electrodes, will reside in the fornices, adjacent to the plexuses that surround the cervix. The device will also be able to target the junction between the left and right hypogastric nerves (that travel to and from the IHP along the uterosacral ligaments) and the IHP. An advantage of the present invention is that positioning the device in the fornices allows access to the collection of plexuses (vesical, inferior hypogastric plexus, and Frankenhauser's plexus) and the hypogastric nerves simultaneously with a single device.

[0037] The device may also have bilateral pairs of electrodes: right and left anterior, right and left anterior-lateral, right and left posterior-lateral, and right and left posterior leads. Any individual electrode or grouping of electrodes may be programmed to work with or independently of any other electrode or grouping of electrodes as described in further detail below. Bilaterality allows great flexibility of use. Each patient has an individual distribution of autonomic nerves and plexuses and some may have a dominant side. Alternating between right and left sides may also be important for any given patient to reduce habituation. Stimulation regimens may be customized for each patient.

[0038] The position of the device is essential to its unique ability to stimulate the target autonomic plexuses in the pelvis. For example, the posterior electrodes are adjacent to the IHP, the posterior-lateral electrodes are adjacent to left and right Frankenhauser's plexuses, the anterior electrodes are adjacent to the vesical plexus and the anterior-lateral electrodes are adjacent to the fibers approaching and leaving the vesical plexus. The anterior-lateral electrodes and posterior-lateral electrodes may ultimately reside adjacent to the vesical plexus or IHP respectively, depending on normal variant distribution of nerves and plexuses in an individual patient. As noted above, some IHP or hypogastric nerve fibers may travel along the undersurface of the cardinal ligament, just anterior to the USL. The posterior or posterior-lateral sets of electrodes may stimulate the autonomic fibers in the IHP or nerve fibers leaving or approaching the IHP that affect autonomic communication with the middle rectal plexus and/or autonomic rectal nerves. They may also affect signaling of the

left and right hypogastric nerves as they approach and leave the IHP along the distal end of the uterosacral ligaments USL.

[0039] There will be multiple embodiments that optimize the direction of signal to the target structures and/or contact with the tissue. For example, in an embodiment the ring will have a flared and/or curved rim to increase electrode contact with the vaginal wall and adjacent nerves. Another embodiment may have protruding tabs extending from the ring to maintain position and/or more effectively direct current to the target nerves or plexuses. The device may also have a marker or positioning feature in order to maintain proper orientation relative to a midline. There may also be a feature available to optimize the transmission of electrical signal across the vaginal wall.

[0040] By directing signals to the peri-cervical plexuses and nerves, stimulation is directed to autonomic nerves while minimizing, and possibly eliminating, stimulation of somatic nerves and pelvic floor muscles. This is an essential distinction of the present invention from current devices. Because the device will reside in the fornices, or uppermost portion of the vaginal apex in some women, it will be well proximal to the somatic sensory nerve distribution. This will allow the patient to wear the device without awareness, making continuous treatment regimens possible. Such continuous regimens may be difficult with conventional devices residing lower in the vagina. Convenience of use, privacy, and comfort may increase compliance and, therefore, treatment success using the devices and methods of the present invention.

[0041] The device being described is able to work unilaterally, bilaterally, anteriorly, posteriorly and/or laterally as a single device that is easily placed and removed. With the device of the present invention the stimulation sites may also be changed or rotated. For example, a stimulation regimen may alternate between the rightward then leftward aspect of the IHP or vesical plexus, right and left Frankenhauser's plexus, or the junction or intersection between the right and left hypogastric nerves and the IHP. The feature allows increased flexibility with treatment regimens, giving certain plexuses or nerves rest while stimulating others.

[0042] The device of the present invention will also be able to target vastly more autonomic signals traveling to and from the pelvis. This may make it more effective at treating global pathologic problems, such as chronic pelvic pain. For example, a patient with severe pelvic pain may require continuous circumferential stimulation while a patient with overactive bladder may only need to target therapy to a single plexus.

[0043] As such, the device of the present invention permits the patient to receive individualized therapy. After initial placement, each patient's symptoms, response to treatment and any side effects may be monitored. A regimen will be customized based on her response to therapy. The device is programmable and the patient will be able to have adjustments to her regimen as desired. The plurality and laterality of electrodes allows a wide variety of stimulation opportunities.

[0044] For example, an overactive bladder patient may do well with the electrodes adjacent to the IHP stimulating 30 minutes daily. A patient with side effects to signaling of the IHP, say constipation, may prefer use of the anterior leads near the vesical plexus. If a patient has a blunted response after a long course of use, a good option could be to stimulate only the right anterior leads for a week and then rest the associated nerves while stimulating the leftward nerves of the vesical plexus during the following week. An interstitial cystitis/painful bladder syndrome patient may benefit from stimulating the vesical plexus and one or both of Frankenhauser's plexuses simultaneously to treat both bladder pain and urgency.

[0045] A patient with a spinal cord injury may do better with signaling the IHP continuously to control high levels of aberrant signal. This could afford treatment of fecal and urinary incontinence. Another patient may benefit from activating Frankenhauser's to treat non-obstructive urinary retention.

[0046] A woman suffering from dysmenorrhea (pain with menstruation) may only need the posterior-lateral leads active in order to stimulate Frankenhauser's plexuses and avoid dampening signal to and from the rectum or bladder. She could use the device five days a month. One patient with chronic pelvic pain may require continuous circumferential stimulation. Another may only require therapy targeted to the plexuses on one side allowing the rectal and bladder signals to function normally on the contralateral side. One therapeutic goal will be to find the least amount of signal required to treat each patient.

[0047] Achieving the therapeutic goal of finding the appropriate amount of treatment will often be based on monitoring and sensing, as well as diagnostic functions. Monitoring a patient via a set of sensors provides baseline data, variations from that baseline, comparison with normal ranges, monitoring of treatment regimens, and a variety of other data analytic functions. Such monitoring and sensing of bodily parameters can be the basis for diagnosis by either software in the device itself, other devices with which it communicates, clinicians treating the patient, the patient herself, or any combination. Therapy can be triggered automatically, based on data from the monitoring and diagnostic functions, triggers related to such data, pre-set software programs, patient input, clinician input, or any combination.

[0048] In this way, therapy may be intermittent, continuous, or not delivered at all, based on the monitoring and sensing, as well as diagnosis, of the data about the patient's condition. This ability to integrate monitoring, diagnosis, and therapy in a flexible way is a significant advantage of the methods and devices described herein.

[0049] While the above discussion has discussed the example of therapy delivered primarily via electrical energy based on electrodes, this is meant only as an example. There are a broad range of modalities (as also mentioned above) supported by the methods and devices described herein, especially as the monitoring and sensing, as well as diagnostic, functions extend well beyond monitoring and diagnosing nerves. A wide range of physical, biological, chemical, and other parameters can be measured and provide input into potential therapy for both the user and her physicians. Furthermore, this data can be communicated to, compared with, combined with, and triangulated wirelessly with information from other devices, allowing even greater flexibility.

[0050] Specific aspects of the present invention are now described. The device has a nerve stimulating element positioned on an exterior surface of a body for contact with the exposed or internal surface of the vagina. The nerve stimulating element may stimulate nerves in any suitable manner including provision of one or more emitting elements, which emit electrical energy, ultrasound energy, a drug, a magnetic field or other suitable stimulus. In a specific embodiment, the nerve stimulating element may be one or more electrodes, which deliver electrical energy to stimulate adjacent plex-

uses, nerves and associated autonomic nerve fibers. The nerve stimulating element may include a sensor or sensors to measure physiological parameters or may communicate with such sensors.

[0051] As mentioned above, many conventional devices contribute to side effects from stimulating somatic nerves adjacent to the distal or lower half of the vagina. These devices also often describe intentionally stimulating pelvic muscles and somatic nerves. The present invention avoids drawbacks associated with these devices by providing a device which has all of the nerve stimulating elements positioned in the proximal half of the vagina and may have the entire device positioned in the proximal half of the vagina. To this end, the present invention provides nerve stimulating elements that are positioned close to the target plexuses. These nerves travel close to the proximal end of the vagina and have branches, which are typically no more than 2 cm from the exposed surface of the vagina and, as such, the preferred embodiments are described with the nerve stimulating element being no more than 3 cm from the target nerve plexus or nerve. Stated another way, the nerve stimulating element may be positioned no more than 3 cm from the uterosacral ligaments which are positioned adjacent the target plexuses. Stated still another way, the nerve stimulating element is positioned to stimulate the vesical plexus, left and right Frankenhauser's plexus, left and right hypogastric nerves, and/or inferior hypogastric plexus without intervening nerves, and in particular without intervening somatic nerves. Stated still another way, the nerve stimulating element may be positioned to contact the exposed surface of the vagina closer to the left or right hypogastric nerve, vesical plexus, Frankenhauser's plexuses, or the inferior hypogastric plexus, than to the pelvic floor. Stated yet another way, the nerve stimulating element (and in some embodiments all nerve stimulating elements) is positioned within 3 cm from a proximal end of the vagina, proximal to a distal end of the cervix, or proximal to the midpoint between the proximal and distal ends of the vagina. Finally, the entire device may be positioned proximal to a midpoint between the proximal and distal ends of the vagina or within 5 cm from the proximal end of the vagina.

[0052] The device may also include a plurality of nerve stimulating elements to stimulate the left and right sides of the target nerve plexuses and/or nerves either simultaneously or independently. Providing independent nerve stimulating elements on the left and right sides of the target plexuses and nerves permits tailoring the therapy for the user and condition being treated. Furthermore, the laterality of treatment regions may be changed periodically to reduce habituation thereby permitting stimulation of the same plexus from different approaches.

[0053] The main body of the device may form a closed loop having a central opening with the cervix positioned in the central opening. Although the main body extends completely around the cervix, the main body may extend only partially around the cervix. To this end, the main body may extend around at least 120 degrees, or even 270 degrees, around the cervix relative to the cervical axis. For example, the main body may be C-shaped or U-shaped. In another aspect of the present invention, the nerve stimulating elements (such as the electrodes) are spaced apart at least 120 degrees, or even 180 degrees, relative to the cervical axis (or the central axis when the cervix is absent) so that the target nerve plexuses may be stimulated independently (or simultaneously) as described herein with a single device on opposite sides of the cervix. Of course, the nerve stimulating element(s) may be positioned only along a posterior or anterior half of the vaginal canal for targeted use as described herein rather than spaced around the periphery of the device.

[0054] The present invention may be useful in stimulating and altering autonomic nerve function for treatment of urinary urgency, frequency, incontinence, incomplete bladder emptying, pain and other pelvic visceral organ dysfunction, such as fecal incontinence. The devices and methods are designed to deliver therapy, an example being electrical stimulation, to specific plexuses that mediate autonomic communication between the visceral pelvic organs and the central nervous system. The device will also alter the signal from visceral pain nerves.

[0055] The indications for use include those referred to below. In addition, alteration of autonomic nerve signal may be used to treat cardiovascular conditions, such as hypertension, bradycardia, tachycardia and other dysrhythmias. Beneficial effects of this treatment may include altering autonomic tone, thereby treating chronic stress related conditions, such as gastritis, inflammatory conditions (such as asthma, inflammatory bowel diseases, atherosclerosis and arthritis), headaches, diabetes and anxiety. An example of integration of monitoring, diagnosis, and treatment is monitoring of heart rate and waveform to support, when necessary, control of heart rate via autonomic nerve stimulation/modulation.

[0056] The present invention is also directed to modulating the peripheral autonomic nervous system to alter, and ultimately reduce, systemic sympathetic tone. The autonomic nervous system functions as a circuit. Modulation of the signal of the autonomic plexuses surrounding the cervix and uppermost aspect of the vagina, namely the inferior hypogastric plexus (IHP), Frankenhauser's plexuses (L and R) and the vesical plexuses (L and R), may alter systemic sympathetic discharge throughout the sympathetic chain. Stimulation of the superior hypogastric plexus (SHP) may have a similar effect and may be included in this group of plexuses. Stimulation of these plexuses may influence the sympathetic tone of individual organs differentially. Alternatively, this therapy may influence the sympathetic tone of some, but not all organs under the control of the autonomic nervous system. In one aspect of the present invention, at least three of the plexuses are stimulated in accordance with methods and systems of the present invention.

[0057] The current invention will decrease sympathetic tone thereby protecting organs (such as the heart and vascular system) from deleterious effects of chronically increased sympathetic stimulation (via hormones, neurotransmitters, chemicals) and/or mitigate systemic disease processes influenced by sympathetic outflow, such as inflammation and immunosuppression.

[0058] In one aspect of the present invention, a battery-operated nerve stimulating device (which includes a handheld programmable and wireless controller) is designed to be positioned in the vagina and specifically the vaginal fornices. An embodiment may also include a version wherein the device and controller are connected via a cable without departing from the scope of the invention. The controller may record information regarding previous stimulation regimens, impedance, patient responses to therapy and other information. The information stored by the controller can be transferred to a computer or other device to review and analyze. The control-

ler may also recommend stimulation regimens, based on patient response to past treatments or standard regimens known to be therapeutic.

[0059] Use of the information is therefore extremely flexible, based on the device's ability to operate independently or in conjunction with other devices. Data can be provided by sensors on the device itself, and/or by other medical and computing devices with which the controller and the device communicate. Data analysis can be completed by the device itself, by the controller, and/or by other medical and computing devices.

[0060] The devices and methods distribute therapy to autonomic plexus targets in the central pelvis while avoiding somatic nerves, general paravaginal nerves and the pelvic floor muscles. Unlike other vaginal neuromodulation devices, the electrodes are positioned in the most cephalad aspect of the device to optimize distribution of therapy above the vault of the vagina. Multiple embodiments are designed to assure adequate coverage of the plexuses. For example, versions include a torus-like, a truncated pyramidal frustum and truncated cone. Variations will include devices with and without a central opening, as the later may be beneficial for women without a cervix.

[0061] The devices of the present invention may be shaped to cause the apical vagina to widen and elevate, thereby bringing the vaginal wall closer to the target plexuses. The shape of the device also induces tenting of the vagina around the surface of the device. This layering of the vagina over the nerve stimulating elements optimizes contact between these elements and the vaginal wall. These embodiments cause a modest increase in vaginal wall tension and decreased resistance within the vaginal wall, thereby providing a more predictable interface between the nerve stimulating elements (such as electrodes) and the target structures.

[0062] The nerve stimulating elements generally conform to the contour of the device to maintain consistent proximity and contact with the vaginal wall. This feature may assure treatment of the entire plexus and plexus associated nerves that travel peripheral to the cervix and/or apex of the vagina. This also facilitates stimulation of pain nerves, both visceral and autonomic, traveling to and from adjacent visceral organs, within the preperitoneal tissue or associated with the peritoneum.

[0063] The invention may also provide surface features designed to optimize stimulation of the targets. In one embodiment, the device surface may have an undulating exterior surface with peaks, or raised areas, between valleys or recesses. The raised areas protrude into the vaginal wall to create a seal between recesses. Each recess will contain at least one nerve stimulating element and may also include a conductive material.

[0064] An embodiment will provide variations of a form-fitting, externally applied and absorbable ring-like insert. The insert includes a plurality of electrically conductive areas coupled to a substrate with the plurality of electrically conductive areas being separated by non-conductive areas. The substrate may form a closed loop with the electrically conductive areas positioned at spaced apart locations on the closed loop. The substrate may dissolve within the body to leave the conductive areas positioned within recesses in the main body of the device. The conductive areas may include a gel, such as a hydrogel, or a porous material having a flowable conductive material contained in the pores (such as a hydrogel or saline). The porous material may be a resilient foam element or any other suitable biocompatible porous element. The substrate may also include an elastic band that secures the insert to the device.

[0065] Once the insert is applied to the device the conductive areas will reside within the recesses and the exposed substrate will cover the external surface of the device ultimately providing a smooth outer contour.

[0066] The device may also include a reservoir (or reservoirs) of a conductive, flowable material (such as a hydrogel or saline). The reservoir is a part of or coupled to the main body of the device and is further fluidly coupled to one or more recesses. The conductive, flowable material may be automatically drawn into the recess. For example, the recess may include a porous element that draws the flowable material automatically out of the reservoir and into the recess. Alternatively, mechanical, chemical, thermal, electrical or hydrogen driven means may be used to force the flowable material out of the reservoir.

[0067] The insert(s) and/or the reservoir(s) may also be used to deliver any compatible substance or flowable material in a controlled fashion. For example, a drug may be delivered in a time-released fashion, based on data correlation with other data provided by the device and/or other medical or computing devices with which the device wirelessly communicates, or on demand from a signal provided from the controller. Clearly, both the propitious location of the device and its communication integration allow for great flexibility in use of inserts and reservoirs.

[0068] The insert(s) and reservoir(s) can collect as well as dispense compatible substances and flowable materials. Collecting such materials when the device is positioned in the body allows data from the materials to be included in the broader data monitoring, sensing, and diagnostic functions. The ease of removing the device, changing insert(s), and re-inserting the device allow data from materials collected to be easily analyzed externally as well.

[0069] The physical characteristics of the devices described herein may also help maintain proper orientation. As mentioned previously, the device may include recesses, which form peaks and valleys that help the device maintain the same position and limit rotation. The truncated pyramid and truncated cone shapes may help to drape the vagina in a similar fashion over the device. The torus shaped embodiment is designed to prevent dislocation, by virtue of the smooth outer circumference. The design will facilitate the vagina to conform to the shape and envelope the device so that when pressure is exerted on the upper vagina the vagina and device move as a unit. The device may also be able to alert the user when the battery is weak. The device may communicate with the handheld controller and a flashing light and/or audible alarm will notify the user. The device may also mechanically pulse and/or send stimulation so that the patient is alerted.

[0070] To comprehensively treat the peripheral pelvic visceral plexuses the system of the present invention may include a vaginal positioned device with multiple nerve stimulating elements that may operate independently to create multiple potential circuits with an implant. The vaginal device allows delivery of therapy through different plexuses via multiple current pathways, as 2 or more groupings of electrodes (one vaginal device and one or more implants) triangulate therapy and provide selective stimulation of target plexuses and associated nerves. Thus, the system being disclosed offers open circuit stimulation (for a single electrode)

and closed circuit and selective stimulation, which may be directed by the user or health care provider.

[0071] The advantage of selective stimulation is the opportunity to employ multiple treatment pathways and potential regimens so that therapy may be individualized. For example, a user with pelvic pain may benefit from modulating nerve signals via Frankenhauser's plexus. She or her healthcare provider may activate the circuit between the vaginal electrodes in the posterior aspect of the vaginal device (near Frankenhauser's plexus) and one or more of the implants, depending on whether she desires unilateral or bilateral treatment. A patient with significant urinary urgency may benefit from creating a circuit between the vesical plexus by activating the stimulating elements on the anterior aspect of the vaginal device and the implant. A patient with fecal incontinence or fecal urgency may favor simply stimulating the IHP via the uterosacral implants with or without input from the vaginal device. The vaginal device allows increased flexibility of use, such that therapy may be tailored to each woman's symptoms and response to therapy.

[0072] Another advantage of the vaginal component and its ability to select and control the delivery of energy through different tissue and nerve pathways is minimization and possibly prevention of habituation. The vaginal component stimulating elements afford right/left and anterior/posterior electrodes as discussed herein. Targeting specific structures also avoids unnecessary stimulation of unintended targets. This feature will minimize side effects. Stimulating as few visceral and autonomic pelvic nerves as necessary may decrease habituation associated with pelvic plexuses, interneuron and the central nervous system stimulation. Focused therapy will require less current and ultimately less energy use, which favors prolonged battery-life.

[0073] The vaginal device and/or controller records data regarding treatment regimens, including start and end time, nerve stimulating elements used, resistance, current, frequency, disruption of therapy and any changes made to a regimen. In real time the user will be able to record subjective and objective information, which will be used to adjust and tailor future regimens to her specific needs. For example, if she has a good response to a certain regimen she may note it at the end of a day or predetermined assessment period. In this case, the regimen will be maintained or she may opt to decrease stimulation intensity towards the threshold of benefit. She may also note when she experiences a side effect. She may also record information about her menstrual cycle and be reminded of ovulation, and her last menstrual period, such that therapy is avoided in the luteal phase, if desired.

[0074] By reviewing the treatment regimen (including current, frequency of stimulation, active electrodes and duration of therapy) employed during the time the side effect was experienced, she and her healthcare team will be able to change the stimulation setting or redirect therapy to another target structure altogether. The user may record experiences via free text, respond to periodic questions or via standardized questionnaires and bladder diaries available in the software. All data will be recorded and downloadable to computers and portable devices, such as phones. The user's personal device (such as a phone) may reprogram the controller and alter the regimen. If the patient desires and consents, this objective, subjective and regimen data may be transmitted electronically for remote assessment by healthcare providers or for research purposes.

[0075] The controller of the vaginally positioned device may also communicate instructions to the device such as selecting a stimulation regimen, including which electrodes are active, the amount of current, pulse characteristics, and duration of therapy. The control system of the vaginal device will also maintain information about the stimulation regimens employed, resistance, current, power usage and other information related to the stimulation. The hand held controller may also record subjective and objective input from the user.

[0076] In another aspect of the present invention, the present invention seeks to modulate the peripheral autonomic nervous system to alter, and ultimately reduce, systemic sympathetic tone. The autonomic nervous system functions as a circuit. Modulation of the signal of the autonomic plexuses surrounding the cervix and uppermost aspect of the vagina, namely the inferior hypogastric plexus (IHP), superior hypogastric plexus (SHP), Frankenhauser's plexuses (L and R) and the vesical plexuses (L and R), may alter systemic sympathetic discharge throughout the sympathetic chain. Stimulation of these plexuses may influence the sympathetic tone of individual organs differentially. Alternatively, this therapy may influence the sympathetic tone of some, but not all organs under the control of the autonomic nervous system. In one aspect of the present invention, at least three of these plexuses are stimulated in accordance with methods and systems of the present invention.

[0077] The current invention will decrease sympathetic tone, thereby protecting organs (such as the heart and vascular system) from deleterious effects of chronically increased sympathetic stimulation (via hormones, neurotransmitters, chemicals) and/or mitigate systemic disease processes influenced by sympathetic outflow, such as inflammation and immunosuppression.

[0078] In another aspect of the present invention, an implant with a nerve stimulating element is implanted and preferably secured to a uterosacral ligaments. The implant, like the vaginal devices, modulates the action of nerves and treats conditions by altering the signals of autonomic nerve plexuses, their associated nerves and nerve endings and potentially interneurons and central nervous systems nerves and processes via one or more nerve stimulating implants. The implant may be used independently, together with other implants, or in combination with the vaginally positioned devices of the present invention. The vaginal device may also stimulate the anatomic structures described either by creating a circuit with the implanted electrodes or independently. In another aspect of the present invention, at least two implants are secured to the same uterosacral ligament.

[0079] The vaginal device may include the controller and power source to deliver therapy to the inferior hypogastric plexus (or pelvic plexus), left and right Frankenhauser's plexus (or Lee's plexus), vesicle plexuses (L and R) and even the superior hypogastric plexus. These plexuses may, of course, be called by other names such as Lee's plexus as another name for Frankenhauser's plexus without departing from the invention. Furthermore, the Frankenhauser's plexus refers to both left and right Frankenhauser's plexuses collectively. Unless otherwise specified, use of Frankenhauser's plexus or plexuses shall mean both plexuses.

[0080] The present invention treats urologic, gynecologic, sexual, colorectal, and pain conditions in women with neuromodulation via electrical stimulation (and other modalities), (including heat, ultrasound, and medication). The

implant and indwelling vaginal device deliver therapy to specific autonomic plexuses that communicate with nerves traveling to and from genitourinary and pelvic structures. The neuromodulation of the present invention stimulates the nerve plexuses to alter signal transmitted by the nerve plexuses and associated autonomic nerves between the pelvic organs and the central nervous system.

[0081] For reference (FIG. **1**) autonomic nerve signals traveling to and from the bladder, urethra, rectum, vagina, uterus, peritoneum and other pelvic structures travel through the inferior hypogastric plexus IHP, carrying the signal between pelvic structures and the spinal cord. The inferior hypogastric plexus IHP is the gateway between the visceral (bladder, gynecologic, rectum) organs and the central nervous system. The IHP is a coalescence of both sympathetic and parasympathetic autonomic fibers. The sympathetic fibers run between the thoracic nerve roots (T10-L2) and into the superior hypogastric plexus, then travel towards the IHP via the left and right hypogastric nerves LHN, RHN along the uterosacral ligaments USL. In some cases a portion of the sympathetic fibers may enter the IHP along the undersurface of the cardinal ligaments. These fibers facilitate bladder storage. The parasympathetic nerves travel from the sacral spinal nerve roots (S2-4) in the sacral or pelvic splanchnic nerves, or nervi erigentes towards the pelvic organs, often in association with the pelvic nerve. They facilitate bladder emptying. Sympathetic and parasympathetic fibers coalesce in the IHP over the posterior and lateral surfaces of the upper cervix, just above the vaginal insertion.

[0082] Importantly, the vagina terminates at the level of the pericervical ring (known by other names) around the uppermost portion of the cervix, just below the uterosacral ligament USL insertions. The recesses of the most proximal, or uppermost, aspect of the vagina that surround the cervix are called the vaginal fornices VF. The pelvic floor PF surrounds the lower portion of the vagina near the vaginal opening, making the "floor" of the pelvic cavity. The inferior hypogastric plexus IHP is a web-like plexus adjacent to the posterior and lateral cervix at the level of the uterocervical junction and the uterosacral ligament USL insertions, just proximal to the posterior vaginal fornix. Inferior hypogastric plexus IHP fibers also cover the distal uterosacral ligaments and possibly reside in the lower or under-portion of the cardinal ligament just anterior to the USL. For reference, the IHP is generally referred to as a singular structure in the literature, but anatomic studies suggest significant concentrations of these ganglia may be distributed bilaterally, as described above. For purposes of this description and application the IHP, when used herein, will refer to the IHP and any lateral extensions around the cervix or most proximal aspect of the vagina.

[0083] Autonomic nerve fibers travel from the IHP around the cervix to the vesical plexus, which communicates with autonomic fibers to innervate the bladder. Some autonomic fibers travel from the IHP to the posterior-lateral aspect of the cervix to right and left Frankenhauser's plexuses FP (also known as Lee's or the uterovaginal plexuses). Frankenhauser's or Lee's plexuses send some nerves upward to innervate the uterus and some nerves inferiorly to innervate the vagina, cervix, urethra, and clitoris. Both of these plexuses may be important in controlling urinary tract function. Autonomic fibers travel between the IHP and the middle rectal plexus to innervate the distal rectum.

[0084] In one embodiment of the present invention, the implant has a nerve stimulating element, such as an electrode, which is positioned around and/or through one or both uterosacral ligaments, adjacent to the inferior hypogastric plexus, Frankenhauser's plexus or the superior hypogastric plexus. The implant may also be secured to other structures, such as pubocervical fascia or the external vaginal wall, without departing from the scope of the invention. The therapy is designed to also treat the autonomic nerves traveling around the pericervical and apical vaginal fascia/connective tissue to visceral pelvic organs and the vesicle plexuses.

[0085] In one embodiment, the implant is generally cylindrical in shape with tapered ends. The implant may include a throughhole to accommodate the uterosacral ligament. The nerve stimulating element may be between 0.5 and 5.0 cm long and up to 2 cm wide. The outer surface of each implant is made of a biocompatible and insulating material to which the nerve stimulating elements are attached. The implant has a power source, such as a battery, which powers the implant. The battery may be rechargable and recharged remotely through tissue as is known in the art. For example, the charger may be positioned in the vagina and, in particular, positioned within the vaginal fornices VF.

[0086] The size and shape of the device is designed to provide an optimal surface area for stimulation of an autonomic plexus and associated nerves. The nerve stimulating element may be a relatively small microstimulator when treating a somatic nerve or nerve junction, such as a dorsal nerve ganglion. Autonomic nerves plexuses, on the other hand, are broader, so the nerves coalesce more diffusely thereby possibly necessitating a larger nerve stimulator. Broader distribution of therapy may be important for treatment success.

[0087] In another aspect of the present invention, the nerve stimulating element pierces the ligament. The uterosacral ligaments contain autonomic nerves as they travel to and from plexuses from the visceral pelvic organs. The implant may have two or more nerve stimulating elements (such as electrodes) in contact with the uterosacral ligament and positioned in series along the ligament. When an implant is secured to each uterosacral ligament, the implants may send current between the bilateral uterosacral ligament implants, thereby increasing the amount of therapy provided to the IHP and broadening the distribution of therapy.

[0088] The control system of the vaginally positioned device may communicate with the control system of implant (s) to coordinate stimulation (such as simultaneous or independent stimulation). The control systems may communicate with one another using the nerve stimulating elements to transmit and receive electrical impulses through tissue. Alternatively, the control system may generate radiofrequency signals, which are received by the control system of the implant.

[0089] The controller of the vaginally positioned device may also be used to control and send stimulation instructions to the implant either directly or indirectly via the vaginal device. The controller is configured to communicate control information (such as duration and intensity of stimulation) to the control system of the vaginal device. The controller may transmit a stimulation instruction to the device, which then transmits the stimulation instruction to the implant.

[0090] The devices, systems and methods of the present invention stimulate target nerves and plexuses while avoiding adversely influencing non-target somatic nerves, such as the pudendal nerve or its branches, adjacent to the distal or lower half of the vagina. Reducing side effects and possible urinary

tract symptoms due to stimulating somatic nerves are thereby avoided in accordance with the present invention.

[0091] In addition to other treatments describe herein, the present invention may be used to treat any one or more of the following conditions: urinary urgency, frequency, nocturia, urge incontinence, stress incontinence of urine, loss of urine without sensory awareness, overflow incontinence, bladder pain, urethral pain, urethral syndrome, urethral stricture, urinary hesitancy, protracted urinary stream, pelvic floor dyssynergia, interstitial cystitis, dysuria, overactive bladder, incomplete bladder emptying, urinary retention, hesitancy, dysmenorrhea, pelvic pain, pelvic venous congestion syndrome, endometriosis, irritable bowel syndrome, constipation, fecal urgency, fecal incontinence, rectal pain, pain with defecation, anal pain, sexual dysfunction, and abnormal heart rhythm. Of course, numerous aspects of the present invention may be practiced for a different condition without departing from the scope of the invention.

[0092] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0093] FIG. **1** is a parasagital view into the female pelvis from the left.

[0094] FIG. **2** is an enlarged view of the upper vagina and uterus.

[0095] FIG. **3** is a posterior view of the gynecologic organs.

[0096] FIG. **4** is an enlarged view of the upper vagina and uterus with the device of the present invention positioned in the vaginal fornices.

[0097] FIG. **5** is a posterior view of the gynecologic organs with the device positioned in the vaginal fornices.

[0098] FIG. **6** shows the device, a charger and a controller.

[0099] FIG. **7** shows removal of the device from the charger.

[0100] FIG. **8** is a top view of the device showing the electrodes.

[0101] FIG. **9** shows the orientation of the electrodes.

[0102] FIG. **10** shows a battery, control system and hub, which interconnects the control system with the electrodes.

[0103] FIG. **11** is an exploded view of the hub, battery and control system.

[0104] FIG. **12** shows the hub connected to the battery and control system.

[0105] FIG. **13** shows a layer applied over the main body to seal the battery and control system within the main body.

[0106] FIG. **14**A is a cross-sectional view of the main body.

[0107] FIG. **14**B is another cross-sectional view of the main body with an alternative electrode.

[0108] FIG. **15**A is a perspective view of one end of the main body.

[0109] FIG. **15**B is a perspective view of the same end of the main body as FIG. **15**A with the alternative electrode of FIG. **14**B.

[0110] FIG. **16** is a perspective view of the end of the main body with the battery positioned in the main body.

[0111] FIG. **17** is a perspective view of the end of the main body with the control system positioned in the main body.

[0112] FIG. **18** shows an end of the hub that abuts against the battery.

[0113] FIG. **19** shows another end of the hub that is coupled to the control system.

[0114] FIG. **20** shows a top view of another device in accordance with the present invention.

[0115] FIG. **21** shows still another device in accordance with the present invention.

[0116] FIG. **22** shows another device for stimulating nerves.

[0117] FIG. **23** shows another device for stimulating nerves for use with the device of FIG. **22**.

[0118] FIG. **24** shows another device for stimulating nerves.

[0119] FIG. **25** shows another device for stimulating nerves with the nerve stimulating element mounted to a movable element on the main body of the device.

[0120] FIG. **26** shows the movable elements of FIG. **25** moved together.

[0121] FIG. **27** shows a first cover and a second cover for covering parts of the devices described herein.

[0122] FIG. **28** shows another device for stimulating nerves.

[0123] FIG. **29** shows a cross section of the device of FIG. **28**.

[0124] FIG. **30** shows an enlarged view of a recess of the device of FIG. **28**.

[0125] FIG. **31** shows the recess filed with a porous material, which holds an electrically conductive substance.

[0126] FIG. **32** shows another device for stimulating nerves.

[0127] FIG. **33** shows still another device for stimulating nerves.

[0128] FIG. **34** shows the device of FIG. **33** with the recess filled with an electrically conductive, pliable material.

[0129] FIG. **35** shows the nerve stimulating element covered by an electrically conductive material.

[0130] FIG. **36** shows another device for stimulating nerves having an insert with conductive and non-conductive regions.

[0131] FIG. **37** is a plan view of another device.

[0132] FIG. **38** is a bottom view of the insert used with the device of FIG. **37**.

[0133] FIG. **39** is a top view of the insert of FIG. **37**.

[0134] FIG. **40** is a partial cross-sectional simplified view showing the nerve stimulating element positioned in the recess.

[0135] FIG. **41** is a partial cross-sectional simplified view showing the nerve stimulating element positioned in the recess with the conductive material positioned over the nerve stimulating element.

[0136] FIG. **42** shows a dissolvable portion forming part of the main body of the device of FIG. **37**.

[0137] FIG. **43** is a plan view of the device with the dissolvable portion removed.

[0138] FIG. **44** shows a device having a torus-shaped exterior surface with a wall positioned near the central opening.

[0139] FIG. **45** shows a device having a torus-shaped exterior surface with the nerve stimulating element positioned in a recess.

[0140] FIG. **46** is a simplified cross-sectional view showing the nerve stimulating element of FIG. **44** contained in a recess.

[0141] FIG. **47** is a simplified cross-sectional view showing the nerve stimulating element of FIG. **45** contained in a recess.

[0142] FIG. **48** is an alternative cross-sectional view for FIG. **47**.

[0143] FIG. **49** shows still another device for stimulating nerves having a torus shaped exterior surface with recesses forming a scalloped appearance.

[0144] FIG. **50** shows a simplified cross-sectional view showing the nerve stimulating element of FIG. **44** contained in a recess.

[0145] FIG. **51** shows an insert that may be coupled to any of the devices described herein.

[0146] FIG. **52** shows an implant.

[0147] FIG. **53** shows another implant.

[0148] FIG. **54** shows a delivery tool holding the implant with the implant in an open position for introduction of the uterosacral ligament.

[0149] FIG. **55** shows a cross-sectional view of the abdomen and pelvic region.

[0150] FIG. **56** shows a window formed in the peritoneum.

[0151] FIG. **57** shows a sizer introduced into the abdoment with the uterosacral ligament elevated.

[0152] FIG. **58** shows the sizer extending around the ligament to size the ligament.

[0153] FIG. **59** shows the delivery tool with the implant approaching the ligament.

[0154] FIG. **60** shows the implant secured to the ligament.

[0155] FIG. **61** shows the delivery tool removed and implant secured to the ligament.

[0156] FIG. **62** shows another implant secured to the other uterosacral ligament.

[0157] FIG. **63** shows another view of the window formed in the peritoneum.

[0158] FIG. **64** is another view of showing the opening formed in the peritoneum.

[0159] FIG. **65** is another view of the ligament being sized.

[0160] FIG. **66** is another view of the delivery tool introducing the implant into the abdomen.

[0161] FIG. **67** shows the implant positioned around the ligament with the delivery tool.

[0162] FIG. **68** shows an implant secured to each uterosacral ligament.

[0163] FIG. **69** shows the device positioned with the vaginal fornices and two implants.

[0164] FIG. **70** shows two implants secured to each uterosacral ligament.

[0165] FIG. **71** shows an exploded view of another implant.

[0166] FIG. **72** shows the fully constructed implant of FIG. **71**.

[0167] FIG. **73** shows another device, which may be positioned in the vagina to stimulate nerves.

[0168] FIG. **74** shows the device of FIG. **73** together with a controller and battery charger for the device.

[0169] FIG. **75** shows a device for charging a power source for an implant of the present invention.

[0170] FIG. **76** shows another device for charging a power source for an implant of the present invention.

[0171] FIG. **77** shows the device of FIG. **76** positioned in the vagina to charge the power sources for two implants each attached to a uterosacral ligament.

[0172] FIG. **78** shows another device for positioning in the vagina.

[0173] FIG. **79** is a side view of the device of FIG. **81**.

[0174] FIG. **80** is a bottom cut-away view of the internal components of the device of FIG. **81**.

[0175] FIG. **81** is another side view of the device of FIGS. **78-80**.

[0176] FIG. **82** is a side view showing the main body manually bent for introduction and placement.

[0177] FIG. **83** shows the device manually bent for introduction and a controller worn on the wrist.

DETAILED DESCRIPTION

[0178] For the purpose of defining the invention, various terms are now defined for use herein with reference to FIGS. **1-3**. Firstly, the vagina V is a fibroelastic, muscular structure that forms a canal (hereinafter "vaginal canal" VC) having a distensible, flexible lining. The surface of this flexible lining has an internal or exposed surface ES. The vagina, and vaginal canal, as defined herein has a proximal end terminating at the proximal aspect of the cervix and a distal end at the introitus where it joins the vulva. If the cervix C has been removed or is congenitally absent, the proximal end of the vagina (and vaginal canal) is simply defined by the uppermost portion of the vagina, also known as the vaginal cuff.

[0179] As used herein, the shape of the vaginal canal VC defines a central axis CA. A cervical axis CVA extends through and is aligned with the cervical canal CC. The cervical axis CVA is also an axis of symmetry, as closely as can be approximated with the anatomy, for the cervix extending through the cervical opening or cervical canal. A midpoint between the proximal and distal ends of the vagina (or the vaginal canal) is determined herein using the midpoint of the central axis. The central axis CA may, of course, have a relatively complex shape so long as the central axis CA generally defines and follows the orientation and shape of the vaginal canal VC. The proximal end of the vagina (and vaginal canal) is defined by the uppermost portion of the vagina. For example, a proximal portion of the vagina or vaginal canal extending 3 cm from the proximal end of the vagina includes the vagina extending 3 cm from the uppermost (proximal) end.

[0180] The vaginal fornices VF, as used herein, refers to a space or recess between the cervix and the adjacent vaginal wall. Specifically, the space is positioned between the exposed surface ES of the vaginal canal VC and an exposed surface of the cervix C and further bounded by a plane P extending perpendicular to the cervical axis CVA and passing through distal end of the cervix C. The vaginal fornices VF may be thought of as a somewhat torus-shaped space but, of course, varies from patient to patient.

[0181] Referring now to FIGS. **4-8**, a device **2** in accordance with the present invention is shown. The device **2** includes a main body **4** having a plurality of nerve stimulating elements **6** positioned on an exterior surface **8** of the main body **4** for contact with the exposed or internal surface ES of the vaginal wall **12**. The nerve stimulating elements **6** may stimulate nerves in a number of different ways without departing from numerous aspects of the invention. For example, the nerve stimulating element **6** may include one or more emitting elements **14** which emit electrical energy, ultrasound energy, a drug, a magnetic field or other suitable stimulus to the target nerves.

[0182] In a specific embodiment, the nerve stimulating elements **6** may be one or more electrodes **16** that deliver electrical energy to stimulate adjacent nerves as described below. As used herein, it is understood that use of "electrode" or "emitting element" herein shall be interchangeable with the term nerve stimulating element, and vice versa, as applicable.

Thus, aspects of the invention described or claimed specifically in relation to the electrodes **16** or nerve stimulating element **6** are equally applicable to the other and such substitution is expressly incorporated here. Furthermore, the application of electrical stimulus is sufficient to change the signals transmitted by the target nerves and plexuses described below. In this manner, neuromodulation of the target nerves is achieved.

[0183] Similarly, aspects of the invention described or claimed in relation to electrodes or nerve stimulating elements will encompass sensing electrodes and related sensing elements, without distinguishing whether electrodes are emitting electrodes or sensing electrodes, nor whether a sensor is integrated with or simply communicates with a nerve stimulating element. In order to determine whether and how much and/or when to deliver neuromodulation or other therapysuch information coming from the nerve stimulating element itself as well as from sensors will be described in greater detail below.

[0184] The electrodes **16** are coupled to a control system **18** which in turn is coupled to a power source **19** such as a battery **20**. The device **2** may include a battery charger **22** or may be charged transcutaneously as is known in the art. Of course, an advantage of the present invention is that the device **2** may easily be removed, charged and repositioned which cannot be accomplished with conventional surgically placed devices. The device **2** may also include an external controller **24** which may operate the device remotely when the device **2** is in place. The battery charger **22** may also be a controller for programming the device **2** in accordance with methods described herein. A few prior art devices which describe suitable control systems, controllers and battery charging systems are described in U.S. Pat. Nos. 7,729,772, 7,813,809 and 8,165,692 which are hereby incorporated by reference. The controller **24** (and charger **22**) may control the duration, frequency, intensity and stimulation protocol as described herein and in the patents incorporated above. The controller **24** may also be incorporated or applied to another suitable personal electronic device, such as a cellphone, programmable watch, tablet, laptop, electronic calendar/organizer or any other suitable personal programmable electronic device, without departing from the scope of the invention. If the controller **24** is incorporated into a personal electronic device the necessary control software can be downloaded and updated as a conventional application. The controller **24** may take advantage of the ability of the personal electronic device to communicate wirelessly with the device **2** (and other devices described below).

[0185] The main body **4** of the device **2** forms a closed loop having a central opening **26** with the cervix C positioned in the central opening **26**. The main body **4** may be substantially circular or may have substantially straight sides **28** as shown in FIG. **21**. Of course, the main body **4** may take any other shape such as oval, elliptical, square, or even hexagonal. Although the main body **4** extends completely around the cervix, the main body **4** may extend only partially around the cervix. To this end, the main body **4** may extend around at least 180 degrees, or at least 270 degrees, around the cervix relative to a cervical axis **30** (which is the same as the central axis CA of the device) and may be, for example, C-shaped, V-shaped or U-shaped. As used herein, the central opening **26** does not need to be completely surrounded by the main body **4** so long as the main body **4** extends partially around the cervix and opening **26** as described herein. Thus, a substantially C-shaped or U-shaped main body still will include a central opening **26** with each central opening **26** defining a central axis of the main body **4** CAB. The nerve stimulating elements **6** (such as the electrodes **16**) are also spaced apart at least **120** degrees, or even 180 degrees, relative to the cervical axis CVA (or the central axis of the main body CAB described further below when the cervix is absent) so that the various nerve plexuses may be stimulated as described herein. Of course, the nerve stimulating element(s) **6** may be positioned only along a posterior or anterior half of the vaginal canal for targeted use as described herein without departing from numerous aspects of invention.

[0186] The device **2** of the present invention may be positioned partially or entirely within the vaginal fornices VF. The nerve stimulating element **6** (and in some embodiments all of the nerve stimulating elements **6**) contacts the exposed surface of the vagina **10** proximal to the distal end **46** of the cervix.

[0187] The main body **4** has an elongate cavity **48** (see FIGS. **14**A and **14**B) in which the control system **18** and the battery **20** are positioned as shown in FIG. **8**. The battery **20** and control system **18** are directly coupled together. The electrodes **16** are coupled to the control system **18** with a wire **52** (or other suitable conductive element) electrically coupled to each of the electrodes **16**. The wires **52** extend through a sidewall **54** of the main body **4** and are directed toward a hub **56** which electrically couples each of the wires **52** to the control system **18**. The hub **56** is positioned between a first connector **58** and a second connector **60**. Half of the wires **52** are directed to each of the first and second connectors **58**, **60** (eight wires **52** for each of the connectors **58**, **60** in the preferred embodiment of FIG. **8**). The wires **52** terminate at wire contacts **62** which are used to electrically couple the wires **52** to the hub **56** and, in turn, to the control system **18** as now described. Referring to FIGS. **14**A and **15**A, the electrode **16** may wrap around from a radially outer surface **53** to a radially inner side **55**. An alternative electrode **57** is shown in FIGS. **14** B and **15**B in which the electrode **57** does not wrap around to a radially inner side **59** thereby potentially minimizing stimulus transmitted through the cervix. All features, devices, embodiments and methods described herein may use either the electrode **16** or electrode **57**.

[0188] Referring to FIGS. **10-19**, the hub **56** has a protrusion **64** on each end that fits within the cavity **48** in the main body **4**. The protrusion **64** on the battery **20** side abuts directly against the battery **20** (see FIGS. **16** and **18**) and the other protrusion **64** abuts against the control system **18** (see FIGS. **17** and **19**). The protrusion **64** includes hub contacts **66** on a radially outer wall that are aligned and electrically coupled to the wire contacts **62** at each of the first and second connectors **58**, **60**. Wires (not shown) leading from the hub contacts **66** are directed through the hub **56** to the control system **18**. Each of the wires terminates at an electrical connector **70** (FIG. **19**) that engages electrical connectors **72** on the control system **18** (FIG. **17**). The electrical connectors **72** may be formed on a first extension **74** of the hub **56** that forms a snap fit connection with a recess **76** in the control system **18**. A second extension **77** on the other side of the hub **56** may form a snap fit connection with the battery **20** (FIG. **18**). Of course, the device **2** may prevent access to the battery **20** and control system **18** rather than providing the snap fit connection. For example, the entire device **2** may be encased in a polymer **49**

to remove spaces and voids and to seal all connections to the hub **56** while leaving the electrodes **16** exposed as shown in FIG. **13**.

[0189] Referring now to FIG. **9**, the electrodes **16** may be paired together to stimulate a specific nerve plexus, and even a specific side of the plexus, as now described. The device **2** includes a marker **81** to orient the device **2** along a midline **85** which generally corresponds with a midline **83** of the user. Adjacent the marker **81** is a left posterior electrode pair LPE**1**, LPE**2** and a right posterior electrode pair RPE**1**, RPE**2**. The left and right posterior electrode pairs are positioned to lie adjacent to the left and right sides of the inferior hypogastric plexus. A left posterior lateral electrode pair LPLE**1**, LPLE**2** and a right posterior lateral electrode pair RPLE**1**, RPLE**2** are positioned to lie adjacent the left and right Frankenhauser's plexuses, respectively. Finally, the vesical plexus may be targeted on the left side with a left anterior lateral electrode pair LALE**1**, LALE**2** and a left anterior electrode pair LAE**1**, LAE**2** while the right side of the vesical plexus may be stimulated with a right anterior lateral electrode pair RALE**1**, RALE**2** and a right anterior electrode pair RAE**1**, RAE**2**. Thus, the present invention may be useful in stimulating the same plexus from the right side and the left side simultaneously, independently and/or at different times. Of course, the user may only actuate the left or right side rather than alternating sides for stimulation if the therapy is tolerated better or more successful on one side or the other. The control system **18** may change the laterality periodically such as every few days.

[0190] Although the above description presents distinct electrode **16** pairings, it is understood that any of the electrodes **16** may be grouped together by the control system **18** for generating nerve stimulus. For example, the two electrodes **16** on opposite sides of the marker **81** may be used to stimulate the inferior hypogastric plexus along the midline **85** rather than preferentially on the left or right sides. In another example, the left hypogastric nerve (and the junction of this nerve and the IHP) may be stimulated using the LPE**2** and the LPLE**1** electrodes while the right hypogastric nerve (and the junction of this and the IHP) may be stimulated using the RPE**2** and the RPLE**1** electrodes. Although the independent stimulation of different regions of the same plexus has been described with respect to left and right sides of the midline of a particular target plexus, the stimulation may take place at any two different regions of the same plexus rather than simply left and right sides as described in further detail below.

[0191] Although only one electrode **16** is used on each side of the circuit described above, two or more electrodes **16** may be used to create either side of the electrical circuit rather than using only one for each side as described above. In another aspect of the present invention, the device **2** may include at least twelve electrodes **16** and in the preferred embodiment sixteen electrodes **16**. The nerve stimulating element **6** may be formed by any two electrodes **16** (or groups of electrodes **16**) and, thus, the device **2** could easily have at least twenty nerve stimulating elements formed by sixteen electrodes **16** by grouping electrodes together, and "skipping" over one or two electrodes **16** (or more) to form the electrode pair rather than using adjacent electrodes **16** to form the pair. An advantage of forming at least twenty different nerve stimulating elements **6** the device **2** may provide greater flexibility of treatment, reduce habituation and targeting different sides of the same plexus at different times as described herein. Skipping electrodes **16** to form a particular nerve stimulating element **6** will increase a spacing between the electrodes **16** (compared to adjacent pairs of electrodes **16**) thereby providing the ability to potentially alter the depth of penetration of the stimulus. The control system **18** is configured to independently actuate each of the nerve stimulating elements **6**. In this manner, the device **2** of the present invention may operate in at least twenty different modes with each mode being represented by a distinct nerve stimulating element **6** formed by a unique group of electrodes **16** in any manner described herein. Thus, the present invention not only is able to target numerous plexuses with a single device but each of these plexuses may be stimulated in a variety of independent modes. For example, the IHP may be stimulated with the four posterior electrodes **16** (LPE**1**, LPE**2**, RPE**1**, RPE**2**) in at least four modes (or stated another way by forming at least four different nerve stimulating elements) to stimulate the IHP. In fact, the four posterior electrodes **16** may form at least eight different modes (or stated another way by forming at least eight different nerve stimulating elements **6**) to stimulate the IHP by simply grouping electrodes **16** in the manner described herein (adjacent pairs, skipping one, skipping two, grouping two or more electrodes on one side of the circuit or on both sides of the circuit). In this manner, different regions or portions of the same plexus may be stimulated. Of course, the regions stimulated will have overlapping portions but use of different electrode **16** configurations described herein will create different stimulus patterns and regions. Although the device **2** of the present invention may form numerous independent nerve stimulating elements **6**, simultaneous actuation may produce fewer nerve stimulating elements **6** (such as eight when using sixteen electrodes **16**), nevertheless, the device **2** still may form far more nerve stimulating elements **6** for independent actuation as described herein. The nerve stimulating elements **6** are also preferably formed by more than mere modification of power, frequency or another parameter for the same nerve stimulating element **6**. As such, the nerve stimulating element **6** may each have a unique position in that the electrodes **6** are grouped, paired or otherwise organized in a unique manner for each of the nerve stimulating elements **6** formed. As such, each nerve stimulating element **6** formed has a unique position even if a grouping or pair share one or more electrodes **6** so long as the groups or pairings are not identical. Each unique position provides a different focus unlike a single nerve stimulating element that can only change power, frequency or some other characteristic while leaving the stimulation pattern substantially the same.

[0192] Although numerous nerve stimulating elements **6** may be formed with the electrodes **16** forming numerous different nerve stimulating elements, in some aspects of the invention the device **2** may have at least four, or at least eight, nerve stimulating elements **6** as described above. Each of the nerve stimulating elements **6** may be actuated independently (or simultaneously, of course) to stimulate different regions of tissue (although these regions may overlap). In another aspect of the invention, the nerve stimulating elements **6** are advantageously distributed around the main body **4** to independently stimulate the various target plexuses. To this end, the device **2** may include at least three nerve stimulating elements **6** which are angularly spaced at least 70 degrees from adjacent nerve stimulating elements relative to the cervical axis CVA or central axis of the main body **4** CAB. If more regions are targeted, the device **2** may include at least four nerve stimulating elements which are angularly spaced

at least 50 degrees from adjacent nerve stimulating elements relative to the cervical axis CVA or central axis of the main body **4**.

[0193] Although the nerve stimulating element **6** has been described with respect to pairs of electrodes **16**, the nerve stimulating element **6** may be formed by a single element or even a single electrode **16** without departing from the scope of the invention. For example, a single piezoelectric element may be used to deliver ultrasound energy or the device **2** may include a single electrode **16** with the other electrode carried by another element (even an implantable element) without departing from the scope of the invention.

[0194] As mentioned above, many conventional devices introduced into the vagina suffer from the drawback that they often stimulate somatic nerves since these devices are typically positioned in the distal (lower) half of the vagina. These devices also often intend to stimulate pelvic muscles, which may lead to further disadvantages described herein. The present invention avoids these drawbacks by positioning the device **2** in the proximal half of the vagina and, in some embodiments, may have all of the nerve stimulating elements **6** (or electrodes **16**) in the proximal half of the vagina. To this end, the present invention provides nerve stimulating elements **6** that are positioned close to the target plexuses; the vesical plexus, left and right Frankenhauser's plexuses, the inferior hypogastric plexus and the intersection of junction between the inferior hypogastric plexus and the left and right hypogastric nerves. These nerve plexuses travel close to the proximal end of the vagina as shown in FIGS. **1-3** and typically have branches within 1-2 cm from the exposed surface ES of the vagina and, as such, the preferred embodiments are described with the nerve stimulating element **6** being no more than 3 cm from the target nerve plexus. Stated another way, the nerve stimulating element **6** may be positioned no more than 3 cm from the uterosacral ligaments which are adjacent the target nerve plexuses. Stated still another way, the nerve stimulating element **6** is positioned to stimulate the vesical plexus, Frankenhauser's plexus, or inferior hypogastric plexus without intervening nerves, and in particular without intervening somatic nerves. Stated yet another way, the nerve stimulating element **6** may be positioned to contact the exposed surface **10** of the vagina closer to the vesical plexus, left or right Frankenhauser's plexus, left and right hypogastric nerves or the inferior hypogastric plexus, than to the pelvic floor. Stated still another way, the nerve stimulating element **6** (and in some embodiments all of the nerve stimulating elements **6**) is positioned to contact the exposed surface ES of the vaginal canal within 3 cm from a proximal end of the vagina or proximal to a distal end of the cervix C. The entire device **2** may be positioned proximal to a midpoint between the proximal and distal ends of the vagina. Stated another way, the entire device **2** may be positioned within 5 cm from the proximal end of the vagina. Stated still another way, the nerve stimulating elements **6** are all positioned proximal to a midpoint between the proximal and distal end of the vaginal canal.

[0195] The electrodes **16** are also oriented and organized so that they will form nerve stimulating elements **6** that will generally direct stimulus proximally. To this end, the electrodes **16**, and the nerve stimulating elements **6**, are organized so that a proximal surface **13** are at the same longitudinal position relative to the central axis of the body CAB and the cervical axis CA. Although the electrodes **16** and nerve stimulating elements are preferably oriented in this manner, they may be longitudinally separated without departing from numerous aspects of the present invention. For example, the electrodes **6** (and in one aspect all of the electrodes **16** or nerve stimulating elements **6**) may be longitudinally spaced so that the proximal surface **13** of the electrodes **6** (and the nerve stimulating element **6** formed by the electrodes **16**) relative to the central axis of the body CAB or the cervical axis CVA by no more than one cm.

[0196] Referring now to FIG. **20**, another device **2**A is shown including a main body **4**A having one or more tabs **34** extending radially outward relative to a central opening **26**A. The tabs **34** may help secure the device **2**A in place and maintain the intended orientation of the device **2**A once positioned. The electrodes **16** may be positioned on the tabs **34** so that the electrodes **16** are on the radially outer surface of the main body **4**A.

[0197] Referring to FIG. **21**, still another device **2**B is shown which has an extension **36** extending radially outward from the main body **4**. The extension **36** has a first curved tip **38** and a second curved tip **40** which help anchor the device **2** in position and help maintain the intended orientation. The main body **4**B may also be flared outwardly which also may help retention. The main body **4**B is flared outwardly to become larger as the body **4**B extends distally in the vagina. It is understood that all of the devices **2**, **2**A, **2**B described herein shall incorporate all methods of using the other devices **2**, **2**A, **2**B and such use is expressly incorporated for each device described herein. Furthermore, all devices **2**, **2**A, **2**B shall share the same inventive features described herein and such features are also expressly incorporated for all devices described herein. For example, the position and use of the electrodes **16** of device **2** shall be applicable to use of device **2**A and device **2**B.

[0198] The device may also be used to stimulate the vesical plexus together with either the Frankenhauser's plexus or with the inferior hypogastric plexus (or both). The vesical plexus may be stimulated independently or simultaneously with one or both of the other two plexuses. In another aspect, an anterior side may be stimulated simultaneously or independently with a posterior side.

[0199] As can be appreciated, the present invention provides the ability to target more than one plexus and, alternatively, the same plexus from a different position. For example, a plurality of nerve stimulating elements **6** are positioned to stimulate the same plexus for each of the plexuses described herein. Switching to different stimulating elements **6** may reduce habituation and/or provide other therapeutic benefits. Furthermore, the user may simply select, based on efficacy determined by the user, which of the areas is most beneficial for the particular treatment. Of course, a computer-controlled algorithm may also be used to target particular areas due to set parameters or from feedback data. The control system **18** may control the device **2** to stimulate a target plexus with a first nerve stimulating element **6** for a first period of time, then stimulate the target plexus with a second nerve stimulating element **6** for a second period of time and independent of the first nerve stimulating element **6**. In this manner, habituation may be addressed without changing the target plexus but changing the position of stimulation by changing the nerve stimulating element. Of course, the target plexus(es) may also be changed from any one (or more) of the target plexuses described herein to another target plexus(es) to address habituation or as otherwise desired.

[0200] In one aspect, a plurality of devices **2**C, **2**D, **2**E, such as at least three, having different patterns of stimulating elements **6** may be provided as shown in FIGS. **22-24**. Of course, any other suitable division of plexuses among the plurality of devices **2**C, **2**D, **2**E may be provided. The user may switch between the devices **2**C, **2**D, **2**E (or others with different patterns of elements) as desired. All aspects and methods of using the devices **2**, **2**A, **2**B are incorporated here for use with the plurality of devices **2**C, **2**D, **2**E as applicable.

[0201] Referring to FIGS. **25** and **26**, the ability to select areas for stimulation may also be provided using device **2**F having first and second movable elements **50**,**61**. The first and second movable elements **50**, **61** are coupled to a support body **4**F which may extend in an arc of at least 270 degrees for positioning around the cervix. Each of the movable elements **50**, **61** includes elements **6**F for stimulating nerves and all aspects described herein of the devices **2**, **2**A, **2**B, and **2**C-**2**E are incorporated here. The first and second movable elements **50**, **61** permit the user to move the elements **6**F to desired positions for stimulating target plexuses. FIG. **25** shows the movable elements **50**, **61** positioned to stimulate nerves when positioned on opposing sides of the cervix (any opposing regions). FIG. **26** shows the movable elements **50**, **61** moved together to form a section, which permits stimulating half of the regions discussed herein and such uses are expressly incorporated here.

[0202] Referring to FIG. **27**, a first cover **73** and a second cover **75** are provided to prevent or reduce stimulating some areas for use with any of the devices **2**, **2**A-**2**F described herein. The first and second covers **73**, **75** are movable along the body to cover elements **6** as desired. The first and second covers may **73**, **75** may also be spaced apart to form a window **79** for stimulating tissue within the window **79**.

[0203] In still another aspect of the present invention, the device **2** is now referred to again with reference to FIGS. **1-22**. The device **2** itself may be used to orient the device **2** within the patient using the nerve stimulating elements **6** themselves. For example, when one of the nerve stimulating elements **6** emits energy, another of the nerve stimulating elements **6** may measure energy received from the emitting element **6**. The control system **18** monitors the energy received at the other nerve stimulating element **6** and records data regarding the energy received. The control system **18** may then recognize the orientation of the device **2** relative to the cervix by recognizing a pattern in the energy received. In another aspect, the control system **18** may simply measure impedance between two or more nerve stimulating elements. The resulting impedance data may also be subsequently used to orient the device **2** with the control system **18** recognizing a pattern of data to orient the device **2**. Stated another way, the control system **18** may be used to orient the device with at least one of the nerve stimulating elements emitting energy and at least one other of the nerve stimulating elements measuring the energy emitted. The control system **18** may save a pattern of a parameter and compare the pattern to current data to orient the device about the cervix. For example, RF energy or ultrasound energy may be emitted by one or more elements **6** and received at others with the control system **18** monitoring and storing the data. In another aspect, impedance between nerve stimulating elements **6** may be used with the control system **18** monitoring and storing the impedance and matching a pattern of saved impedance data to orient the device **2**, **2**A. The device **2** may then change the pattern of stimulation using the nerve stimulating elements **6** in accordance with the orientation determined by the control system **18**. Of course, an angular shift of the device **2** around the cervix may orient different elements **6** adjacent different targets but, of course, such a shift and change of nerve stimulating elements **6** is clearly contemplated with the present invention and, as such, the particular elements **6** used to stimulate the target area (plexus) may change.

[0204] This ability to measure and compare parameters provides numerous additional benefits. The example of measuring impedance can, for example, provide data on blood and tissue. In general, the ability for electrodes to measure as well as deliver energy can provide other data on electrical properties of the tissue and fluids in the environment of the device. Both the ability to acquire measurements at different points in time, and the fact that the device **2** extends further in space than leads of implanted devices, allow for comparisons of parameters by the device. The ability of the device **2** to communicate with other medical and computing devices internal and external to the body extend all of these capabilities. The device **2** can incorporate any of a wide range of other sensors into the nerve stimulating elements or communicate with such sensors elsewhere on the device or on other devices internal or external to the body. Thus, a wide range of parameters can be sensed and monitored, diagnosed, and therapeutically treated. The data integration of such a device worn internally is novel in utilizing multiple sources and extending from sensing, through diagnosis, to therapy.

[0205] Referring to FIGS. **28-51**, various additional devices are shown. As with all other embodiments in this application, all methods of use and physical characteristics mentioned herein for one embodiment are equally applicable to all other embodiments. Thus, for the embodiments of FIGS. **28-51**, all methods of stimulating any of the target nerves or plexuses, or for any other therapeutic use mentioned herein, are incorporated here. For example, all devices described herein may include a first nerve stimulating element stimulating nerves adjacent the vagina, a second nerve stimulating element positioned to stimulate nerves on an opposing side of the cervix from the first nerve stimulating element when viewed along a cervical axis (independently or simultaneously and without moving the device). Similarly, all other applicable methods may be used specifically with every other embodiment. Furthermore, all physical characteristics, such as size, orientation, number and position of nerve stimulating elements, are also all incorporated here and for all embodiments described herein. Finally, although not specifically shown for each embodiment, each device includes the power supply, such as the battery, and the control system described herein and the characteristics of each are applicable to all embodiments.

[0206] Referring now to FIGS. **28-31**, another device **2**G for stimulating nerves is shown wherein the same or similar reference numbers refer to the same or similar structure. As mentioned above, all features of corresponding structures and methods shall be incorporated here. For example, the nerve stimulating element **6**G, although shaped uniquely compared to the other nerve stimulating elements, nevertheless may incorporate any of the features of the nerve stimulating elements described above such as the nerve stimulating element **6**G may be an electrode **16**G. The nerve stimulating elements **6**G are positioned on an exterior surface **8**G of a main body **4**G. The main body **4**G may form a closed ring **88** having a central opening **90** in which the cervix is positioned. The term "closed ring" or "closed loop" as used herein shall mean any

closed shape regardless of shape and, as such, all of the closed shapes described herein shall constitute closed rings or closed loops.

[0207] The exterior surface **8**G of the main body **4**G forms a truncated pyramid having four sides **92** and rounded edges. At least one nerve stimulating element (or at least two) is positioned on each side **92**. Alternatively, at least three of the four sides **92** may each have at least two nerve stimulating elements **6**G.

[0208] The main body **4**G includes a recess **80** in which the nerve stimulating element **6**G is positioned. The main body **4**G may include at least four recesses **80** and at least four nerve stimulating elements **6**G each positioned in one of the recesses **80**. The main body **4**G may also include a non-conductive wall **82** extending between the recesses **80**. The wall **82** may be electrically insulated (non-conductive) to isolate the nerve stimulating elements **6**G from one another. The wall **82** may also help to contain a conductive material within the recess **80** as explained further below. The main body **4**G may also have another wall **84** that extends around the opening **90**. The wall **84** may also be a non-conductive material to help isolate the nerve stimulating elements **6**G from one another (particularly when electrodes **16** are used) and to contain a conductive material. The wall **84** is positioned between the nerve stimulating elements **6**G and a radially inner edge **93** (smaller end) of a central opening **95** in the main body **4**G. Another wall **91** is positioned at a radially outer edge **107** (larger end of the opening) of the central opening **90**.

[0209] The main body **4**G may also include a reservoir **94** which contains a flowable substance **96** such as saline or a hydrogel. The reservoir **94** has a lumen **89** fluidly coupled to the recess **80** and a permeable and/or porous structure **98** (depending on application) such as an open cell foam exposed and positioned in the recess **80**. The structure **98** has pores **100** that hold the flowable substance **96** which may be electrically conductive (such as saline or a hydrogel). The flowable substance **96** may continue to weep from the structure **98**, depending on the physical characteristics of the structure **98**, lumen **89** and flowable substance **96**, to position the flowable substance **96** in the recess **80** adjacent the nerve stimulating element **6**G. The structure **98** may automatically draw the flowable substance **96** from the reservoir **94** thereby automatically replenishing the flowable substance **96** as necessary. Of course, the flowable substance **96** may also be forced from the reservoir **94** without departing from the scope of the invention. The flowable substance may be a conductive substance to enhance electrical contact between the nerve stimulating element **6**G and tissue. A fill hole **97** may be used to fill the reservoir **94** as necessary. The reservoirs **94** may each deliver to a single recess **80** but may, of course, deliver to multiple recesses **80** without departing from the scope of the invention. Referring to FIG. **31**, the flowable substance is shown filling the recess **80**. The recess **80** may also be filled with a permeable material **99** which holds the flowable substance **96** in pores **100** therein as describe in connection with other embodiments described herein.

[0210] Referring to FIG. **32**, another device **2**H for stimulating nerves is shown wherein the same or similar reference numbers refer to the same or similar structure. The device **2**H includes a permeable and porous structure **98**H surrounding the nerve stimulating element **6**H. In this manner, the flowable substance **96** is delivered directly to the area around the nerve stimulating element **6**H. The flowable substance **96** weeps from the permeable structure **98** and is contained within the recess **80** with the walls bounding the recess **80** helping to contain the substance **96**. The walls also provide a non-conductive barrier to reduce the likelihood of a short circuit between adjacent elements **6** (particularly when using electrodes).

[0211] Referring to FIGS. **33-35**, another device **2**J for stimulating nerves is shown wherein the same or similar reference numbers refer to the same or similar structure. The device **2**J has nerve stimulating elements **6**J on an exterior surface **8**J of a main body **4**J. The main body **4**J may have the shape of a truncated four-sided pyramid and may include the features associated with this shape described above.

[0212] The main body **4**J includes a wall **82**J extending between recesses **80**J. The wall **82**J may be electrically insulated (non-conductive) to isolate the nerve stimulating elements **6**J from one another. The wall **82**J may also help to contain a conductive material **105** within the recess **80**J as explained further below. The main body **4**J may also have another wall **84**J that extends around a smaller end **101** of central opening **90**J. The wall **84**J may also be a non-conductive material to help isolate the nerve stimulating elements **6**J from one another (particularly when electrodes **16** are used) and to contain a conductive material. A lip **103** forms another wall **107** that extends around the larger end (radially outer side) of the central opening **90**J thereby surrounding each recess **80**J with walls **82**J, **84**J and wall **107**. A conductive material **105** is positioned in the recess. The material **105** may be a soft, pliable, electrically conductive structure such as any of those described herein including a porous material or substance (using saline or a gel such as a hydrogel). In this manner, the conductive material **105** may conform somewhat to the shape of the tissue to enhance contact with tissue and electrical conduction.

[0213] Referring to FIG. **35**, the nerve stimulating element **6**J may be covered by a pliable, electrically conductive material **109**. The conductive material **109** may also be pliable so that the conductive material **109** also conforms somewhat to the shape of the tissue. The conductive material **109** may be a permeable open cell foam element **111** with a conductive fluid, such as saline, contained in the pores of the element **111**.

[0214] Referring to FIG. **36**, still another nerve stimulating device **2**K is shown wherein the same or similar reference numbers refer to the same or similar structure. Nerve stimulating elements **6**K are positioned on a main body **4**K having an exterior surface **8**K having a shape similar to a truncated four-sided pyramid and all characteristics of this shape described herein are incorporated here. The device **2**K includes an insert **120** which may be a separate device that is attached to the main body **4**K by the user. Alternatively, the insert **120** may be integrated into the device **2**K without departing from the scope of the invention.

[0215] The insert **120** has conductive elements **122** positioned over the nerve stimulating element **6**K which may be pliable to conform to tissue and thereby enhance electrical conduction. The plurality of conductive elements **122** are coupled to and separated by non-conductive elements **124** which may also be pliable. The electrically conductive element **122** may be a gel, such as a hydrogel, or a porous material **126** having a flowable material, such as saline, contained in the pores of the porous material **126**. To this end, the term electrically conductive shall include porous materials that are not electrically conductive but can conduct electricity

when the pores are filled with an electrically conductive material. The non-conductive element **124** may also be a thin layer of material such as a closed cell structure made of a non-conductive material. Alternatively, the non-conductive element **125** may simply be a pliable layer **127** of non-conductive material such as silicone. The pliable nature of the layer **127** may help to conform to tissue to create a barrier to electrical conduction between adjacent nerve stimulating elements **6**k. The insert may include a main body **129** that may simply be an elastic band **131** at a radially outer (larger end) of a central opening **133**. The band **131** may be coupled to one or both of the non-conductive elements **125** and/or conductive elements **122**.

[0216] Referring to FIGS. **37-43**, another device **21** is shown for use with an insert **130** wherein the same or similar reference numbers refer to the same or similar structure. The device **21** is substantially the same as the device **2**K and all aspects of device **2**K are incorporated here. The insert **130** has conductive elements **132** mounted to a main body **137**, which may form a closed loop **145**, at spaced apart locations. The conductive elements **132** may be any of those described herein including the pliable structures described above. The main body **137** includes non-conductive elements **135**, such as a thin layer, positioned between the conductive elements so that the conductive elements **132** are coupled to and separated by non-conductive elements **135**. The main body **137** may include a dissolvable portion **142** that dissolves within the body under normal conditions (vagina in this application). Referring to FIGS. **41** and **43**, the dissolvable portion **142** may include the non-conductive elements **135** thereby leaving only the electrically conductive elements **132**.

[0217] Referring to FIGS. **44-51**, a device **2**L, a device **2**M and a device **2**N are shown having bodies **4**L, **4**M, **4**N with an exterior surface **8**L, **8**M, **8**N that each form a torus. As used herein "torus" shall apply to shapes that are torus-like or generally torus-shaped. The devices **2**L, **2**M and **2**N also form a closed ring **150** like other embodiments described above. The nerve stimulating elements **6** are positioned in recesses **80**L, **80**M, **80**N as shown in the cross-sectional view of FIGS. **46**, **47**, **48** and **50**. The main body **2**L of the device **2**L has a central opening **154**. The main body **4**L has a non-conductive wall **156** which may be a closed loop **158** adjacent the opening **154** and positioned between the nerve stimulating element **6** and a radially inner side **170** of the torus. The recesses **80**L, **80**M, **80**N and nerve stimulating elements **6** are positioned predominantly on a radially outer side **164** of the torus. The device **2**N includes recesses **80**N which form a scalloped shaped wall **165** extending around the central opening **174** and positioned between the nerve stimulating element **6**N and the radially inner side **170** of the torus. As shown in the various cross-sectional views, the exterior surface **8**L, **8**M, **8**N at the radially inner side **170** of the torus may be somewhat flattened.

[0218] Referring to FIG. **51**, another insert **190** is shown which may be applied to any of the devices **2**L, **2**M, and **2**N. The insert **190** may be integrated with the devices **2**L, **2**M, **2**N or may be a separate, disposable device that is applied by the user. The insert **190** has conductive elements **192** separated by non-conductive elements **194** similar to the other inserts described above and all discussion above is equally applicable and incorporated here concerning the conductive element **192** and non-conductive element **194**. The non-conductive element **192** may, for example, be a layer **193** of non-conductive material such as silicone. The insert **190** may include a body **204** which may simply be an elastic band **199** extending around one end to secure the insert **190** onto the devices **2**L, **2**M, **2**N. The body **190** may form a closed loop **195** (as broadly described herein) with the elastic band **199** circumscribing the closed loop **195** around the central opening **209**. The non-conductive element **194** may also form a raised wall **211** relative to the conductive element **192**. The raised wall **211** may also be a thin layer of silicone. The insert **190** may include openings **197** through which the nerve stimulating element **6** is exposed. The openings **197** are positioned to expose the nerve stimulating elements **6** with at least one nerve stimulating element **6** in each opening **197**. The term "insert" as used herein is used to describe a disposable device used with a reusable part although the insert may, in fact, not be "inserted" into any part of the device and, as shown, may in fact simply surround the other reusable device. Of course, at times the insert is introduced into another object (such as a recess) yet such interaction is not required. The term "system" as used herein may refer to an integrated, single piece device and does not imply or require multiple parts (other than those integrated into a system). Of course, the system may still be provided in separate parts, such as separate controller, control system or battery external to the vagina, without departing from the invention as well since a system may still include separate components coupled together wirelessly or with wires.

[0219] Referring now to FIG. **52**, an implant **220** in accordance with the present invention is shown. The implant **220** is used to stimulate nerves independently, in conjunction with other implants **220** or in conjunction with any of the devices **2**, **2**A-**2**N. The implant **220** is surgically placed and secured adjacent to the uterosacral ligament so that a first nerve stimulating element **224** (coupled to an implant body **226**) is positioned in contact with the uterosacral ligament. The implant body **226** may be secured directly to the uterosacral ligament with the uterosacral ligament positioned in a throughhole **227** extending through the implant body **226**. Alternatively, the implant **220** may be secured to another structure with the nerve stimulating element **224** positioned in contact with the uterosacral ligament. A second nerve stimulating element **228** may be positioned on an outer surface **233** of the implant body **226** so that it is in contact with the peritoneum after placement. A third nerve stimulating element **230** (also coupled to the implant body **226**) may also be provided and positioned in contact with the uterosacral ligament at an opposite end of the throughhole **227** from the first nerve stimulating element **224**. A fourth nerve stimulating element **232** may also be in contact with the peritoneum and spaced apart from the second nerve stimulating element **228**. For the purpose of defining the invention and in particular the claims, the numerical nomenclature associated with the nerve stimulating elements and other structures, such as the "fifth nerve stimulating element" shall not carry numerical significance in that reciting the "fifth nerve stimulating element" does not necessitate four additional nerve stimulating elements and the numerical significance shall not be taken into account. Thus, the "fifth nerve stimulating element" may, in accordance with the claims, be the second recited nerve stimulating element with only two recited. Use of the "fifth nerve stimulating element" may, in fact, be the first (and possibly only) nerve stimulating element for a particular implant but is used since another implant recites (at times in subsequent dependent claims) the second, third and fourth nerve stimulating elements. All aspects of the nerve stimulating elements described herein are

applicable to the nerve stimulating elements of the implant **220** and all features and characteristics are incorporated here for the nerve stimulating elements of the implant **220**.

[0220] The uterosacral ligament passes through a slot **234** when introduced into the throughhole **227**. The implant body **226** is movable from an open position, which permits the uterosacral ligament to enter the throughhole **227** to a locked position which prevents the uterosacral ligament from moving out of the throughhole **227**. The locked position may also be provided in any suitable manner such as with a separate structure including as a suture, clasp, cinch, clamp, or a sliding door or gate over the slot **234** without departing from the scope of the invention.

[0221] Referring to FIG. **54**, the implant body **226** may also be held in the open position with a delivery tool **236**. The delivery tool **236** has a movable jaw **235** so that the delivery tool **236** can hold the implant **220** in the open position of FIG. **54** and release the implant **220** when desired. The implant body **226** is introduced into the abdomen in the open position and released when the uterosacral ligament is positioned in the throughhole **227**. The implant **220** may naturally move to the locked position with the delivery tool **236** holding the implant **220** in the open position. Alternatively, the implant body **226** may be naturally biased to the open position and closed by the delivery tool **236** to clamp and secure the implant **220** to the ligament. Of course, the clamping force must be applied in a controlled manner to prevent excessive pressure on the uterosacral ligament while still adequately securing the implant **220**. The implant **220** may include other securing features, such as one or more eyelets to receive suture passed through the uterosacral ligament, without departing from the scope of the invention.

[0222] The implant **220** also includes a power source **238**, such as a battery **240**, coupled to the implant body **226**. A control system **242** (positioned within the implant body **226**) is coupled to the power source **238** and to the nerve stimulating elements in a conventional manner. The battery **240** may be rechargeable (not shown) without departing from the invention and may be charged with a charging device positioned in the vagina in the same position as the device **2** as described in greater detail below.

[0223] As mentioned above, the first and third nerve stimulating elements **224**, **230** are in contact with the uterosacral ligament which itself is physically connected through various tissue paths to the target plexuses as described herein. Thus, the uterosacral ligament is used to transmit nerve stimuli to the target plexuses and nerves and the anatomic position of the uterosacral ligaments relative to the target areas is advantageous as described above. The nerve stimulating elements on the implant **220** may also be useful for stimulating other nerve plexuses such as the superior hypogastric plexus (SHP) which would be difficult to stimulate using the device **2**. The nerve stimulating elements on the implant **220** may also be suitable for delivering stimulation to the middle rectal plexus to treat fecal urge, rectal conditions, and/or incontinence.

[0224] Referring to FIG. **53**, another implant **220**A is shown wherein the same or similar reference numbers refer to the same or similar structure. The implant has a throughhole **227**A, a control system **242**, and first, second, third and fourth nerve stimulating elements **224**A, **228**A, **230**A, **232**A. The throughhole **227**A is tapered to accommodate a tapered geometry of the ligament. When sizing the implant **220**A, the size may be taken at two positions so that a tapered geometry may also be considered when selecting the appropriate size of implant **220**A. The first nerve stimulating element **224**A has a piercing element **250** configured to extend into and pierce the uterosacral ligament when securing the first nerve stimulating element **224** to the uterosacral ligament. To this end, the piercing element **250**, may be a barb, needle, spike or pin extending into the throughhole **227**. When the implant **220**A is placed around the ligament the piercing element **250** automatically extends into and pierces the ligament. The piercing element **250** may help prevent migration (slipping) of the implant **220**A along the ligament and also may improve stimulation by improving contact between the first nerve stimulating element **224**A and the uterosacral ligament and associated autonomic nerves. The piercing element **250** is preferably made of a conductive material so that the piercing element **250** forms part of the first nerve stimulating element **224**. It is understood that whenever implant **220** is described that implant **220**A may be substituted with all features and methods incorporated.

[0225] The implant **220** may also be small enough so that two implants **220** can be positioned adjacent (and even secured) to the same uterosacral ligament. If the implants **220** are separated with one positioned anteriorly on the uterosacral ligament and the other positioned posteriorly (as shown in FIG. **70**) it is possible to primarily stimulate the IHP with one implant and the SHP with the other.

[0226] The implant **220** may be used by itself, together with additional implants **220**, **220**A or in conjunction with any of the devices **2**, **2**A-**2**N positioned in the vagina described herein and shown in FIG. **69**. It is understood that when device **2** is described for the combination with the implant **220** that any of the other devices **2**A-**2**N may be used as a substitute and those features and methods of use, including all claims, are expressly incorporated. Furthermore, all aspects of the devices **2**, **2**A-**2**N positioned in the vagina and described herein may be used with the implant **220** of the present invention for stimulating nerves and nerve plexuses and all aspects, uses and characteristics of the nerve stimulating elements and methods for devices **2**, **2**A-**2**N are specifically incorporated here for combining with the implant **220** of the present invention.

[0227] The implant **220** and the devices **2**, **2**A-**2**N may work together to stimulate nerves to modulate the signal of the autonomic plexuses surrounding the cervix and uppermost aspect of the vagina, namely, the inferior hypogastric plexus (IHP), Frankenhauser's plexus (L and R) and the vesical plexuses (L and R). In this manner, the stimulation may alter systemic sympathetic discharge throughout the sympathetic chain. In a specific aspect, the device **2** may have two nerve stimulating elements **6**. The two nerve stimulating elements **6** on the device **2** and the nerve stimulating element(s) on the implant **220** together stimulate at least three nerve plexuses from the following list; SHP, IHP, L vesical, R vesical, L Frankenhauser's, and R Frankenhauser's. For example, the implant **220** may stimulate the IHP (or the SHP) while the device **2** has at least one of the nerve stimulating elements **6** stimulating a side of the Frankenhauser's plexus (L or R) and another nerve stimulating element **6** stimulating the other side of the Frankenhauser's plexus relative to the midline **83** (see FIG. **22**). Alternatively, the nerve stimulating elements **6** may be positioned with one nerve stimulating element **6** positioned on a side of the vesical plexus and another nerve stimulating element **6** positioned on the other side of the vesical plexus relative to the midline **83**. The "other side" of a plexus as used herein shall mean any position on the

opposing side of the midline to the other nerve stimulating element and, thus, the nerve stimulating elements positioned on "the other side" do not have to be 180 degrees from one another.

[0228] The device **2** may also communicate with the implant **220** to coordinate stimulation. For example, various therapies may require simultaneous stimulation while others require independent stimulation. The device **2** and the implant **220** may communicate by simply transmitting and receiving electrical signals through tissue using the nerve stimulating element **6** of the device **2** and the nerve stimulating element of the implant **220**. For the purpose of the present invention, "communication" shall require either transmission or receipt of signals or information but does not require both. The controller **24** of the device **2** may be used to communicate with the control system **18** of the device **2** to control, for example, a duration of stimulation and an intensity of stimulation. The controller **24** may also be configured to communicate stimulation instructions for the control system **242** of the implant **220** to the device **2** which then communicates the instructions to the implant **220**. Of course, the controller **24** may be configured to communicate instructions directly to the control system of the implant **220** as well. For example, the controller **24** (and/or the implant **220**) may generate radiofrequency signals to communicate with one another in a conventional manner.

[0229] More than one implant **220** may be delivered and secured to the same uterosacral ligament. Each implant **220** may include all features related to the implants of the present invention. When more than one implant **220** is used, the control systems **242** of the implants **220** may also communicate with one another to coordinate stimulation (such as simultaneous stimulation or independent stimulation). The implants **220** may communicate using electrical signals transmitted to and from the nerve stimulating elements and transmitted through tissue. Alternatively, the nerve stimulating elements (or a separate antenna, not shown) may be used to transmit and receive radiofrequency signals. Of course, any other suitable method of communication between the implants **220** is within the scope of the invention including a physical connection between the implants **220** (such as a filament or wire) although wireless communication is preferred.

[0230] Referring now to FIGS. **55-67**, methods of delivering the implant **220** are now described. The implant **220** may be placed using traditional and/or robotic assisted laparoscopic techniques. A female patient is placed under general anesthesia and positioned for gynecologist laparoscopy in dorsal lithotomy and Trendelenberg position as shown in FIG. **55**. Using laparoscopic and/or robotic technique with a camera and assisting port, the peritoneum over the intended portion of the uterosacral ligament is tented and an opening or window developed to gain retroperitoneal access as shown in FIG. **56**. The ligament is then elevated with a grasper and mobilized medially as shown in FIG. **57**.

[0231] A ligament sizer **225** is introduced and the size of the ligament (circumference, diameter and/or thickness) is measured as shown in FIG. **58**. When the implant **220**A is used, at least two measurements are taken to provide an appropriately shaped tapered throughhole **227**A. The sizer **225** may use any conventional method of determining thickness, for example, using magnetic, electromagnetic (not shown) objects to determine a spacing between the objects. The delivery tool **236**, loaded with the implant **220** of proper size, is then introduced into the abdomen as shown in FIG. **59**. The delivery tool **236** is then used to position the ligament within the throughhole **227** of the implant **220**. The delivery tool **236** may include a pivoting holder **229** to facilitate positioning the implant **220** around the ligament. The surgeon will actuate the movable jaw **235** to simply release the implant **220** if the implant **220** is held open by the delivery tool **236**. Alternatively, the delivery tool **236** may clamp the implant **220** to the ligament using the movable jaw **235**. FIG. **60** shows the implant **220** secured to the ligament and FIG. **61** shows the peritoneum closed. FIG. **62** shows one implant secured to each uterosacral ligament. FIGS. **63-68** present an alternative view of the above-described procedure for placing the implant **220**.

[0232] The implant **220** may be further secured to the ligament with permanent, monofilament sutures (not shown). Either end of the exposed longitudinal edges of the implant **220** may also include an arrow-like barb (not shown), attached to a fixed length of suture that is projected via an internal mechanism into the receiving opening on the opposing side of the throughhole **227**. The arrow-like barb may be relatively large so that it becomes trapped and contained within the implant **220**. The proximal and distal sutures may be delivered simultaneously with a fixed suture length. A properly fitted implant **220** will demonstrate two approximately 2-3 mm, exposed sutures on the medial surface. One or more suture(s) may be passed through the ligament to further prevent the implant **220** from traveling or slipping along the ligament. The implant **220** is then retroperitonealized surgically with absorbable suture. The profile of the implant **220** and the suture features are designed to prevent bowel adherence, in the case that the retroperitonealized implants become intraperitoneal.

[0233] Referring to FIGS. **71** and **72**, another implant **220**B is shown which may be used in the same manner as any of the other implants **220**, **220**A (including combinations with any of the devices **2**A-N described herein) and all such uses are expressly incorporated here. For example, the implant **220**B may be positioned with a uterosacral ligament positioned in a throughhole **227**B. The implant **220**B has a power source **238**B which is preferably a capacitor **239** but may be the battery **240** (see FIG. **52**) without departing from numerous aspects of the present invention. Battery powered implants, including rechargeable batteries, suffer from several disadvantages. First, battery life is often the limiting factor in implant life. Implants are also often limited in size due to size constraints for many implant applications. Unfortunately, a smaller battery obviously results in a shorter battery life. Rechargeable batteries may extend the life of a conventional implant, however, rechargeable batteries are still limited in the number of recharge cycles they can typically withstand. Replacing the battery (or removing the implant) typically requires another surgical procedure. Finally, batteries also contain potentially toxic materials, complicating the design, manufacture and regulatory tasks for an implantable medical device.

[0234] The capacitor **239** may be made of any suitable capacitor materials with more recently developed materials offering high energy densities comparable to a battery. Another advantage of the capacitor **239** is a very high cycle life. One distinct advantage of the capacitor **239** over a rechargeable battery is that the capacitor **239** can be recharged thousands, even tens of thousands, of times. One such material for capacitor **239** is made of layers of graphene and polymer **247**. The implant **220**B includes an induction

element **260**, such as an induction coil **262**, printed, etched or otherwise deposited or formed on a first flexible substrate **264**. The implant **220**B has four induction elements **260**. A control system **242**B is formed on a second substrate **266**. The capacitor **239**, the control system **242**B and an implant body **226** are formed into a roll and bonded together and sandwiched between the nerve stimulating elements **6** to form the implant **220**B of FIG. **72**. During operation, the control system **242**B regulates discharge of the capacitor **239** to power the implant **220**B and generate nerve stimulating impulses as described herein. The control system **242**B may include switches (not shown) to selectively isolate or couple the induction coil **262** to the capacitor **239** as necessary. In one mode of operation, the capacitor **239** is either being charged or energy is drawn from the capacitor **239** to power the implant **220**B. The induction coils **262** are each coupled to a rectifier **267** which supplies DC current to charge the capacitor **239**.

[0235] The capacitor **239** may also facilitate design of a smaller implant **220**B compared to conventional battery-powered implants since some capacitor materials can be recharged tens of thousands of times and, therefore, the capacitor **239** does not require high storage capacity since it can be reliably recharged thousands of times (unlike batteries which can withstand a much more limited number of recharges). To this end, the capacitor **239** may be sized to provide at least 2 days of power under peak operating conditions, and may be no more than 60 days, under peak operating conditions thereby maintaining a small size. Sizing the capacitor **239** in this manner will facilitate design of smaller implants **220**B than a comparable battery-operated implant while also providing longer implant life since the capacitor **239** can be recharged many more times than typical rechargeable batteries.

[0236] Referring now to FIGS. **73** and **74**, another device **2**P designed to be positioned in the vagina (and in particular the vaginal fornices) is shown. The device **2**P may also be used to charge the power source **238** of the implant **220**B (such as the capacitor **239**) of FIGS. **71** and **72** but may be used with any other implanted medical device as well. The device **2**P is similar to the devices **2**, **2**A-N and all uses and aspects of devices **2**, **2**A-N are incorporated here. The device **2**P is similar to the device **2** except that two nerve stimulating elements **6** have each been replaced with a magnetic field creating element **268**. The magnetic field creating element **268** includes one or more coils **269** configured to create a magnetic field, which impinges on the induction coils **262** of the implant **220**B to charge the power source **238**. The device **2**P also includes nerve stimulating elements **6** which may be used in any manner described herein including all combinations described with the implants **220**, **220**A, **220**B. A control system **18**P regulates the current passing through the coils **269** in a conventional manner to provide a fluctuating, pulsing or otherwise changing magnetic field at the induction element **262** of the implant **220**B. The induction elements **262** are electrically coupled to the capacitor **239** via contacts **265** on the front and back sides of the capacitor **239**. The capacitor **239** is coupled to the implant control system **242**B which draws electrical energy from the capacitor **239** and generates and delivers nerve stimulating therapy. The device **2**P and control system **18**P may operate in any manner described herein. Notably, all target plexuses may still be treated and targeted with the device **2**P since adjacent nerve stimulating elements **6** are still capable of stimulating the target locations adjacent the magnetic field creating elements **268**.

[0237] The implants **220**, **220**A, **220**B may also be recharged with a separate device rather than using the nerve stimulating devices **2**, **2**A-P. Referring to FIGS. **75** and **76**, a first charger **302** and a second charger **304** are shown. The first and second chargers **302**, **304** each include a magnetic field creating element **306** extending around a recess **309**. The recess **309** may be part of a throughhole similar to the device **2** or may the recess **309** may be covered at the end of the recess **309** as shown. The first charger **302** has a handle **307** with an actuator **308** to turn the charger on and off. The second charger **304** includes a pull string **311** to aid in removing the second charger **304**. The first and second chargers **302**, **304** are substantially the same except for shape and the anatomy of the user may dictate which charger **302**, **304** is more comfortable for the wearer. FIG. **77** shows the charger **306** in position to charge the power sources for the implants **220**.

[0238] Referring again to the devices **2**, **2**A-P, the following discussion relates to methods and devices for confirming that the device **2**, **2**A-P is in the proper orientation, that is, that the device **2**, **2**A-P has not shifted so that the nerve stimulating elements **6** have changed position. The devices **2**, **2**A-**2**P are initially positioned by the user in a known starting orientation so that the nerve stimulating elements **6** are positioned adjacent their intended targets for stimulation. The marker **81** (see FIG. **9**) may be useful when initially positioning and orienting the device **2**P. The device **2**P (or any of the other devices **2**A-P) may also include a procedure to confirm that the device **2**P has maintained the starting or intended orientation. To confirm that the device **2**P is still positioned as intended, the device **2**P is configured to assess the current orientation of device **2**P to confirm that the orientation has not changed. The control system **18**P may periodically assess the orientation of the device **2**P or the user may transmit an instruction to the device **2**P using the controller **24**P to assess whether the device **2**P has moved from the desired orientation relative to the cervix or the CVA. If the orientation has changed, the control system **18**P uses the change in orientation information to reassign, as necessary, the nerve stimulating elements (based on the change in orientation) so that the nerve stimulating elements are again positioned adjacent the intended nerves and/or plexus(es) in the known orientation. In this manner, the device **2**P may continue to operate normally without the need to reposition the device **2**P as would otherwise be necessary.

[0239] As mentioned above, the control system **18**P may assess the current orientation of the device **2**P automatically and reassign the nerve stimulating elements **6** as necessary without user input. In one aspect, the device **2**P may include a sensor **270** coupled to the control system **18**P for sensing a parameter, which relates to the orientation of the device **2**P. The control system **18**P may sample the same parameter periodically to confirm that the device **2**P has not moved. As mentioned above, the parameter may be an electrical signal received at one or more nerve stimulating elements **6** and emitted by another nerve stimulating element **6**. Alternatively, the parameter may be another electrophysiological parameter such as tissue impedance or may simply be a measure of native electrical activity. Depending upon the particular parameter selected, the control system **18**P may also sense and store the parameter relating to the starting or desired orientation for comparison to the parameter sensed for the current orientation.

[0240] Referring to FIG. **74**, the sensor **270** is mounted within a hub **56**P and positioned at or near the midline **83** (see FIG. **9**). The sensor **270** may be an independent element as shown or may be one or more of the nerve stimulating element (s) **6** as mentioned herein without departing from the scope of the invention. In one aspect, the sensor **270** may be configured to sense proximity to an object **272** which may be part of the controller **24**P or may be independent of the controller **24**P. The sensor **270** may be a magnetic sensor **270** and the object **272** may create a magnetic field, which the sensor **270** can remotely sense. The sensor **270** may, of course, operate in any other suitable manner such as a metal sensor **270** for use with the object **272** being metallic, an ultraviolet light sensor which senses UV light emitted by the object **272**, or the sensor **270** may be an RF antennae which receives RF signals emitted by the object **272**. The object **272** may optionally be worn by the user, for example, the object **272** may be secured to clothing or an accessory (such as a belt) at a predetermined position. When the object is worn or carried by the user at the predetermined location the device **2**P may periodically assess orientation automatically.

[0241] The object **272** may be carried by the controller **24**P. The controller **24**P is positioned at the predetermined location relative to the body of the user and the control system **18**P is used to transmit an instruction to the device **2**P to assess the current orientation of the device **2**P. To this end, the user simply positions the controller **24**P at the predetermined location, such as the belly button, and the controller **24**P is then used to transmit an instruction to the device **2**P to assess the orientation of the device **2**P. The sensor **270** (such as the magnetic sensor) senses the object **272** and determines the orientation of the device based on the sensed data.

[0242] The sensor **270** may be a gravity sensor. Similar to other methods described above, the controller **24**P initiates assessing device orientation by using the controller **24**P to send an instruction to the device **2**P to assess the orientation of the device **2**P. Prior to sending the instruction to the device **2**P, the user first positions herself in a predetermined body position, such as lying flat on her back. The controller **24**P is then used to send a signal to instruct the control system **18**P of the device **2**P to assess the orientation. At this time, the sensor **270** determines the current orientation of the device **2**P. The control system **18**P may compare the sensor **270** gravity related data for the current orientation to data (either stored data or sensed and saved data) relating to the starting orientation. To this end, the control system **18**P may store data relating to the starting orientation in the same manner. The user will assume the predetermined body position, such as lying down, and then uses the controller **24**P to instruct the device **2**P to use the sensor **270** to obtain sensor data relating to the starting or intended orientation for comparison to the sensor data relating to the current orientation. The sensor **270** and object **272** may also switch positions with the sensor **270** mounted to the controller **24**P and the object **272** mounted to the device **2**P. For example, the object **272** may simply be a metallic part of the hub **56**P and the sensor **270** may be a metallic sensor **270** mounted to the controller **24**P. The controller **24**P receives information from the sensor **270** to assess the current orientation of the device **2**P. The control system **18**P transmits a signal to the device **2**P to reassign the nerve stimulating elements **6** in accordance with the current orientation of the device **2**P if necessary.

[0243] Assessing the orientation of the device **2**P may also be accomplished by using one or more of the implants **220**, **220**A, **220**B of the present invention like an internal marker or reference point. When the device **2**P and implant **220**B are used together, the implant **220**B may emit a signal detected by the sensor **270** to assess orientation of the device **2**P. The device **2**P may also use two or more sensors **270** to triangulate the sensor data. Two or more nerve stimulating elements **6** may also be used to sense the electrical activity of one or more of the implants **220**B. The device **2**P may sense any suitable parameter relating to electrical activity of the implant **220**B.

[0244] Referring to FIGS. **78-83**, another device **400**Q is shown which is positioned in the vagina. The device **400**Q includes a main body **4**Q and nerve stimulating elements **6** positioned on exterior surface **8**Q of the main body **4**Q. The nerve stimulating elements **6** are controlled by control system **18**Q and powered by battery **20** as described herein with reference to FIG. **80**. The control system **18**Q is coupled to each of the operating elements in a known manner.

[0245] As mentioned herein, the nerve stimulating elements **6** may also be sensors (see sensors **270** and accompanying description). For example, when the nerve stimulating elements **6** include conductive electrodes the nerve stimulating elements **6** may be used to obtain ECG data. For this purpose, electrodes on opposing sides of the ring may be selected. Various other sensors have also been previously described in connection with the devices of the present invention and those sensors are also incorporated here.

[0246] Embodiments will also provide features designed to optimize data sensing and monitoring, which further permits integration of data sensing with delivery of therapy. Both the device surface and the nerve stimulating elements may contain sensors and/or sensing electrodes for measuring such variables as acoustics, pressure, temperature, flow, acceleration, and pH. Semiconductor and fibre technologies, such as stretched Mylar, may both be used. Thus, the sensors may be of piezoelectric fibers, allowing some, or all, of the surface of the device to provide sensing information, different conductive layers measuring different signals. Capacitive pressure sensing may utilize bioMEMS.

[0247] The device **400**Q may include additional sensors as now described. A blood pressure sensor **409** extends along the main body **4**Q on a side facing the central opening. The blood pressure sensor **409** is in communication with the control system **18**Q. The blood pressure sensor **409** may include a material **411**, and may be an elongate strip of material **413**, that can produce the required pressure information. For example, the material **411** may produce an electrical signal when deformed or produce a change in electrical resistance similar to a strain gauge. Piezoelectric materials, and other materials which convert vibration to an electrical signal, may also be useful for the blood pressure sensor **409** as any other known method of obtaining blood pressure. The blood pressure sensor **409** is coupled to the main body **4**Q and may be embedded in a thin-walled portion of the main body **4**Q. Furthermore, as will be further explained below, the blood pressure sensor **409** may also be separate from the main body **4**Q and in wireless communication with the control system **18**Q.

[0248] The device **400**Q may also include other sensors. For example, a chemical sensor **421** (shown schematically in dotted-line), may sense an ion concentration, a pH or conductivity, for example. Known micro-devices can be incorporated for these uses. Each of these uses is expressly incorporated for the chemical sensor **421**. The material is drawn through valve **423** which prevents material from entering

under atmospheric pressure. The chemical sensor **421** may lead to a collection **551** as described further below.

[0249] The sensor data derived with any of the sensors described herein may be used to determine whether a condition exists that will trigger a corresponding therapeutic response from the device **400**Q. For example, the nerve stimulating step using the elements **6** may be altered in response to the condition being met. As used herein, the term sensor may refer to devices that directly measure and transmit raw data or to devices that process the data and perform additional calculations and/or estimations to achieve the "sensor data" without departing from the scope of the invention or meaning of the word "sensor" or "sensor data" as used herein. The sensor data is assessed to determine whether the condition exists to provide a therapeutic response by the control system **18**.

[0250] The sensor may be provided separate from the main body **4**Q and positioned outside the vagina when the main body **4**Q is positioned in the vagina. For example, a sensor **425**, which may be a blood pressure sensor for example, may communicate raw data to the control system **18**Q and is worn on the wrist as shown in FIG. **83**. As used herein, such a relationship still falls within the term "controller" since the blood pressure sensor supplies data which controls the operation of the control system **18** at times. Referring to FIG. **83**, for example, the controller **424**Q may be worn around the wrist although any other suitable controller, such as a cell phone, may be used. The controller **424**Q may operate in any manner and take any form of the controllers described herein.

[0251] The controller **424**Q may include the sensor **423**, such as the blood pressure sensor **425**, as is known in the art. The controller **424**Q may take any form described herein including a device worn on a limb, such as the arm and specifically wrist, and could be worn around the waist by simply lengthening a strap **427**. Further, the controller **424**Q may be used to control stimulation in any manner described herein. The controller **424**Q is in wireless communication with control system **18**Q. The sensor **425** may be coupled to at least one of the controller **424**Q and to the main body **4**Q. When coupled to the controller, the controller **424**Q wirelessly communicates with the control system **18**Q when the condition is determined to exist. As used herein, transmission of raw data to the control system **18**Q shall be sufficient transmission of data when the data ultimately meets the condition warranting therapy in that the data still "controls" actions of the control system **18**Q.

[0252] The device **400**Q may include additional sensors such as a microphone **431**. Magnetic actuators **433** are used to expand the main body **4**Q, as described below, but may also act as microphones **431** to gather data by essentially listening or monitoring vibrations. For example, the microphone **431** may listen to respiration, heart beat, pulse and other suitable cardiovascular parameters. In a further specific example, the heart beat may be assessed to determine whether an arrhythmia condition exists. The condition could be related to heart rate, blood pressure, heart rate variability or any combination of factors with each factor being "related to" the condition.

[0253] The device **400**Q may also include an optical sensor **441** which includes an emitter and receiver (not shown) to provide blood flow, pulse and heart rate data among other known values that may be derived from an optical sensor as is known in the art. A temperature sensor **443**, in the form of a small wire probe **445**, may also provide core body temperature. Other previously mentioned sensors, such as an accelerometer, may also be used here and such uses are expressly incorporated.

[0254] The sensors of the present invention may determine quantitative values or may be used to assess and determine changes in values rather than precise amounts. To this end, the condition may be based, at least in part, upon a baseline condition. Further, this condition may be based on a measurement taken at a prior time. For example, the condition may be determined with the measurement being taken by the same sensor related to the condition at a prior time. In another specific example, the sensor senses the heart beat for a period of time to obtain heartbeat data. The heart beat data is used to determine whether a heart beat variability of the heart beat data meets the condition. The heart beat variability may include a baseline for comparison from previously calculated heart beat variability at a prior time.

[0255] In another aspect of the device of **400**Q, the device may include the collection reservoir **551** coupled to the main body **4**Q. The collection reservoir **551** is configured to hold and collect material, including target material such as a microbe, from the vagina. The material may be assessed by the device **400**Q itself. For example, the device **400**Q may use the chemical sensor **421**, such as a pH sensor. A low-pressure source **556** (at a pressure less than atmospheric pressure) is in fluid communication with the collection reservoir **551** to assist in drawing material into the material reservoir. A regulating valve **555** regulates pressure to control intake of the material into the collection reservoir **551**. A small valve, such as a duck-bill valve, (not shown) prevents material from entering the collection reservoir under atmospheric pressure.

[0256] In still another aspect, a therapeutic material may also be delivered as now described based upon the sensor data meeting the particular condition. The therapeutic material **459** may be coupled to the main body **4**Q of the device **400**Q and held in a material reservoir **461**. The therapeutic material **459** is delivered to the vagina by repositioning the device **400**Q in the vagina once the therapeutic material is coupled to the main body **4**Q such as by delivering the therapeutic material **459** into the material reservoir **461**, by syringe or the like, or coupling the material reservoir **461** to the main body **4**Q when the material reservoir **461** is removable and replaceable. FIG. **82** shows a module **465** that is removable and the material reservoir **461** and other components such as the battery and collection reservoir **551** may be formed in this manner for removal and replacement. The material reservoir **461** may be part of another module **465**. A magnetic actuator **590** forces material out of the material reservoir. The magnetic actuator **590** may also be used to vibrate the main body **4**Q. A valve, such as a duck bill valve, prevents material from entering the material reservoir.

[0257] The main body **4**Q includes a first expandable portion **571** to increase a first dimension on the main body **4**Q. The main body **4**Q has a central axis CA with the first expandable portion **571** increasing the first dimension in a transverse direction to the central axis (or cervical axis CVA). Stated another way, the first expandable portion **571** increases a peripheral length of the main body **4**Q when viewed along the central axis CA.

[0258] The main body **4**Q may also have a second expandable portion **573** which also increases the first dimension, such as the peripheral length, when expanded. Alternatively, the second expandable portion may reduce the size of the central opening **426** when expanded. A third expandable por-

tion **575** may be provided in parallel to the second expandable portion **573** to increase the force exerted. Furthermore, the second and third expandable portions **573**, **575** may expand radially inward or outward.

[0259] The first, second and third expandable portions **571**, **573**, **575** are driven by magnetic actuators as is known in the art. The magnetic actuators each have two **579** arms extending to a common cross-member **561** supported by the two arms **579**. The cross-members **561** may be embedded in a sidewall of the main body **4**Q. A side slot **563** permits the second and third actuators **573**, **575** to become slightly recessed to accommodate the opposing motion. Alternatively, the arms **579** may include telescoping elements (not shown) that permit the arms to extend rather than providing the side slot **563**. The expandable portions **571**, **573**, **575** may be used to stretch the vaginal walls, which are believed to have therapeutic effect.

[0260] In another aspect of the present invention, the device **400**Q may be used to deliver a therapeutic material. The material reservoir **461** containing the therapeutic material **459** may be coupled to the main body **4**Q. Any one of the sensors described herein, such as the optical sensor, may be used to obtain sensor data. The sensor data is used to determine whether a condition exists from the data in the sensing step. If so, the therapeutic material **459** may be delivered. For example, the sensor may be a pH sensor, which determines whether a pH condition is met. The control system may control the delivery of the therapeutic material in appropriate amounts based upon, for example, the pH measurement by the pH sensor. One such clinical application for local (intravaginal) drug delivery would involve titrating the dose and delivery of vaginal estrogen to the pH of the vagina in postmenopausal women with atrophic vaginitis. In premenopausal women the vagina is relatively acidic. Healthy vaginal flora is rich with estrogen responsive *Lactobacilli. Lactobacilli* make lactic acid and keep the vaginal pH approximately 3.8 to 4.5. In menopause the flora changes, as estrogen dependent *Lactobacilli* fail to thrive. As a result the vaginal pH rises in menopause, generally above 5.0 and potentially to 7.5. 40% of postmenopausal women suffer from atrophic vaginitis symptoms. Vaginal hormone, such as estrogen, is an effective treatment. However, many women are hesitant to use even low dose estrogen out of concern for the known risks. Currently the dosing is not very individualizable, as standard doses are used. The vaginal device described could periodically assess vaginal pH and adjust estrogen dosing and delivery such that the user receives the lowest dose of estrogen required to maintain a healthy vaginal pH. In this manner, the pH of the vagina may be altered with the therapeutic material.

[0261] Thus, a few of the numerous applications of the insert and/or reservoir are now briefly provided. pH can be measured by a sensor and a rise in pH treated with dose-controlled estrogen. Cytology collection allows for study of cell biology, and application of therapeutic material. Collection of vaginal flora (that part of the microbiome that inhabits the vaginal cavity) allows for analysis of microbes and delivery of therapeutic material, for example related to infection.

[0262] In another embodiment of the closed-loop sensing and treatment of a parameter, the device described may treat systemic parameters. For example, the device may sense blood pressure (measured with a sensor on the controller or on the main body), heart rate or heart rate rhythm and dispense an appropriate amount of therapeutic material to alter that parameter. For example, the therapeutic material being selected to alter at least one of a heart rate and a heart rhythm. The parameters for treatment response would be based on a predetermined and programmed algorithm. The device could sense and interpret parameter response to the drug, assuring that dosing is appropriately titrated to response.

[0263] The vaginal wall is permeable via diffusion, paracellular tight junction mediated mechanisms, and receptor or vesicular transport mechanisms. Chemical polymers may also aid in macromolecule delivery through the vaginal wall. Advantages to vaginal delivery of systemic drugs include the absorptive wall, which is more permeable than external skin, has a rich arterial and venous blood supply, and avoids first-pass metabolism.

[0264] This ability of the device **2**A-P to utilize sensors and other means to assess and automatically adjust orientation based on measured parameters allows for much wider use of sensors by the device to monitor bodily parameters. As mentioned above, sensors on the device **2**A-P may be one or more of the nerve stimulating elements or may be independent elements. The sensors used may include some of the sensors mentioned in the above discussion of orientation, but may also include any other sensors, biosensors, and transducers known in the art. These sensors may communicate with other sensors on the device **2**A-P itself, with sensors on an object which is independent of or integrated into the controller as described above (that controller being separate from or part of a user's personal device, such as a smartphone), and with sensors on other medical and computing devices. The sensors may include transducers, converting energy between forms.

[0265] This ability to compare and communicate sensor data provides numerous advantages. On the one hand, some important parameters are accessible from the location of the device **2**A-P in the vaginal fornices, but not accessible from external devices, such as those worn by a user. In other words, the device **2**A-P is uniquely positioned in the core of the body. Therefore, the device **2**A-P has access to such measurements as core body temperature, and can sense tissue and bodily fluids in its internal bodily environment. On the other hand, there are other parameters measured by the device **2**A-P, which can also be measured by other devices positioned internal or external to the body. For example, the user may be wearing a device with sensors, which can make measurements from an external location through the skin. This allows for comparing and triangulating data from device **2**A-P to provide information beyond that available from the externally-worn device alone. Device **2**A-P can also draw on other historical data. All data sensed by device **2**A-P can be integrated into complementary diagnostic and therapeutic functions.

[0266] The control systems **242**, **242**B of the devices **2**, **2**A-**2**N and/or the handheld controller **24** may record data regarding treatment regimens including start and end times, nerve stimulating elements used, resistance, current, frequency, disruption of therapy and any changes made to a regimen. The user will also be able to record subjective and objective information, which will be used to adjust and tailor future regimens to her specific needs. For example, if she has a good response to a certain regimen she may note it at the end of a day or predetermined assessment period. In this case, the regimen will be maintained or she may opt to decrease stimulation intensity towards the threshold of benefit.

[0267] The user may also note when she experiences a side effect. By reviewing the treatment regimen (including current, frequency of stimulation, active electrodes and duration

of therapy) employed during the time the side effect was experienced, she and her healthcare team will be able to change the stimulation setting or redirect therapy to another target structure altogether.

[0268] The user may record experiences using the controller **24** or via free text respond to periodic questions or standardized questionnaires and bladder diaries. All data will be recorded and downloadable to computers and portable devices, such as phones. In one aspect, the user's personal device (ie., phone) may reprogram the controller **24** and alter the regimen. If the patient desires and consents, this objective, subjective and regimen data may be transmitted electronically for remote assessment by healthcare providers or for research purposes.

[0269] The present invention may be used to treat a number of different conditions such as urge, frequency, nocturia, urge incontinence, stress incontinence, loss of urine without sensory awareness, bladder pain, urethral pain, urethral syndrome, urinary hesitancy, pelvic floor dyssynergia, interstitial cystitis, dysuria, overactive bladder, urinary retention, hesitancy, protracted urinary stream, dysmenorrhea, pelvic pain, pelvic venous congestion syndrome, endometriosis, irritable bowel syndrome, constipation, fecal urgency, fecal incontinence, rectal pain, pain with defecation, and anal pain. The conditions that may be treated extend to sympathetic tone, cardiovascular function, sexual function, and other conditions related to autonomic nerves. Of course, other uses of the present invention may become apparent without departing from the scope of the invention.

[0270] The present invention has been described in connection with preferred embodiments but it is understood that numerous modifications could be made to the preferred embodiments without departing from the scope of the invention. For example, the main body could be V-shaped or the nerve stimulating element could be a coil through which a current is passed to induce a magnetic field without departing from numerous aspects of the present invention.

1-176. (canceled)

177. A system for stimulating nerves, comprising

a first body having an exterior surface;

a first nerve stimulating element coupled to the first body;

a first power source coupled to the first body; and

a first control system coupled to the first power source and the first nerve stimulating element.

178. The system of claim **177**, further comprising:

a second nerve stimulating element coupled to the body, the second nerve stimulating element positioned to apply nerve stimulus at a different position along a uterosacral ligament from the first nerve stimulating element when the first body is secured to the uterosacral ligament.

179. The system of claim **177**, wherein:

the first nerve stimulating element is configured to stimulate nerves sufficiently to change a signal transmitted by the nerves to associated nerves and nerve endings.

180. The system of claim **177**, wherein:

the control system is configured to actuate the first nerve stimulating element at a different time from the second nerve stimulating element.

181. The system of claim **177**, wherein:

the first body has a first throughhole sized to receive the uterosacral ligament.

182-208. (canceled)

209. The system of claim **177**, wherein:

the body has a throughhole in which the uterosacral ligament is positioned, the throughhole being tapered.

210-270. (canceled)

271. The system of claim **177**, wherein:

the first implant has a first power source coupled to the implant control system.

272. The system of claim **271**, wherein:

the first implant power source is a capacitor.

273. (canceled)

274. The system of claim **272**, wherein:

the capacitor includes graphene and polymer.

275-276. (canceled)

277. The system of claim **272**, wherein:

the capacitor is sized to provide at least 2 days of power to operate the first implant under peak operating conditions.

278. The system of claim **272**, wherein:

the capacitor is sized to provide no more than 60 days of power for operating the first implant under peak operating conditions.

279. A method of implanting a nerve stimulator to stimulate

a hypogastric nerve, comprising the steps of:

providing a first implant having a first body, a first nerve stimulating element coupled to the first body, and an implant control system coupled to the first nerve stimulating element;

forming an access opening in the patient leading to the peritoneum;

creating an opening in the peritoneum to expose a hypogastric nerve;

securing the first implant to the patient so that the first nerve stimulating element is in contact with the hypogastric nerve; and

stimulating the hypogastric nerve using the first nerve stimulating element.

280-420. (canceled)

421. A system of delivering a therapeutic material in a vaginal canal, comprising:

a main body;

a first sensor coupled to the main body, the main body also including a material reservoir containing a therapeutic material and coupled to the main body;

a control system in communication with the first sensor, the control system determining whether a condition exists from data received from the sensor, the control system configured to release the therapeutic material from the material reservoir when the condition exists.

422. The system of claim **421**; wherein:

the sensor senses an ion concentration.

423. The system of claim **421**, wherein:

the sensor is a pH sensor that produces pH sensor data; and

the control system selecting the amount of therapeutic material to deliver based on the pH sensor data to alter the pH of the vagina.

424. The system of claim **421**, wherein:

the therapeutic material contained in the material reservoir includes estrogen.

425. The system of claim **421**, wherein:

the sensor is a blood pressure sensor; and

the therapeutic material selected to alter the blood pressure.

426. The system of claim **421**, wherein:
the sensor is a heart beat sensor; and
the therapeutic material being selected to alter at least one of a heart rate and a heart rhythm.
427. The system of claim **421**, wherein:
the main body has a central opening, the cervix being positioned in the central opening and the main body extending at least 270 degrees around the cervix.
428. The system of claim **421**, wherein;
the sensor is a pH sensor; and
the control system delivers a controlled amount of therapeutic material based upon the pH measurement by the pH sensor to alter the pH of the vagina.
429-439. (canceled)

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