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(54) **ULTRASOUND THERAPY FOR BLADDER DYSFUNCTION**

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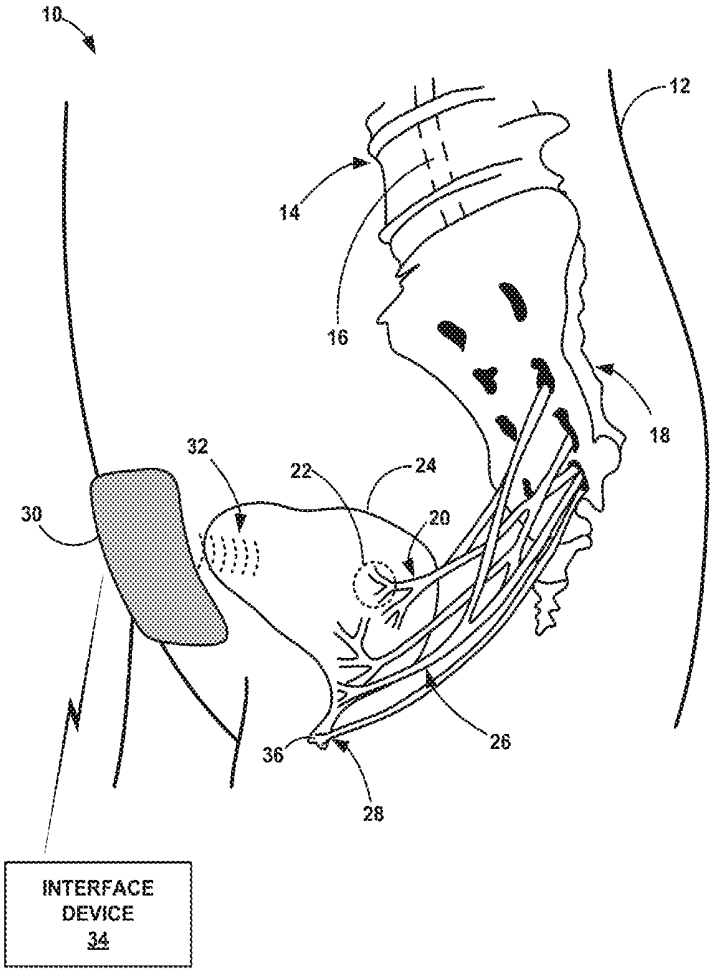
(57) **ABSTRACT**

The disclosure describes devices, systems, and techniques for delivering therapy configured to treat bladder dysfunction. For example, a system may be configured to modulate bladder activity by determining a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with bladder activity of a patient. The system may then control, according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the bladder of the patient to modulate bladder activity and influence patient voiding.



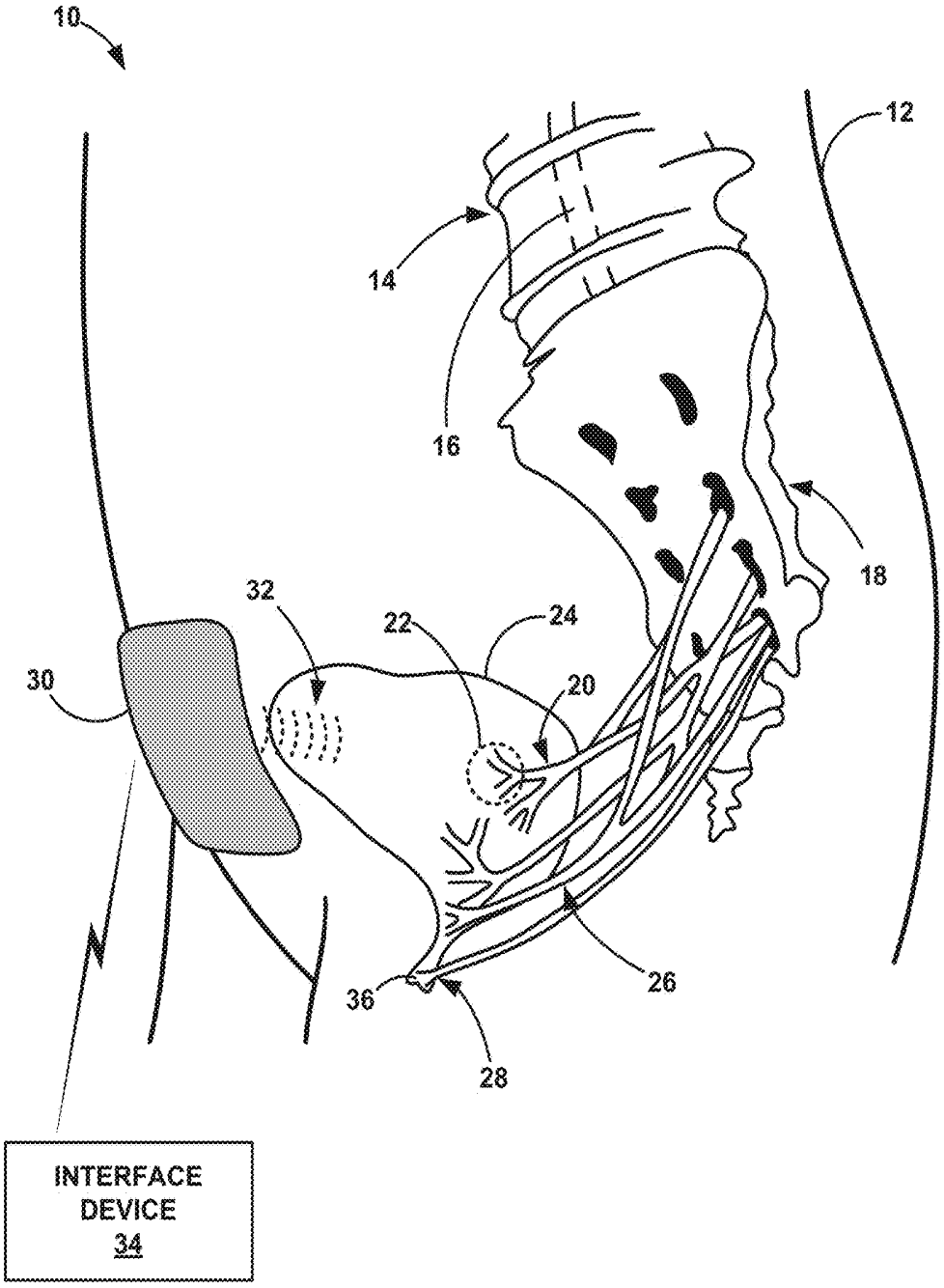


FIG. 1A

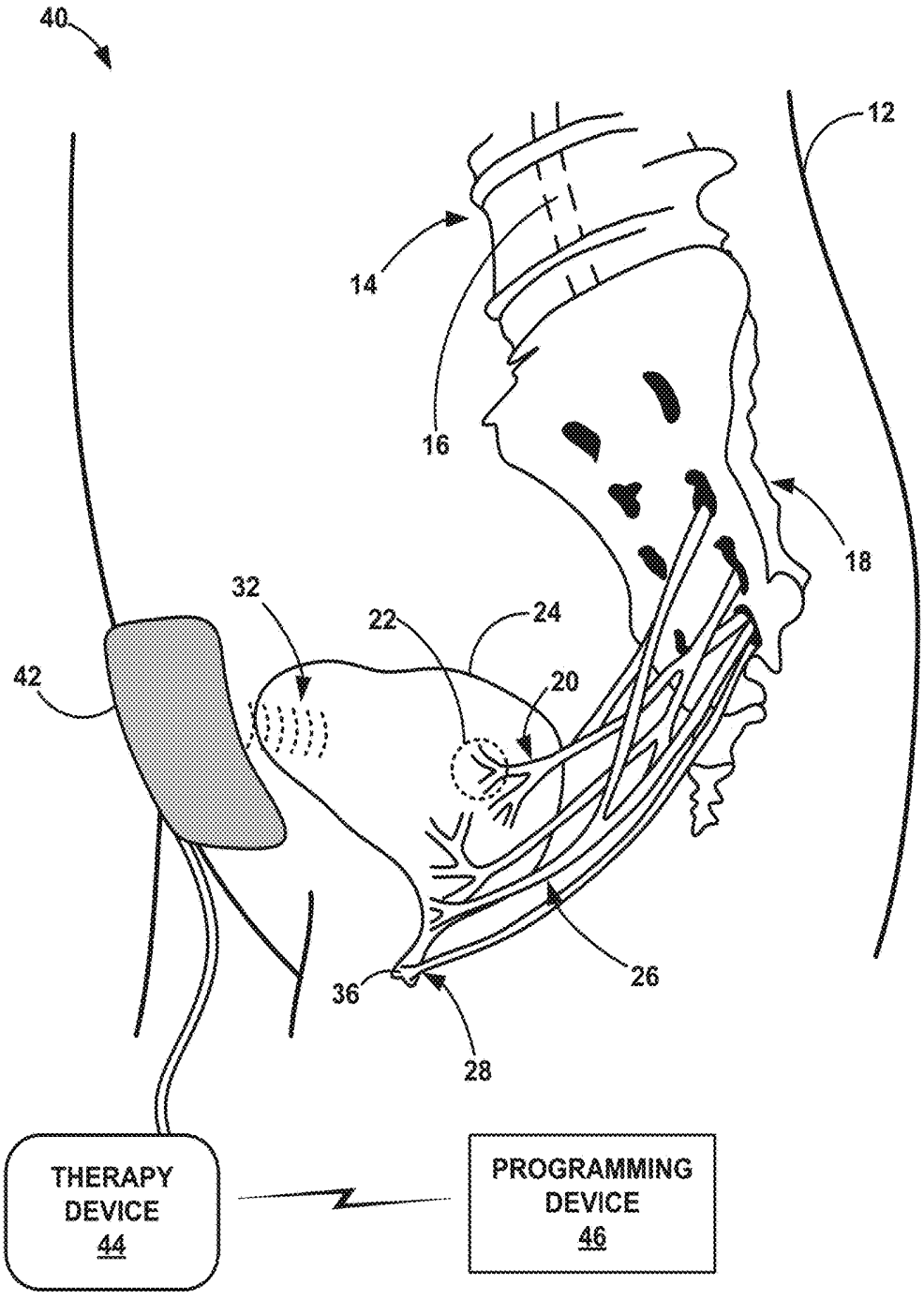

40
12
14
16
18
32
22
24
20
42
26
36
28
THERAPY DEVICE 44
PROGRAMMING DEVICE 46

FIG. 1B

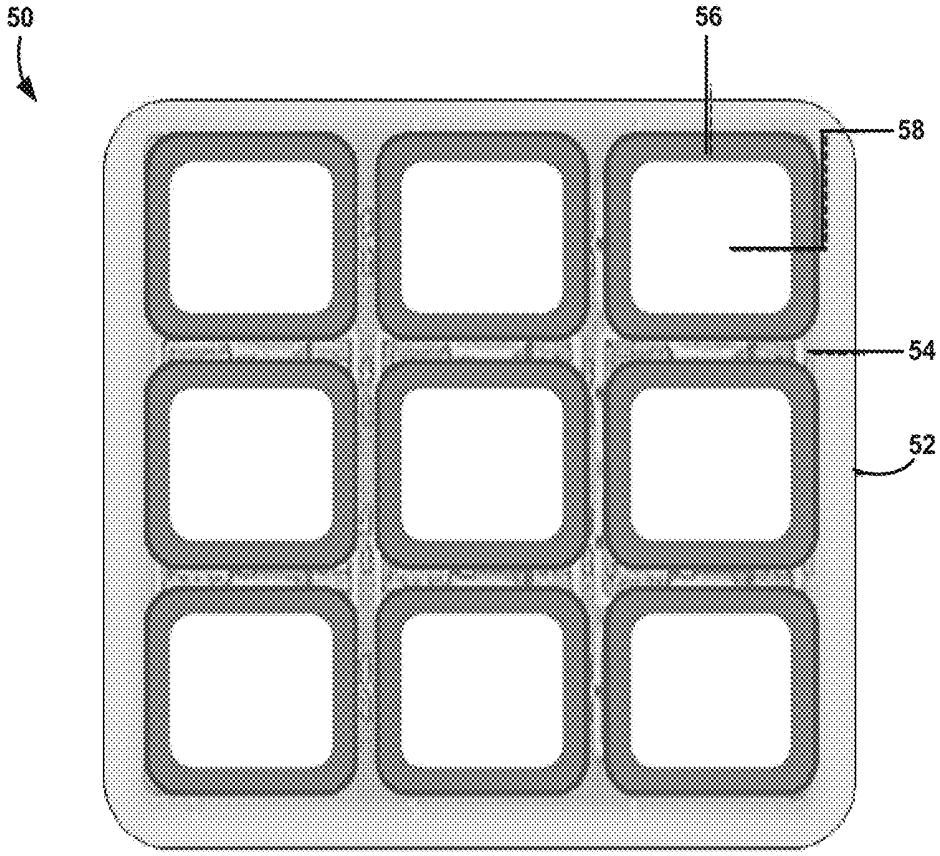


FIG. 2A

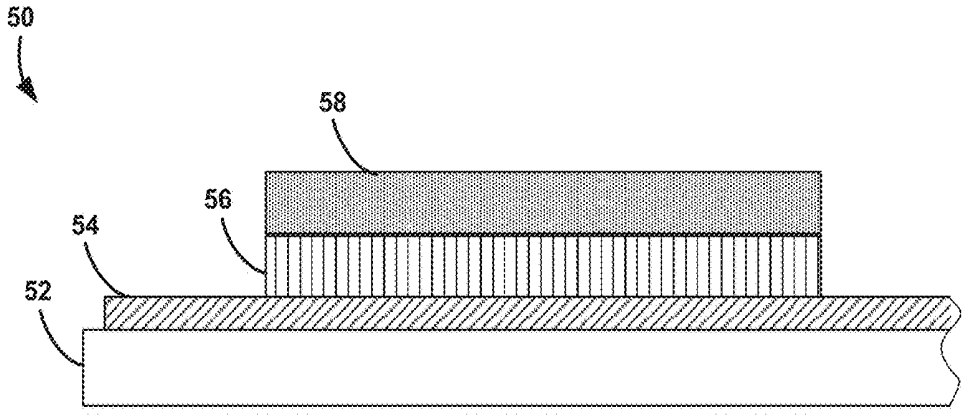


FIG. 2B

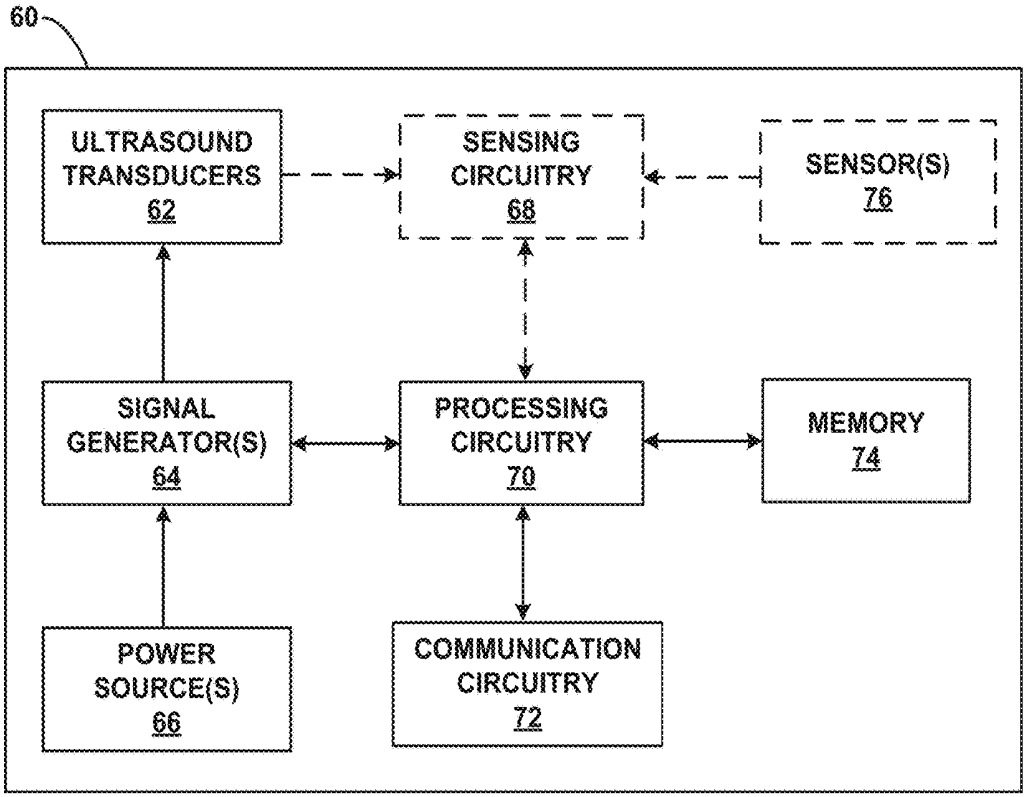

60
ULTRASOUND TRANSDUCERS 62
SENSING CIRCUITRY 68
SENSOR(S) 76
SIGNAL GENERATOR(S) 64
PROCESSING CIRCUITRY 70
MEMORY 74
POWER SOURCE(S) 66
COMMUNICATION CIRCUITRY 72

FIG. 3

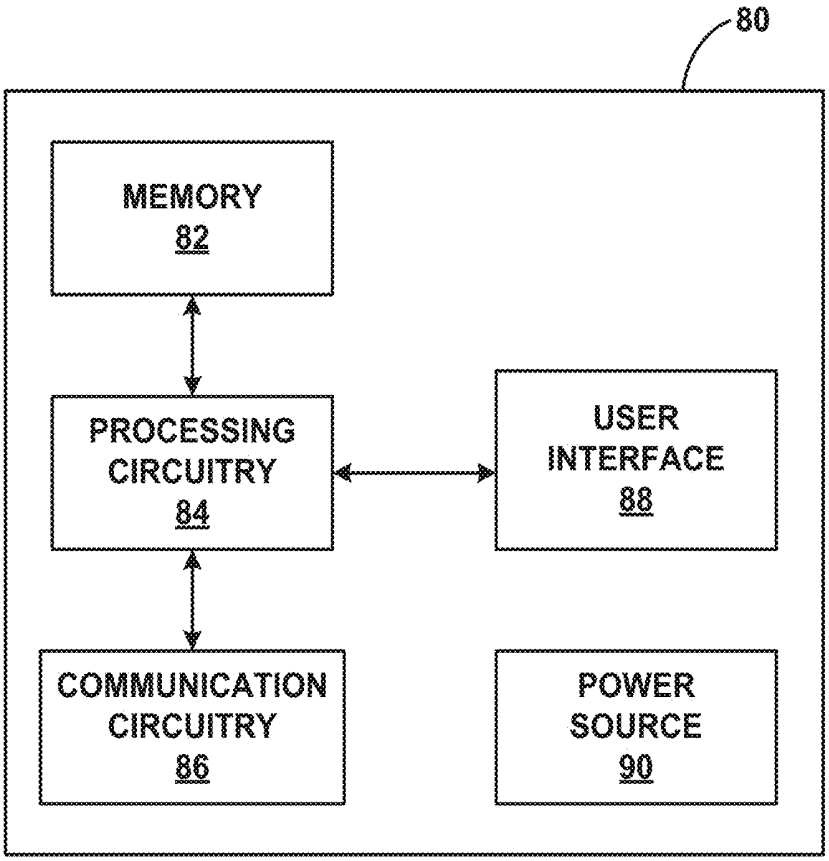

80
MEMORY
82
PROCESSING
CIRCUITRY
84
USER
INTERFACE
88
COMMUNICATION
CIRCUITRY
86
POWER
SOURCE
90

FIG. 4

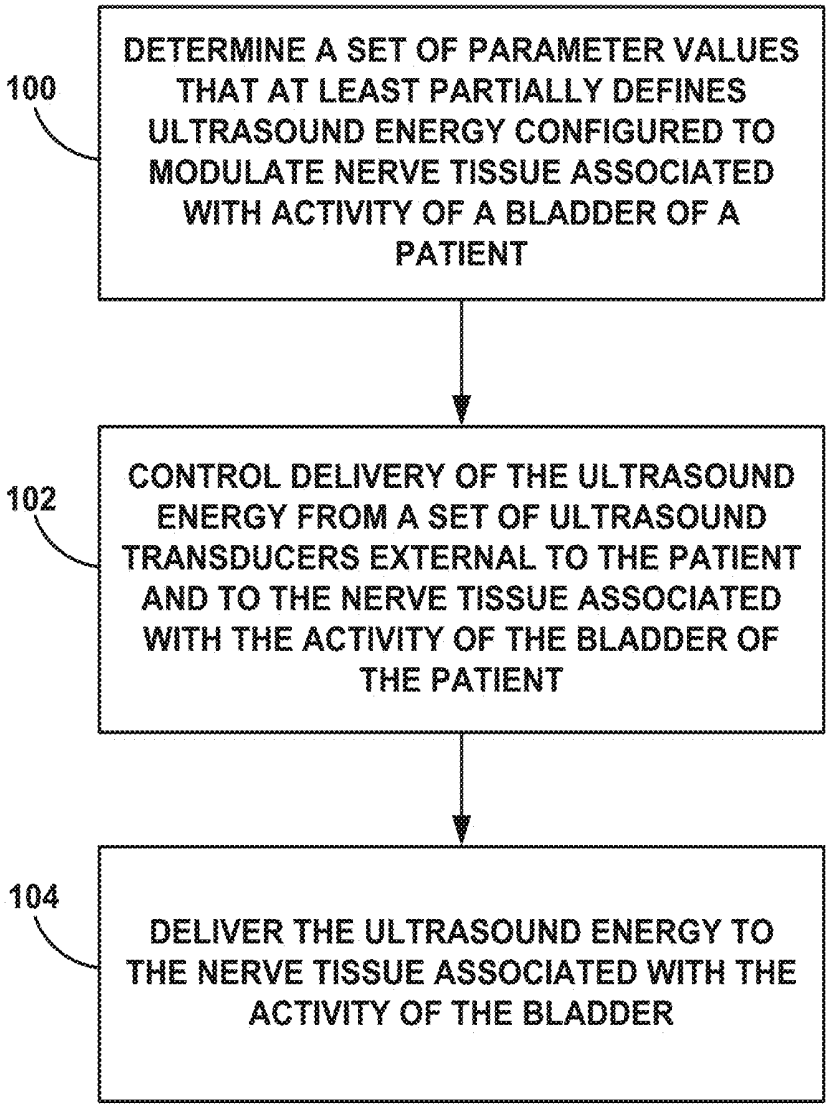

100
DETERMINE A SET OF PARAMETER VALUES THAT AT LEAST PARTIALLY DEFINES ULTRASOUND ENERGY CONFIGURED TO MODULATE NERVE TISSUE ASSOCIATED WITH ACTIVITY OF A BLADDER OF A PATIENT
102
CONTROL DELIVERY OF THE ULTRASOUND ENERGY FROM A SET OF ULTRASOUND TRANSDUCERS EXTERNAL TO THE PATIENT AND TO THE NERVE TISSUE ASSOCIATED WITH THE ACTIVITY OF THE BLADDER OF THE PATIENT
104
DELIVER THE ULTRASOUND ENERGY TO THE NERVE TISSUE ASSOCIATED WITH THE ACTIVITY OF THE BLADDER

FIG. 5

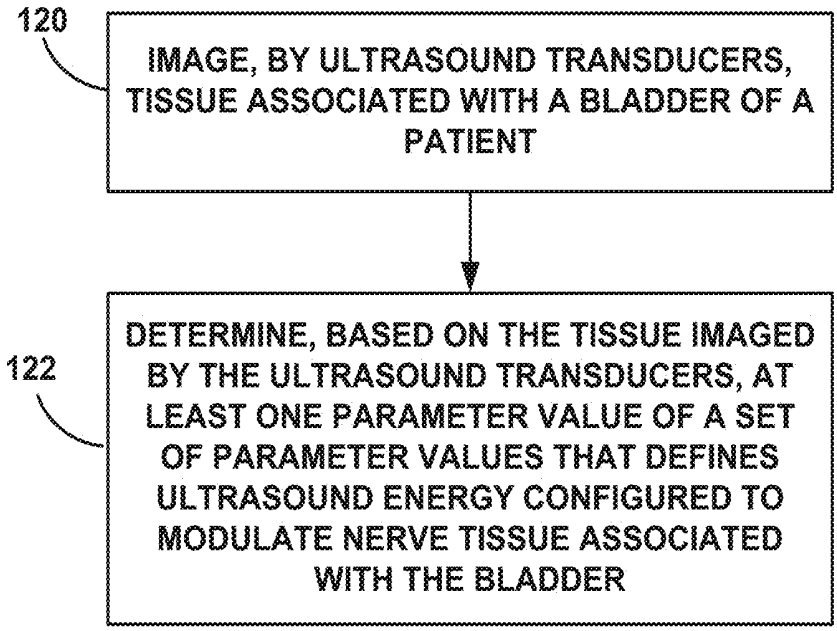

120
IMAGE, BY ULTRASOUND TRANSDUCERS, TISSUE ASSOCIATED WITH A BLADDER OF A PATIENT
122
DETERMINE, BASED ON THE TISSUE IMAGED BY THE ULTRASOUND TRANSDUCERS, AT LEAST ONE PARAMETER VALUE OF A SET OF PARAMETER VALUES THAT DEFINES ULTRASOUND ENERGY CONFIGURED TO MODULATE NERVE TISSUE ASSOCIATED WITH THE BLADDER

FIG. 6

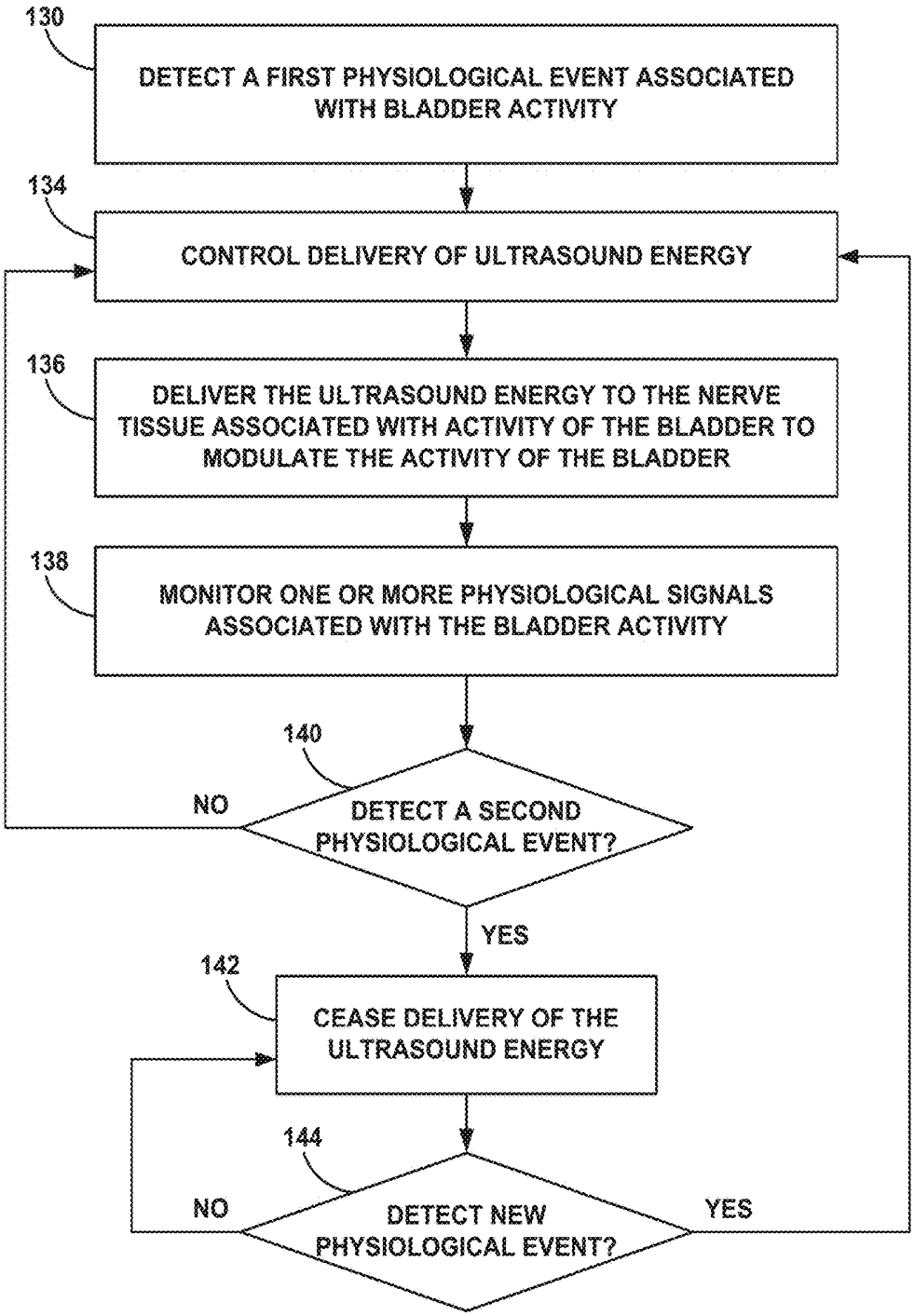

130
DETECT A FIRST PHYSIOLOGICAL EVENT ASSOCIATED WITH BLADDER ACTIVITY
134
CONTROL DELIVERY OF ULTRASOUND ENERGY
136
DELIVER THE ULTRASOUND ENERGY TO THE NERVE TISSUE ASSOCIATED WITH ACTIVITY OF THE BLADDER TO MODULATE THE ACTIVITY OF THE BLADDER
138
MONITOR ONE OR MORE PHYSIOLOGICAL SIGNALS ASSOCIATED WITH THE BLADDER ACTIVITY
140
DETECT A SECOND PHYSIOLOGICAL EVENT?
NO
YES
142
CEASE DELIVERY OF THE ULTRASOUND ENERGY
144
DETECT NEW PHYSIOLOGICAL EVENT?
NO
YES

FIG. 7

ULTRASOUND THERAPY FOR BLADDER DYSFUNCTION

[0001] This application claims the benefit of U.S. Provisional Application Ser. No. 62/638,634 entitled "ULTRASOUND THERAPY FOR BLADDER DYSFUNCTION" and filed Mar. 5, 2018, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The disclosure relates to medical therapies and, more particularly, delivery of ultrasound therapy.

BACKGROUND

[0003] Delivery of ultrasound involves delivering sound waves with frequencies higher than the upper audible limit of human hearing. Delivery of ultrasound is performed for diagnostic imaging, e.g., to visualize internal body structures such as tendons, muscles, joints, vessels, and internal organs. Ultrasound images are made delivering ultrasound, e.g., pulses of ultrasound, into tissue using one or more ultrasound transducers. The sound echoes, or reflects, off the tissue, with different tissues having different characteristics reflecting and diffracting the sound differently. The reflected and diffracted sound is sensed by one or more ultrasound transducers.

[0004] Ultrasound has also been delivered to patients for therapeutic purposes. For example, ultrasound has been delivered to promote healing and/or blood flow. As another example, ultrasound has been delivered to modify or destroy problematic tissue, such as tumors. Delivery of ultrasound for medical purposes often involves a relatively-large, cart-based piece of equipment that includes, for example, circuitry for generating and sensing ultrasound signals, processing circuitry, a user interface, and an internal power source and/or the ability to be plugged to AC mains power. A probe may be hand-held and include the one or more ultrasound transducers connected to ultrasound device by a cable.

SUMMARY

[0005] In general, the disclosure is directed to techniques and/or systems for delivering therapy configured to treat bladder dysfunction of a patient. For example, a system may deliver ultrasound energy to nerve tissue associated with activity of the bladder, such as stretch receptors on the bladder and/or efferent nerves that contribute to bladder over-activity. The ultrasound transducers may be part of an array of ultrasound transducers part of a patch or other wearable device attached to the patient. The system may select appropriate transducers for targeting desired nerve tissue within the patient and/or select transducers to image patient anatomy and/or physiological events such as bladder and/or nerve activity. In some examples, the system may trigger the start of ultrasound therapy delivery in response to detecting an event via the ultrasound transducers and/or via another type of sensor configured to monitor the patient (e.g., an accelerometer, a set of electrodes, or a temperature sensor).

[0006] In one example, a method for modulating bladder activity includes determining, by processing circuitry, a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with activity of a bladder of a patient, and controlling, by processing circuitry and according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the activity of the bladder of the patient.

[0007] In another example, a system for modulating bladder activity includes processing circuitry configured to determine a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with activity of a bladder of a patient, and control, according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the activity of the bladder of the patient.

[0008] In another example, a non-transitory computer readable medium includes instructions that, when executed, cause processing circuitry to determine a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with activity of a bladder of a patient, and control, according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the activity of the bladder of the patient.

[0009] The details of one or more examples are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. **1**A is a conceptual diagram illustrating an example system for delivering ultrasound therapy configured to treat bladder dysfunction of a patient via a wearable ultrasound device.

[0011] FIG. **1**B is a conceptual diagram illustrating another example system for delivering ultrasound therapy configured to treat bladder dysfunction of a patient via a wearable ultrasound device.

[0012] FIGS. **2**A and **2**B are top-view and side-view diagrams, respectively, illustrating an example wearable ultrasound device.

[0013] FIG. **3** is a functional block diagram illustrating an example configuration of a wearable ultrasound device.

[0014] FIG. **4** is a functional block diagram illustrating an example configuration of an interface device.

[0015] FIG. **5** is a flow diagram illustrating an example technique of modulating bladder activity of a patient via a wearable ultrasound device.

[0016] FIG. **6** is a flow diagram illustrating an example technique of determining a set of parameters based on imaging via ultrasound transducers of a wearable ultrasound device.

[0017] FIG. **7** is a flow diagram illustrating an example technique of delivering ultrasound energy to nerve tissue of a patient based on detection of a physiological event.

DETAILED DESCRIPTION

[0018] The disclosure is directed to techniques, systems, and devices configured to deliver ultrasound therapy configured to treat pelvic dysfunctions that may include urinary or bladder dysfunction and/or fecal dysfunction of a patient. Bladder dysfunction generally refers to a condition of

improper functioning of the bladder or urinary tract, and may include, for example, an overactive bladder, urgency, and urinary incontinence. Urgency is a sudden, compelling urge to urinate, and may often, though not always, be associated with urinary incontinence. Overactive bladder may include excessive contractions of the detrusor muscle (e.g., smooth muscle residing in the wall of the bladder) and may be one of the causes for urgency. Urinary incontinence refers to a condition of involuntary loss of urine, and may include urge incontinence, stress incontinence, or both stress and urge incontinence, which may be referred to as mixed urinary incontinence. As used in this disclosure, the term "urinary incontinence" includes disorders in which urination occurs when not desired, such as stress or urge incontinence (e.g., overactive bladder).

[0019] In order to void urine, the nervous system and several muscles of the body typically work in concert to expel urine from the bladder. For example, the internal urinary sphincter muscle and the external urinary sphincter muscle relax to allow urine to pass through the openings in these sphincters. In addition, the detrusor muscle in the wall of the bladder contracts to increase the internal bladder pressure and force urine out of the bladder and through the urethra and past the urinary sphincters. Bladder dysfunction can occur when portions of the nervous system that innervate these muscles, or the muscles themselves, prevent the patient from retaining urine until the patient voluntarily decides to urinate.

[0020] For example, urge incontinence may be caused by disorders of peripheral or central nervous systems that control bladder micturition reflexes. Some patients may also suffer from nerve disorders that prevent proper triggering and operation of the bladder, sphincter muscles or nerve disorders that lead to overactive bladder activities or urge incontinence. Additionally, or alternatively, urinary incontinence can be attributed to improper sphincter function, either in the internal urinary sphincter or external urinary sphincter. In some examples, aging can result in weakened sphincter muscles, which may cause incontinence. Nerves running though the pelvic floor stimulate contractility in the sphincter. An improper communication between the nervous system and the urethra or urinary sphincter can result in a bladder dysfunction, such as overactive bladder, urgency, urge incontinence, or another type of urinary incontinence.

[0021] Some treatments for bladder disorders such overactive bladder or urge incontinence may include pharmaceutical treatment from one or more drugs intended to relax the detrusor muscle and increase the amount of urine held by the patient. In other examples, electrical stimulation therapy may be employed when pharmaceutical treatment is not effective. In electrical stimulation therapy, one or more medical leads carrying electrodes may be implanted into the patient and coupled to an implanted medical device (IMD). The IMD may then generate electrical stimulation pulses and deliver those pulses to nerves or muscles via the electrodes to reduce detrusor muscle activity and/or increase sphincter contraction, as necessary. However, electrical stimulation therapy requires the surgical implantation of devices into the patient. Implantation of a stimulation device may involve one or more time-consuming medical procedures, increased patient recovery time, increased cost, or the like.

[0022] As described in this disclosure, various techniques and systems may be used to modulate bladder activity to treat bladder dysfunction of a patient. For example, a system may include ultrasound transducers configured to deliver ultrasound energy to one or more nerve tissues of the patient to inhibit or activate various muscles. The system may determine a set of parameter values at least partially defining ultrasound energy, and control ultrasound energy delivered to nerve tissue associated with activity of a bladder of the patient. The nerve tissue may innervate the bladder or other muscles associated with bladder function, such as the urinary or external sphincters. The system may control a set of ultrasound transducers external to the patient to deliver the ultrasound energy to target nerve tissue associated with bladder activity. In this way, the ultrasound therapy configured to treat bladder dysfunction of the patient as described herein may be less invasive than some other therapy delivery methods, such as electrical stimulation therapy delivered from implanted devices.

[0023] In some examples, placement of such invasive stimulation devices near desired nerve tissue configured to innervate the bladder of the patient may present additional challenges. For example, placement of an electrical lead near nerve tissue configured to innervate the bladder that is relatively far from the bladder itself may result in stimulation of nerve tissue configured to innervate other organs in addition to the bladder. In turn, one or more additional organs may be stimulated in response to the stimulation intended to innervate only the bladder or related structures. Moreover, placement of an electrical lead near nerve tissue relatively close to the bladder itself may be more difficult to identify, more difficult to position the electrical lead near, or smaller than nerve tissue farther from the bladder, all of which may lead to less effective outcomes. In this way, the medical procedure to implant the electrical lead may be more difficult to achieve desired therapeutic outcomes, more time-consuming, or both. The use of the techniques and systems described herein to non-invasively modulate bladder activity to treat bladder dysfunction of a patient may reduce the number of invasive medical procedures experienced by the patient, patient recovery time, clinician time, cost, or the like.

[0024] Although certain aspects and examples of this disclosure are generally directed to treating urinary and/or bladder dysfunction, such as dysfunction related to holding and releasing urine, this disclosure is not meant to be limiting to urinary and/or bladder dysfunction. For example, systems and techniques described herein may instead, or additionally, be used to treat fecal incontinence or dysfunction related to the rectum and/or bowel. For example, a system may control the delivery of ultrasound energy to nerves innervating the bowel and/or anal sphincters to improve the retention of fecal matter for the patient. In this manner, examples herein are directed toward pelvic dysfunctions that may include urinary dysfunction and/or fecal dysfunction.

[0025] FIG. **1**A is a conceptual and schematic diagram illustrating an example system **10** for delivering therapy configured to treat bladder dysfunction of a patient **12** via a wearable ultrasound device **30**. Patient **12** ordinarily will be a human patient. In some cases, however, system **10** may be applied to other mammalian or non-mammalian, non-human patients. In some examples, patient **12** experiences bladder dysfunction, such as, for example, improper functioning of a bladder **24**, a urinary sphincter **36**, or a urinary tract, and

may include an overactive bladder, urgency, urinary incontinence, or combinations thereof.

[0026] As will be described in greater detail below, wearable ultrasound device **30** may include a plurality of ultrasound transducers, signal generation circuitry configured to drive the plurality of ultrasound transducers, one or more power sources configured to power the signal generation circuitry, and one or more processors or other processing circuitry configured to control the signal generation circuitry. The plurality of ultrasound transducers of wearable ultrasound device **30** are configured to deliver ultrasound energy **32** to nerve tissue associated with activity of bladder **24**, such as nerve tissue that at least partially innervates bladder **24** of patient **12**. In some examples, the plurality of ultrasound transducers may include one or more sets of ultrasound transducers. As used in this disclosure, the phrase "set of ultrasound transducers" may refer to a single ultrasound transducer or more than one ultrasound transducer. For example, a set of ultrasound transducers may include 1 ultrasound transducer, 2 ultrasound transducers, 3 ultrasound transducers, 4 ultrasound transducers, or more than 4 ultrasound transducers. In some examples, the set of ultrasound transducers may include tens, hundreds, or even thousands of ultrasound transducers.

[0027] Wearable ultrasound device **30** is configured to deliver ultrasound energy **32** from the plurality of ultrasound transducers external to nerve tissue associated with bladder **24** of patient **12**. In this way, system **10** provides a non-invasive way to modulate activity of bladder **24** and/or associated structures. In some examples, wearable ultrasound device **30** may include an attachment element, such as an adhesive layer, for attaching the device to patient **12**. In addition to, or instead of an adhesive layer, in some examples, an attachment element may include a strap or garment. In turn, patient **12** may be able to position and maintain the position of the ultrasound transducers of wearable ultrasound device **30** relative to a treatment or diagnostic area of patient **12**. For example, wearable ultrasound device **30** may be an external patch configured to be attached to an external skin surface of patient **12**.

[0028] Wearable ultrasound device **30** may be positioned at one or more external positions of patient **12**. In some examples, the position of wearable ultrasound device **30** may be selected based on the nerve tissue wearable ultrasound device **30** is configured to modulate. For example, wearable ultrasound device **30** may be positioned at a midline of a suprapubic area of patient **12** (e.g., to be positioned approximately near bladder **24**) in cases in which wearable ultrasound device **30** is configured to deliver ultrasound energy **32** to nerve tissue **26** (efferent nerves such as sympathetic and/or parasympathetic nerves), afferent nerves **20**, and/or stretch receptors **22**. In other cases, such as if wearable ultrasound device **30** is configured to deliver ultrasound energy **32** to pudendal nerve **28**, wearable ultrasound device **30** may also be positioned in a suprapubic area, but other locations are also contemplated. For example, wearable ultrasound device **30** may be positioned at the perineum of patient **12**. As yet another example, wearable ultrasound device **30** may be positioned at or near the genitals of patient **12**, such as if wearable ultrasound device **30** is configured to deliver ultrasound energy **32** to a dorsal genital nerve. As still another example, wearable ultrasound device **30** may be configured to deliver ultrasound energy **32** to a sacral dermatome and/or a sacral nerve, and may be positioned on the lower back or upper buttocks area of patient **12**. In other examples, wearable ultrasound device **30** may be positioned differently based on the nerve tissue wearable ultrasound device **30** is configured to modulate, or wearable ultrasound device **30** may not be positioned based on the nerve tissue wearable ultrasound device **30** is configured to modulate. Since wearable ultrasound device **30** may be configured to direct ultrasound to numerous locations from an array of ultrasound transducers, exact location of wearable ultrasound device may not be crucial to the ability of the device to target certain nerve tissues targeted for treatment.

[0029] In some examples, the components of wearable ultrasound device **30** may be configured, e.g., constructed and arranged, such that wearable ultrasound device **30** is flexible. In some examples, wearable ultrasound device **30** is flexible such that it conforms to a surface of patient **12** on which the wearable ultrasound device is attached. Wearable ultrasound device **30** may be used, and attached to patient **12**, for time periods as brief as a few minutes to as long as several months. The flexibility of wearable ultrasound device **30** may increase the comfort of patient **12**.

[0030] Wearable ultrasound device **30** includes one or more power sources. The one or more power sources may include an attached battery, such as an attached rechargeable battery or an attached primary battery. In examples in which wearable ultrasound device **30** includes a rechargeable battery, wearable ultrasound device **30** may include a recharge interface, such as a coil for inductive recharging or connector, e.g., universal serial bus (USB), mini-USB, or micro-USB, for wired recharging of the one or more power sources. In some examples, an interface device **34** or another device may charge the one or more power sources of wearable ultrasound device **30**.

[0031] Ultrasound energy **32** may be delivered to patient **12** by a set of ultrasound transducers for therapeutic purposes, such as to modulate activity of bladder **24**. For example, ultrasound energy **32** may modulate nerve tissue that extends from sacrum **18** that at least partially innervates bladder **24**. In some examples, ultrasound energy **32** modulates nerve tissue **26** including one or more pelvic nerves (e.g., parasympathetic nerves) and/or hypogastric nerves (e.g., sympathetic nerves). In some such examples, ultrasound energy **32** may modulate nerve tissue **26** to stimulate or inhibit the relaxation and/or contraction of the detrusor muscle (e.g., smooth muscle of the wall of bladder **24**) to treat bladder dysfunction of patient **12**.

[0032] Additionally, or alternatively, ultrasound energy **32** may be configured to modulate nerve tissue including afferent nerves **20** that at least partially innervates bladder **24** of patient **12**. Afferent nerves **20** are sensory nerves that terminate in stretch receptors **22** on bladder **24**. Ultrasound energy **32** may modulate afferent nerves **20** and/or stretch receptors **22** to stimulate or inhibit signals from afferent nerves **20** and/or stretch receptors **22** to the brain of patient **12** (e.g., via spinal cord **16**). For example, ultrasound energy **32** may inhibit signals from afferent nerves **20** and/or stretch receptors **22** to the brain of patient **12** that may indicate the need to void bladder **24** to patient **12**. In other words, ultrasound modulation of afferent nerves **20** and/or stretch receptors **22** may be selected to reduce signaling that may result in increased detrusor activity.

[0033] As another example, ultrasound energy **32** may be configured to modulate nerve tissue including a pudendal

nerve **28** that at least partially innervates urinary sphincter **36** of bladder **24** of patient **12**. Ultrasound energy **32** may modulate pudendal nerve **28** to stimulate or inhibit constriction and/or relaxation of urinary sphincter **36**. In some examples, modulation of pudendal nerve **28** to stimulate or inhibit constriction and/or relaxation of urinary sphincter **36** may help prevent patient **12** from experiencing urinary incontinence.

[0034] In other examples, in addition to nerve tissue **26** (e.g., pelvic nerves and/or hypogastric nerves), afferent nerves **20**, stretch receptors **22**, and/or pudendal nerve **28**, ultrasound energy **32** may be configured to additionally, or alternatively, modulate nerve tissue including a sciatic nerve, a tibial nerve, a sacral nerve, a sacral dermatome, a dorsal root ganglion, a dorsal genital nerve, a spinal root, spinal cord **16** within vertebrae **14**, or combinations thereof. In this way, modulation of at least one of nerve tissue **26** (e.g., pelvic nerves and/or hypogastric nerves), afferent nerves **20**, stretch receptors **22**, pudendal nerve **28**, a sciatic nerve, a tibial nerve, a sacral nerve, a sacral dermatome, a dorsal root ganglion, a dorsal genital nerve, a spinal root, spinal cord **16**, or combinations thereof may result in modulation of the activity of bladder **24**, such as bladder activity associated with an overactive bladder, urgency, urinary incontinence, or the like. It is contemplated that wearable ultrasound device **30** may control ultrasound transducers to target ultrasound energy to multiple different nerve tissues simultaneously or at different times (e.g., a time-interleaved manner or as needed according to feedback).

[0035] Wearable ultrasound device **30** may be configured to determine a set of parameter values that at least partially defines ultrasound energy **32**. Wearable ultrasound device **30** may determine the set of parameter values by accessing the parameter values stored in a memory, based on information from another device, such as an interface device **34**, or the like. The set of parameter values defining ultrasound energy **32** may include one or more of an ultrasound frequency, an energy level, a duration, a waveform, an amplitude, an intensity, a set of transducers of wearable ultrasound device **30**, or the like. In some examples, the set of parameter values defining ultrasound energy **32** may be based on the desired modulation of the activity of bladder **24**. For example, a set of parameter values may define ultrasound energy **32** configured to inhibit one or more stretch receptors **22** or inhibit the activity of nerve tissue **26** (e.g., pelvic nerves and/or hypogastric nerves). Wearable ultrasound device **30** may control delivery of ultrasound energy **32** according to the set of parameter values. Wearable ultrasound device **30** may determine the set of parameter values by retrieving preselected parameter values from memory or selecting parameter values based on sensor and/or user input.

[0036] In some examples, the activity of nerve tissue, and therefore bladder activity, may be suppressed or inhibited by slightly heating the neurons of the nerve tissue using ultrasound energy. In some examples, the set of parameter values defining ultrasound energy **32** configured to slightly heat the neurons of the nerve tissue may include a high duty cycle (e.g., a duty cycle greater than about 40%, 50%, 60%, 70%, 80%, or even 90%) of ultrasound energy **32**. Such a set of parameter values defining ultrasound energy **32** may result in the neurons of the nerve tissue increasing in temperature by a few degrees Celsius, such as about less than 5° C., less than 3° C. or less than about 2° C. In other examples, the increase in temperature may be less than 2° C. or even less than 1° C. In some examples, wearable ultrasound device **30** may be configured to detect this increase in temperature of target nerve tissue. As an additional example, a set of parameter values configured to suppress and decrease activity of the nerve tissue and/or bladder **24** may define longer bursts of ultrasound energy **32**. For example, the set of parameter values may define ultrasound energy **32** with a continuous duration between about 10 milliseconds and about 100 milliseconds, such as, for example, between about 10 milliseconds and about 50 milliseconds or between about 10 milliseconds and about 30 milliseconds. The set of parameter values may also define that ultrasound energy is delivered as a continuous sine waveform during such a duration of time.

[0037] As another example, a set of parameter values may be configured to mechanically flex the nerve tissue to increase activity of neurons and bladder **24** or other structures associated with bladder **24**. In some such examples, the set of parameter values may define shorter bursts of ultrasound energy **32**. For example, the parameters defining such ultrasound energy **32** may include pulses with a duration of between about 1 millisecond and about 10 milliseconds, such as, for example, between about 1 millisecond and about 5 milliseconds or between about 1 millisecond and about 3 milliseconds. In addition, or as an alternative, the set of parameter values configured to mechanically flex and activate nerve tissue may define ultrasound energy **32** with about a relatively smaller duty cycle, such as less than 5% duty cycle or less than 1% duty cycle.

[0038] In other examples, the set of parameter values that at least partially defines ultrasound energy may include additional or alternative parameters to define ultrasound energy **32** to activate, suppress, or inhibit nerve tissue, bladder **24**, and/or other structures associated with the activity of bladder **24**. In some examples, the set of parameter values defines an ultrasound frequency in a range from about 300 kHz to about 2.0 MHz. The ultrasound frequency delivered by the set of ultrasound transducers may be less than an ultrasound frequency typically used for ultrasound imaging. For example, ultrasound frequency used for imaging (e.g., detecting ultrasound energy reflected from anatomical tissues) may use an ultrasound frequency ranging from about 2 MHz to about 10 MHz. The use of lower ultrasound frequencies may reduce the risk of a high temperature increase of the tissues of patient **12** or hearing damage to patient **12**. However, higher frequencies may provide higher resolution of imaging in some circumstances. Additionally, or alternatively, the set of parameter values may define ultrasound energy with an energy level of less than about 0.7 watts per square centimeters.

[0039] In some examples, wearable ultrasound device **30** may include two or more sets of ultrasound transducers. In some such examples, each set of ultrasound transducers may be configured to deliver ultrasound energy **32** defined by different sets of parameters. For example, a first set of ultrasound transducers may be configured to define ultrasound energy to suppress one or more stretch receptors **22**, and a second set of ultrasound transducers may be configured to slightly heat the neurons of nerve tissue **26**. In some examples, different sets of ultrasound transducers may be configured to deliver ultrasound energy **32** for different purposes. For example, a first set of ultrasound transducers may be configured to deliver ultrasound energy **32** for therapeutic purposes, and a second set of transducers may be

configured to deliver ultrasound energy **32** for imaging purposes. The first set of transducers may include all different transducers than the transducers of the second set of transducers. In this manner, transducers of the first set of transducers may be tuned to a first frequency selected for delivering ultrasound therapy, while transducers of the second set of transducers may be tubed to a second frequency selected for imaging anatomical structures. Wearable ultrasound device **30** may this have different types of ultrasound transducers that are intended to provide respective different functionality. In other examples, however, a same set of ultrasound transducers may be configured to deliver ultrasound energy for both therapeutic purposes and imaging. In some examples, the set of transducers that deliver ultrasound therapy and the set of transducers configured for imaging may include one or more of the same transducers (e.g., one or more transducer may be configured to provide therapy and imaging functionality). In still other examples, three sets of different transducers may be used for therapy and imaging, where a first set of transducers is configured to deliver therapeutic ultrasound energy, a second set of transducers is configured to deliver imaging ultrasound energy, and a third set of transducers may be configured to detect reflected ultrasound waves from the second set of transducers. The ultrasound transducers used for different purposes may be structurally identical, but, in other examples, a first set of ultrasound transducers carried by wearable ultrasound device **30** may be structurally different from a second set of ultrasound transducers carried by wearable ultrasound device **30** for a different purpose. For example, a first set of transducers may be configured to emit ultrasound energy and a second set of transducers may be configured to receive reflected ultrasound energy to image anatomical structures.

[0040] Moreover, different sets of ultrasound transducers may be configured to target different locations (e.g., different nerve tissues). For example, a first set of ultrasound transducers may be configured to deliver ultrasound energy **32** that modulates nerve tissue including pudendal nerve **28**, and a second set of ultrasound transducers may be configured to deliver ultrasound energy **32** that modulates nerve tissue including one or more stretch receptors **22**. In other examples, system **10** may include more than one wearable ultrasound device **30** to target different locations. For example, patient **12** may have a first wearable ultrasound device **30** positioned at a midline of a suprapubic area of patient **12** (e.g., to be positioned approximately near bladder **24**) to deliver ultrasound energy **32** to nerve tissue **26**, afferent nerves **20**, and/or stretch receptors **22**, and a second wearable ultrasound device (not shown) positioned on the lower back or upper buttocks area to deliver ultrasound energy **32** to a sacral dermatome and/or a sacral nerve. These different sets of ultrasound transducers may be interspersed about the wearable ultrasound device **30** or positioned in distinct areas of the wearable ultrasound device **30**.

[0041] In any case, wearable ultrasound device **30** may include a plurality of ultrasound transducers, which may include one or more sets of ultrasound transducers. In some examples, each of the one or more sets of ultrasound transducers may be configured to deliver ultrasound energy **32** defined by different sets of parameters, for different purposes, or the like (e.g., each set of ultrasound transducers is configured a particular way to deliver a particular ultrasound energy **32**). In other examples, the one or more sets may be configured to deliver ultrasound energy **32** defined by multiple sets of parameters, for different purposes, or the like (e.g., one or more of the sets of ultrasound transducers can deliver a wider range of ultrasound energy **32**). In addition to a set of parameter values defining ultrasound energy **32**, the set of parameter values may also identify a set of ultrasound transducers from the plurality of ultrasound transducers to deliver ultrasound energy **32** to the nerve tissue of patient **12**. In this way, the plurality of ultrasound transducers may be selectable such that at least some of the plurality of ultrasound transducers including the one or more sets ultrasound transducers are configured to deliver ultrasound energy **32**, while a different one or more sets of ultrasound transducers are not configured to deliver ultrasound energy **32** at the same time.

[0042] In some examples, a set of ultrasound transducers of wearable ultrasound device **30** may deliver ultrasound energy **32** to patient **12** for imaging. Imaging may be used for visualization of a target region, determining a physiological event, monitoring temperature, monitoring cavitation, evaluating therapy effectiveness, therapy side effects, patient safety, or beam aberration correction. For example, wearable ultrasound device **30** may deliver ultrasound energy **32** to patient **12** for therapeutic purposes, and may image during delivery of such ultrasound energy **32** by detecting reflections of ultrasound energy **32** from one or more tissues of patient **12**. In other examples, wearable ultrasound device **30** may image anatomical structures by interleaving delivery of therapeutic ultrasound energy **32** with ultrasound energy **32** intended to elicit reflections detectable by wearable ultrasound device **30**. For example, therapeutic ultrasound energy **32** may be of a lower frequency and/or target a different location than ultrasound energy **32** configured for imaging. In this manner, wearable ultrasound device **30** may be configured to deliver therapeutic ultrasound energy and imaging ultrasound energy on a time-interleaved or multiplexed fashion.

[0043] In some examples, imaging from wearable ultrasound device **30** may be used to detect a physiological event. For example, wearable ultrasound device **30** may image tissues to detect a size of bladder **24** that may change over time (e.g., increasing size of bladder **24** may indicate a greater likelihood of voiding. Detection of a physiological event may be used to determine one or more parameter values of the set of parameter values. As one example, the size of bladder **24** may be compared to a bladder size threshold, such as a bladder size threshold based on patient history, population data, average bladder sizes, or the like, which may indicate that bladder **24** is full or relatively full (e.g., if the size of bladder **24** exceeds the bladder size threshold). If it is determined that bladder **24** is full or relatively full based on the comparison, one or more parameter values of the set of parameter values may be configured to define ultrasound energy **32** that prevents suppression or inhibition of the nerve tissue, or activates the nerve tissue, such that patient **12** can void bladder **24**. For example, as the size of bladder **24** increases, wearable ultrasound device **30** may change the frequency and/or amplitude of ultrasound energy **32** to aid patient **12** in withholding urine in bladder **24**. In other examples, the physiological event may include nerve activity, an anxiety level, a patient orientation, a sleep state, a breathing rate, a time of day, an activity level, a blood pressure, electromyography (EMG) information, or a heart rate of patient **12**.

[0044] Wearable ultrasound device **30** may control delivery of ultrasound energy **32** in response to detecting a physiological event via another sensor or device in addition to, or as an alternative to, wearable ultrasound device **30** detecting the physiological event via imaging or another method utilizing ultrasound energy **32**. For example, an accelerometer on wearable ultrasound device **30**, elsewhere on patient **12**, in a mobile device carried by patient **12** (e.g., interface device **34**), or the like may generate a signals representative of a physiological event, such as an increased anxiety level of patient **12**. Wearable ultrasound device **30** may interpret fidgeting or movement of patient **12** to be indicative of a symptom from bladder dysfunction, such as an urge to void bladder **24** (e.g., trying to avoid an incontinence event or trying to move to a restroom to void). In turn, wearable ultrasound device **30** may control delivering of ultrasound energy **32** based on the indication of the increased anxiety level. Wearable ultrasound device **30** may incorporate information from other sensors, such as a heart rate sensor, a breathing rate sensor, surface electrodes, or the like, when controlling an ultrasound parameter value and/or delivery of ultrasound energy **32**.

[0045] In some cases, wearable ultrasound device **30** controls delivery of ultrasound energy **32** in response to detecting the physiological event (e.g., a trigger event). For example, wearable ultrasound device **32** may begin delivering ultrasound energy **32** to the nerve tissue in response to detecting a physiological event, such as delivering ultrasound energy **32** configured to inhibit one or more stretch receptors **22** in response to detecting increased activity of one or more stretch receptors **22** and/or inhibit efferent nerve activity that may signal contractions of the detrusor muscle of bladder **24**.

[0046] Additionally, or alternatively, system **10** may use input from patient **12** (e.g., via interface device **34**) to determine a parameter value of the set of parameter values or control delivery of ultrasound energy **32**. In some examples, patient **12** may be able to input information such as an urge to void, an increased urge to void, an involuntary void episode occurred, a void is desired (e.g., system **10** may refrain from providing inhibitory therapy or provide voiding assistive therapy), or the like, to system **10** via interface device **34**. System **10** may, responsive to receiving the user input, determine a change to a parameter value of the set of parameter values or otherwise control delivery of ultrasound energy **32**. In some cases, patient **12** may be able to modify the therapy delivered by wearable ultrasound device **30** by entering user input (e.g., such as by interface device **34**). For example, if patient **12** feels urgency to void bladder **24**, patient **12** may be able to control delivery of therapy via interface device **34** such that the activity of bladder **24** and/or nerve tissue associated with bladder **24** is suppressed or inhibited. In this manner, interface device **34** may be configured to receive user input requesting an increase or decrease on the amount of therapy to be delivered or other adjust therapy.

[0047] Any combination of information may be used to determine a parameter value of the set of parameter values or control delivery of ultrasound energy **32**. For example, system **10** (e.g., interface device **34** and/or wearable ultrasound device **30**) may be configured to use any of imaging information, a size of bladder **24**, nerve activity, an anxiety level, a patient orientation, a sleep state, a breathing rate, a time of day, an activity level, a blood pressure, EMG information, or a heart rate of patient **12** to determine a parameter value of the set of parameter values or control delivery of ultrasound energy **32**. For example, wearable ultrasound device **30** may synthesize information from multiple sensors and identify a change in patient condition, such as the occurrence of a physiological event, when values of multiple signals exceed respective thresholds. Moreover, any of imaging information, a size of bladder **24**, nerve activity, an anxiety level, a patient orientation, a sleep state, a breathing rate, a time of day, an activity level, a blood pressure, EMG information, or a heart rate of patient **12** may be detected from one or more devices or sensors, such as wearable ultrasound device **30**, interface device **34**, input from patient **12**, or an accelerometer, a heart rate sensor, a breathing rate sensor, surface electrodes, or the like carried by another device associated with patient **12**.

[0048] In addition to, or as an alternative to, determining a parameter value of the set of parameter values or controlling delivery of ultrasound energy **32**, wearable ultrasound device **30** (or another device of system **10**) may control ultrasound delivery using closed loop feedback from sensed patient information such as imaging information, ultrasound energy **32** reflection information, a size of bladder **24**, nerve activity, an anxiety level, a patient orientation, a sleep state, a breathing rate, a time of day, an activity level, a blood pressure, EMG information, or a heart rate of patient **12**. For example, imaging information and/or ultrasound energy **32** reflection information may be used to map the location of bladder **24** and/or nerve tissue that is to be targeted to receive therapeutic ultrasound energy **32**. In turn, such mapping information may be used to select and/or change a set of ultrasound transducers to deliver ultrasound energy or other parameter values that define ultrasound energy **32** such that ultrasound energy **32** reaches the intended target nerve tissue for modulation. The closed loop feedback may also indicate changes in nerve activity or activity of bladder **24**, which may indicate that one or more parameter values of a set of parameter values should also be changed.

[0049] In some examples, the closed loop feedback may enable system **10** to monitor the therapy delivered by wearable ultrasound device **30**. For example, imaging information and/or characteristics of reflected waves from ultrasound energy **32** may be used to a monitor a temperature change, which may be used to monitor ultrasound energy **32** configured to slightly heat neurons of nerve tissue. The closed loop feedback may also provide EMG information, such as EMG amplitude or latency, which may indicate if ultrasound energy **32** is reaching the intended target nerve tissue. In turn, system **10** may be able to determine if ultrasound energy **32** is producing the desired effect, reaching the intended target nerve tissue, or the like, and if one or more parameter values of the set of the parameters should be altered to achieve the desired effect and/or reach the intended target nerve tissue.

[0050] System **10** may also be configured to determine intrinsic activity of bladder **24**, nerve tissue associated with bladder activity, or some other activity of another anatomical structure. Intrinsic activity may be derived from imaging information, ultrasound energy **32** reflection information, a size of bladder **24**, nerve activity, an anxiety level, a patient orientation, a sleep state, a breathing rate, a time of day, an activity level, a blood pressure, EMG information, or a heart rate of patient **12**, for example. The intrinsic activity may enable the set of parameters defining ultrasound energy **32**

to be determined such that ultrasound energy **32** modulates nerve tissue that at least partially innervates bladder **24** of patient **24** in synchrony with the intrinsic activity. For example, wearable ultrasound device **30** may be configured to detect intrinsic amplitude and/or frequency of nerve impulses and select one or more parameter values of ultrasound energy to amplify and/or inhibit those intrinsic nerve impulses, depending on whether or not nerve inhibiting or activity is desired to treat the bladder activity. In some examples, wearable ultrasound device **30** may determine a pattern (e.g., frequency and/or pulse width) of ultrasound energy to mimic and/or inverse the detected intrinsic patterns of nerve impulses.

[0051] In some examples, wearable ultrasound device **30** may also be configured to deliver one or more drugs or other chemicals to patient **12**. For example, wearable ultrasound device **30** may be configured to release a drug or other chemical through the skin of patient **12**. Such a wearable ultrasound device **30** may be able to deliver drugs or other chemicals to patient **12** at a specific rate from a reservoir carried by wearable ultrasound device **30**. The drugs may be passively released or released via an active mechanism such as a drug pump. The drugs or other chemicals released by wearable ultrasound device **30** may be related to the bladder dysfunction of patient **12**, or the drugs or other chemicals may be related to something other than the bladder dysfunction of patient **12**.

[0052] As illustrated in FIG. **1**A, system **10** also includes an interface device **34**, which may be a computing device having a user interface, e.g., a personal computer, workstation, tablet computing device, or cellular telephone. In some examples, interface device **34** may be a programmer dedicated to controlling the functionality of system **10** as described herein. Interface device **34** may be configured to accept user input from patient **12**, such as information relating to the bladder dysfunction (e.g., voiding, urgency, or the like) of patient **12**.

[0053] In the example of FIG. **1**A, interface device **34** is configured to communicate, e.g., via a wireless connection, with wearable ultrasound device **30**. In other examples, interface device **34** is configured to communicate, e.g., via a wired connection, with wearable ultrasound device **30**. Interface device **34** may also be configured to communicate, e.g., via a wired or wireless connection, with implanted or wearable sensors and/or external sensing devices. Interface device **34** may control, e.g., program, wearable ultrasound device **30**, and/or other sensors or sensing devices. Interface device **34** may also receive sensed physiological events from wearable ultrasound device **30**, sensors, and/or external sensing devices. Although not illustrated in FIG. **1**A, system **10** may include one or more other remote computing devices connected to interface device **34** via a network, and the one or more remote computing devices may control and/or receive information from wearable ultrasound device **30**, sensors, and/or external sensing devices via interface device **34**. In some examples, interface device **34** and one or more external sensing devices may be integrated as a single device.

[0054] System **10** includes one or more processors or other processing circuitry, e.g., of wearable ultrasound device **30**, interface device **34**, and/or the one or more remote computing devices, that are configured to control wearable ultrasound device **30** and interface device **34**, or any other ultrasound device, sensor, sensing device, or any other device described herein to provide the functionality described herein.

[0055] For example, the one or more processors or other processing circuitry of one or more of these devices may also be configured to determine a set of parameter values that at least partially defines ultrasound energy **32** configured to modulate nerve tissue that at least partially innervates bladder **24** of patient **12**. The one or more processors or other processing circuitry of one or more of these devices may also be configured to control wearable ultrasound device **30** to deliver ultrasound energy **32** from a set of ultrasound transducers external to patient **12** and to the nerve tissue that at least partially innervates bladder **24** of the patient **12**. In some examples, the one or more processors or other processing circuitry are configured to detect a physiological event, compare a detected physiological event to a threshold, change a parameter value of the set of parameter values, select a set of ultrasound transducers, image tissue associated with bladder **24**, or the like to provide the functionality described herein. Although a single wearable ultrasound device **30** is shown in the example of FIG. **1**A, multiple wearable ultrasound devices may be attached to patient **12** and operate independently from each other or communicate with each other to provide coordinated therapy. In one example, one wearable ultrasound device **30** may be configured to deliver ultrasound energy for therapy and another wearable ultrasound device **30** may be configured to generate imaging information using ultrasound.

[0056] FIG. **1**B is a conceptual and schematic diagram illustrating another example system **40** configured to deliver therapy that treats bladder dysfunction of a patient **12** via a wearable ultrasound device **42**. System **40** may be substantially the same as system **10** of FIG. **1**A. For example, wearable ultrasound device **42** may be the same or substantially the same as wearable ultrasound device **30** of FIG. **1**A. However, as illustrated in FIG. **1**B, wearable ultrasound device **42** is configured to communicate with a therapy device **44** via a wired connection, and therapy device **44** is configured to communicate with a programming device **46**, e.g., via a wireless or wired connection. In some examples, therapy device **44** and/or programming device **46** may be the same or substantially the same as interface device **34** of FIG. **1**A. For example, therapy device **44**, programming device **46**, or both may be configured to provide the functionality of interface device **34** as described herein.

[0057] Therapy device **44** and/or programming device **46** may also be configured to communicate, e.g., via a wired or wireless connection, with implanted or wearable sensors, external sensing devices, or the like. Therapy device **44** may control, e.g., program, wearable ultrasound device **30** and/or other sensors or sensing devices, and programming device **46** may control, e.g., program, therapy device **44** and/or other sensors or sensing devices. Programming device **46** may be a remote computing device, and/or system **40** may include one or more other remote computing devices connected to therapy device **44** or programming device **46** via a network, and the one or more remote computing devices may control and/or receive information from wearable ultrasound device **42**, therapy device **44**, programming device **46**, sensors, and/or external sensing devices. In some examples, therapy device **44** and programming device **46** may be integrated as a single device.

[0058] Therapy device **44**, and in some examples, programming device **46**, may be carried with patient **12** during use of wearable ultrasound device **42**. Therapy device **44** and/or programming device **46** may be able to be carried in clothing of patient **12**, such as in a pocket, include an adhesive element to attach to a skin surface of patient **12**, or may be attached to patient **12** using a strap or other garment. Therapy device **44** may be configured to couple to two or more wearable ultrasound devices **42**.

[0059] In some examples, system **40** may be used as a trial therapy system. For example, wearable ultrasound device **42** may be larger and include more ultrasound transducers or sensors, which may enable system **40** to determine additional information about patient **12** than wearable ultrasound device **30** of FIG. **1**A. In such examples, wearable ultrasound device **42** may include more than 100 ultrasound transducers or even more than 1,000 ultrasound transducers. The large amount of ultrasound transducers may enable system **40** to determine a treatment or diagnostic area of patient **12** (e.g., to position a wearable ultrasound device for chronic use) without being moved during the trial period, determine one or more sets of parameter values to define ultrasound energy **32**, determine the efficacy of one or more sets of parameter values defining ultrasound energy **32**, or the like. In some examples, patient **12** may wear wearable ultrasound device **42** for a shorter period time, such as less than a month, less than a week, or less than a day, to determine initial information regarding patient **12** and system **40**. After wearable ultrasound device **42** indicates therapy efficacy, a clinician may prescribe therapy for patient **12** via wearing wearable ultrasound device **30** for a longer, chronic, period of time. In some examples, wearable ultrasound device **30** may be positioned, controlled, and/or programmed based on at least some of the information determined by wearable ultrasound device **42** during the trial therapy period. In other examples, wearable ultrasound device **30** may function as a trial therapy system, or patient **12** may not use a trial therapy system.

[0060] FIGS. **2**A and **2**B are top-view and side-view diagrams, respectively, illustrating an example wearable ultrasound device **50**. In the example of FIGS. **2**A and **2**B, wearable ultrasound device **50** includes an adhesive layer **52**, a flexible interconnect element **54**, a plurality of ultrasound transducers **56** connected to flexible interconnect element **54**, and a plurality of power sources **58**, e.g., batteries, connected to flexible interconnect element **54**. FIG. **2**B illustrates one ultrasound transducer **56** and one power source **58**. Although not illustrated in FIGS. **2**A and **2**B, wearable ultrasound device **50** may also include signal generation circuitry, one or more processors or processing circuitry, sensing circuitry, and communication circuitry, e.g., configured to communicate with interface device **34** (FIG. **1**A) or therapy device **44** (FIG. **1**B), connected to flexible interconnect element **54**. Wearable ultrasound device **50** may be an example of wearable ultrasound devices **30** or **42** of FIGS. **1**A and **1**B.

[0061] The components of wearable ultrasound device **50** may be configured, e.g., constructed and arranged, such that wearable ultrasound device **50** is flexible. For example, flexible interconnect element **54** may comprise a flexible circuit, e.g., a flex circuit that electrically connects two or more of the components of wearable ultrasound device **50**. Flexible interconnect element **54** and adhesive layer **52** may comprise mechanically compliant materials. Additionally, ultrasound transducers **56** and power sources **58** may be discrete and distributed across wearable ultrasound device **50**, e.g., in a two-dimensional array as illustrated in FIG. **2**A, which may facilitate flexibility of wearable ultrasound device **50**. In some examples, signal generation circuitry that drives ultrasound transducers **56** may include flexible driving electronics.

[0062] Wearable ultrasound device **50** including plurality of power sources **58** may increase the onboard power capacity of wearable ultrasound device **50**. In some examples, power sources **58** include rechargeable batteries. In such examples, wearable ultrasound device **50** may include a recharge interface, such as a coil for inductive recharging or connector, e.g., universal serial bus (USB), mini-USB, or micro-USB, for wired recharging of power sources **58**. In some examples, interface device **34** (FIG. **1**A), therapy device **44** (FIG. **1**B), or another device charges power sources **58** of wearable ultrasound device **50**. In other examples, power sources **58** include primary batteries.

[0063] In some examples, as illustrated in FIG. **2**A, each of power sources **58** is associated with a respective one of ultrasound transducers **56**. In some examples, each of power sources **58** is attached to the respective ultrasound transducer **56**. In such examples, power sources **58** may be configured as a backing material for ultrasound transducers **56**, which may tune an ultrasound frequency of the respective ultrasound transducer **56**. Using power sources **58** as a backing material may reduce or eliminate the need for a dedicated backing material to tune ultrasound transducers **56**, which may in turn reduce the size, e.g., volume, thickness, or weight, of ultrasound transducers **56**. Various features of power sources **58**, such as thickness and mass, may be chosen to tune the ultrasound output parameters, e.g., ultrasound frequency. In some examples, flexible interconnect element **54** may also be configured as a backing material for ultrasound transducers **56**, in addition to, or instead of, power source **58**. In some examples, additional electrical components may be affixed, e.g., directly, to the ultrasound material, e.g., during the manufacturing process, and may act as backing material for ultrasound transducers **56**, alone or in combination with other components of wearable ultrasound device **50**.

[0064] The relative vertical arrangement of adhesive layer **52**, interconnect layer **54**, ultrasound transducers **56**, and power sources **58** illustrated in FIG. **2**B is merely one example. In other examples, interconnect layer **54** may be at least partially between ultrasound transducers **56** and power sources **58**, or power sources **58** may be at least partially between interconnect layer **54** and ultrasound transducers **56**. In some examples, discrete components, such as ultrasound transducers **56** and power sources **58**, may be located at least partially within, e.g., may be at least partially surrounded by, interconnect layer **54** and/or adhesive layer **52**.

[0065] Although nine ultrasound transducers **56** and nine power sources **58** are illustrated in FIG. **2**A, in other examples, the numbers of transducers and power sources may be different than illustrated, and/or the number of ultrasound transducers **56** may be different than the number of power sources. In some examples, there may be at least three, at least nine, at least thirty-two, or at least sixty-four ultrasound transducers **56** and/or power sources **58**. In some examples, power sources **58** may be horizontally adjacent ultrasound transducers **56**. In some examples, one or more

power sources **58** may be located anywhere in interconnect element **54** in relation to power transducers (e.g., the signal generation circuitry that drives ultrasound transducers **56**) or other components of wearable ultrasound device **50**. In other examples, ultrasound device **50** may include hundreds or even thousands of ultrasound transducers **56**.

[0066] Power sources **58** may be connected in series, in parallel, or in some series/parallel combination. At least partial series combination may boost voltage of the resulting power source **58**. To improve acoustic coupling and tune ultrasound transducers **56**, the cavity within the power source case (e.g., a battery case) may be substantially free of gas (e.g., free or nearly free), such as by completely filling the space between electrodes with an electrolyte that may be liquid, gel, or solid. In some examples, power sources **58** include battery chemistry that does not generate gas during charge/discharge (for example, using a lithium titanate anode) and/or to allow for removal of gas that is usually formed during the initial charge cycle (known in the art as formation) of the cell. The power source encasement may be a metal such as titanium or aluminum or a metal/polymer foil laminate, although other materials can be used in other examples. The performance of power sources **58** as a backing material may be configured based on acoustic impedance (density×sound speed), thickness, and attenuation coefficient to reduce reflections.

[0067] Ultrasound transducers **56** may include a piezoelectric material, such as, lead zirconate titanate (PZT) composite, a PZT film, polyvinylidene fluoride (PVDF), which is a plastic with piezoelectric properties, and/or capacitive micromachined ultrasonic transducers (CMUTs). In other examples, ultrasound transducers **56** may additionally or alternatively include piezoelectric micro machined ultrasonic transducers (PMUTs). PMUTs may draw less power for operation than CMUTs, and, as a result, PMUTs may be advantageous when power is limited. In examples in which power sources **58** and ultrasound transducers **56** are attached, the ultrasound material may be glued or otherwise bonded to the surface of power source **58**. In some examples, a metallic housing of power source **58** may be part of an electrical circuit of wearable ultrasound device **50**, e.g., to couple ultrasound material of ultrasound transducer **56** to power source **58**, signal generation circuitry for driving ultrasound transducer **56**, and/or sensing circuitry for processing reflected ultrasound for sensing, diagnostic, or monitoring purposes.

[0068] Adhesive layer **52** attaches wearable ultrasound device **50** to patient **12** (FIGS. **1**A and **1**B). In some examples, adhesive layer **52** is also configured to provide an acoustic interface between ultrasound transducers **56** and tissue of patient **12** for ultrasound. In such examples, the adhesive of adhesive layer **52** may be between, e.g., substantially completely fill the space between, each of ultrasound transducers **56** and an external surface of patient **12**.

[0069] FIG. **3** is a functional block diagram illustrating an example configuration of a wearable ultrasound device **60**, which may correspond to any of wearable ultrasound devices **30** (FIG. **1**A), **42** (FIG. **1**B), or **50** (FIGS. **2**A and **2**B). As illustrated in FIG. **3**, wearable ultrasound device **60** includes one or more processing circuitry **70**, a plurality of ultrasound transducers **62**, one or more signal generators **64** for driving ultrasound transducers **62** to deliver ultrasound energy, and one or more power sources **66** that provide power to the one or more signal generators **64** for driving ultrasound transducers **62**, as well as providing power to other components of wearable ultrasound device **60**. Ultrasound transducers **62** and power sources **66** may correspond to any ultrasound transducers, e.g., **56** (FIGS. **2**A and **2**B), and power sources, e.g., power sources **58** (FIGS. **2**A and **2**B), respectively, described herein.

[0070] As illustrated in FIG. **3**, wearable ultrasound device **60** may also include a communication circuitry **72** and memory **74**. Memory **74**, as well as other memories described herein, may include any volatile or non-volatile media, such as a random access memory (RAM), read only memory (ROM), non-volatile RAM (NVRAM), electrically erasable programmable ROM (EEPROM), flash memory, or the like. Memory **74** may store computer-readable instructions that, when executed by processing circuitry **70**, cause wearable ultrasound device **60** to perform various functions described herein. Processing circuitry **70** may include any combination of one or more processors including one or more microprocessors, digital signal processors (DSPs), application specific integrated circuits (ASICs), field programmable gate arrays (FPGAs), or other equivalent integrated or discrete logic circuitry. Accordingly, processing circuitry **70** may include any suitable structure, whether in hardware, software, firmware, or any combination thereof, to perform the functions ascribed herein to processing circuitry **70** and wearable ultrasound device **60**.

[0071] Processing circuitry **70** are configured to control ultrasound transducers **62** to deliver ultrasound energy, e.g., for a therapeutic or an imaging purpose. More particularly, processing circuitry **70** control signal generators **64** to generate a signal based on power from power sources **66** that drives ultrasound transducers **62** to deliver ultrasound energy. Signal generators **64** may include one or more oscillators configured to generate signals of a desired frequency for the ultrasound energy, amplification or other circuitry to control the amplitude of the driving signals, as well as switching circuitry to selectively direct the signal to one or more of ultrasound transducers **62** and/or selectively control the on/off state of individual ones or sets of transducers **62**. Some or all of the signal generation circuitry may be respectively associated with certain sets of ultrasound transducers **62**, or shared by all or a subset of ultrasound transducers **62**. Processing circuitry **70** may control ultrasound transducers **62** to deliver ultrasound energy to a particular depth, region, or point of tissue, with a particular amplitude, by selecting which of ultrasound transducers **62** is on or driven, and controlling one or more of the amplitude or phase of the driving signal provided to the driven ultrasound transducers **62** by signal generators **64**. Different active ultrasound transducers **62** or sets of ultrasound transducers may be driven with different signals, e.g., different amplitudes and/or phases, to target a desired, depth, region, or point of tissue.

[0072] In examples in which ultrasound device **60** is configured for imaging or otherwise detecting reflected ultrasound, ultrasound device **60** may include sensing circuitry **68** to selectively, e.g., as controlled by processing circuitry **70**, receive and condition electrical signals produced ultrasound transducers **62** as a function of reflected ultrasound, for processing by processing circuitry **70**. Sensing circuitry **68** may include one or more switches to control which one or more of transducers **62** are active to sense reflected ultrasound.

[0073] In some examples in which wearable ultrasound device **60** is configured to sense physiological events, wearable ultrasound device **60** may include one or more sensors **76**, which may correspond to any sensors described herein, such as an accelerometer, a heart rate sensor, a breathing rate sensor, surface electrodes, or the like. Sensing circuitry **68** may selectively, e.g., as controlled by processing circuitry **70**, receive and condition electrical signals produced sensors **76** for processing by processing circuitry **70**. Sensing circuitry **68** may include one or more switches to control which one or more of sensors are active to sense physiological events.

[0074] Power sources **66** may deliver operating power to various components of wearable ultrasound device **60**. Power sources **66** may include a small rechargeable or a non-rechargeable battery and a power generation circuit to produce the operating power. Recharging may be accomplished through proximal inductive interaction between a charging device and an inductive charging coil of wearable ultrasound device **60**, or a wired connection between the charging device and wearable ultrasound device **60**.

[0075] Communication circuitry **72** is configured to support wired or wireless communication between wearable ultrasound device **60** and one or more other devices, such as interface device **34**, therapy device **44**, and/or programming device **46**. A user may control the delivery of ultrasound energy by wearable ultrasound device **60**, as well as the collection of imaging ultrasound and/or sensing by wearable ultrasound device **60**, via communication with processing circuitry **70** through communication circuitry **72**. In some examples, programs that control the delivery of ultrasound energy, collection of imaging ultrasound, and/or sensing may be stored in memory **74**, and executed by processing circuitry **70**. A user may generate or update such programs, using interface device **34**, therapy device **44**, and/or programming device **46**, through communication with wearable ultrasound device **60** via communication circuitry **72**. Interface device **34**, therapy device **44**, programming device **46**, and/or another device, may also receive ultrasound images or sensed physiological events collected by processing circuitry **70**, or any other information generated by processing circuitry **70**, via communication circuitry **72**. Such information may be stored in memory **74**.

[0076] FIG. **4** is a functional block diagram illustrating an example configuration of interface device **80**. Interface device **80** may correspond to any of interface device **34** (FIG. **1**A), therapy device **44** (FIG. **1**B), or programming device **46** (FIG. **2**B). As illustrated in FIG. **4**, interface device **80** includes processing circuitry **84**, a memory **82**, a communication circuitry **86**, a user interface **88**, and a power source **90** configured to power the components of interface device **90**. Processing circuitry **84** controls user interface **88** and communication circuitry **86**, and stores and retrieves information and instructions to and from memory **82**.

[0077] Processing circuitry **84** may include any combination of one or more processors including one or more microprocessors, DSPs, ASICs, FPGAs, or other equivalent integrated or discrete logic circuitry. Accordingly, processing circuitry **84** may include any suitable structure, whether in hardware, software, firmware, or any combination thereof, to perform the functions ascribed herein to processing circuitry **84** and interface device **80**. Memory **82** may include program instructions that, when executed by processing circuitry **84**, cause processing circuitry **84** and interface device **80** to perform any of the functions ascribed to them herein. Memory **82** may include any volatile or nonvolatile memory, such as RAM, ROM, EEPROM or flash memory.

[0078] A user, such as a clinician, other caregiver, or patient **12** (FIGS. **1**A and **1**B), may interact with interface device **90** through user interface **88**. User interface **88** includes a display, with which processing circuitry **84** may present information, such as information relating to bladder or nerve tissue activity, or other information retrieved from wearable ultrasound device **60** (FIG. **3**). In addition, user interface **88** may include an input mechanism to receive input from the user, though which the user may control or program delivery of ultrasound energy or input occurrence of a physiological event according to any of the techniques described herein. Communication circuitry **86** is configured for wired or wireless communication with the corresponding communication circuitry **64** of ultrasound device **60** (FIG. **3**), to facilitate user control or programming of wearable ultrasound device **60**, or retrieval of information from wearable ultrasound device **60**.

[0079] FIG. **5** is a flow diagram illustrating an example technique of modulating bladder activity of a patient via a wearable ultrasound device. The technique of FIG. **5** will be described with respect to system **10** of FIG. **1**A. In other examples, however, the technique of FIG. **5** may be used with a system other than system **10** of FIG. **1**A, such as with example system **40** of FIG. **1**B.

[0080] The technique of FIG. **5** includes processing circuitry of wearable ultrasound device **30** determining a set of parameter values that at least partially defines ultrasound energy **32** configured to modulate nerve tissue (e.g., nerve tissue **26**, pudendal nerve **28**, afferent nerves **20**, and/or stretch receptors **22**) associated with activity of bladder **24** of patient **12** (**100**). For example, the nerve tissue may at least partially innervate bladder **24** or another structure (e.g., a sphincter) associated with the activity of bladder **24**. Determining the set of parameter values may include accessing the parameter values stored in a memory of wearable ultrasound device **30**, determining the set of parameter values based on information from another device, such as an interface device **34**, or determining the set of parameter values for ultrasound energy based on one or more sensors that generate information representative of the physiological condition of patient **12**. The set of parameter values defining ultrasound energy **32** may include one or more of an ultrasound frequency, an energy level, a duration, a waveform, an amplitude, an intensity, a set of transducers of wearable ultrasound device **30**, or other parameter values that define ultrasound energy **32**. In some examples, the set of parameter values defining ultrasound energy **32** may be based on the desired modulation of the activity of bladder **24**. For example, a set of parameter values may define ultrasound energy **32** configured to inhibit one or more stretch receptors **22** or inhibit the activity of nerve tissue **26** (e.g., pelvic nerves and/or hypogastric nerves). In other examples, the set of parameters may define ultrasound energy **32** configured to inhibit, suppress, and/or activate one or more additional or alternative nerve tissues configured to innervate bladder **24**.

[0081] In some examples, determining the set of parameter values may include determining one or more parameter values of the set of parameter values based on detecting a physiological event. For example, detecting the physiologi-

cal event may include detecting the size of bladder **24**. The size of bladder **24** may be compared to a bladder size threshold, such as a bladder size threshold based on patient history, data from the general population, average bladder sizes, or the like, which may indicate that bladder **24** is full or relatively full (e.g., if the size of bladder **24** exceeds the bladder size threshold) or otherwise that therapeutic ultrasound energy should be delivered to intervene in bladder activity. If wearable ultrasound device **30** determines that bladder **24** is full or relatively full based on the comparison, one or more parameter values of the set of parameter values may be configured to define ultrasound energy **32** that prevents suppression or inhibition of the nerve tissue, or activates the nerve tissue, such that patient **12** can void bladder **24**. In this manner, wearable ultrasound device **30** may initiate delivery of ultrasound energy in response to detecting a physiological event.

[0082] In some examples, wearable ultrasound device **30** may detect the physiological event, such as via imaging. In other examples, a sensor on wearable ultrasound device **30** or another sensor (e.g., an accelerometer, one or more electrodes, a temperature sensor, etc.) may generate signals used by wearable ultrasound device **30** to detect the physiological event. Moreover, in some examples, more than one physiological event may be used to determine one or more parameter values of the set of parameter values.

[0083] The technique of FIG. **5** further includes controlling, according to the set of parameter values, delivery of ultrasound energy **32** from a set of ultrasound transducers external to patient **12** and to the nerve tissue associated with activity of bladder **24** of patient **12** (**102**). For example, wearable ultrasound device **30** may control delivery of ultrasound energy **32** to begin, stop, or continue delivery of the ultrasound energy. Wearable ultrasound device **30** may also change one or more parameter values that define ultrasound energy **34** to control delivery of ultrasound energy **32**.

[0084] In some cases, wearable ultrasound device **30** may control delivery of ultrasound energy **32** in response to detecting a physiological event. For example, wearable ultrasound device **30** may determine that a signal value representative of a physiological condition exceeds a threshold to identified that the physiological event has occurred. In response to detecting this physiological event, wearable ultrasound device **30** may control delivery of ultrasound energy **32** may to begin delivery of ultrasound energy **32**. Examples of a physiological event may include detection of increased activity of one or more stretch receptors **22**, increased movement or fidgeting of the patient, or other physiological events that may be related to the activity of bladder **24** and/or bladder dysfunction. Additionally, or alternatively, controlling delivery of ultrasound energy **32** may be in response to user input from patient **12**, such as through the use of interface device **34**.

[0085] The technique of FIG. **5** also includes delivering ultrasound energy **32** to the nerve tissue that at least partially innervates bladder **24** (**104**). Ultrasound energy **32** may be delivered via one or more sets of ultrasound transducers of wearable ultrasound device **30**. In some examples, delivering ultrasound energy **32** includes delivering ultrasound energy **32** with an ultrasound frequency in a range from about 500 kHz to about 1.5 MHz and/or with an energy level of less than about 0.7 watts per square centimeters, as may be defined by the set of parameter values determined in step **100**.

[0086] In some examples, delivering ultrasound energy **32** may include slightly heating the neurons of the nerve tissue, such as increasing the temperature of the nerve tissue by about less than 5° C., less than about 3° C., or by less than about 2° C. In other examples, delivering ultrasound energy **32** may include delivering longer bursts of ultrasound energy **32**. For example, delivering burst of ultrasound energy **32** for a duration between about 10 milliseconds and about 100 milliseconds, such as, for example, between about 10 milliseconds and about 50 milliseconds or between about 10 milliseconds and about 30 milliseconds. As another example, delivering ultrasound energy **32** may include mechanically flexing the nerve tissue to increase activity of the nerve tissue and/or bladder **24**. In some such examples, delivering ultrasound energy **32** may include delivering shorter bursts of ultrasound energy **32**, such as delivering ultrasound energy **32** in pulses with a duration of between about 1 millisecond and about 10 milliseconds, such as, for example, between about 1 millisecond and about 5 milliseconds or between about 1 millisecond and about 3 milliseconds.

[0087] The technique of FIG. **5** to modulate nerve tissue configured to at least partially innervate bladder **24** of patient **12** may be used for a therapeutic purpose to manage, alleviate, control, or reduce bladder dysfunction and/or symptoms associated with bladder dysfunction. In some examples, wearable ultrasound device **30** may additionally, or alternatively, be configured to detect reflected ultrasound waves for imaging physiological structures which may include generating information related to structure dimensions and distances between structures. This imaging information may be used to, for example, target ultrasound energy to appropriate never tissue and/or monitor activity of the bladder or other structures associated with the activity of bladder **24**.

[0088] FIG. **6** is a flow diagram illustrating an example technique of determining a set of parameters based on imaging via a wearable ultrasound device. The technique of FIG. **6** will be described with respect to system **10** of FIG. **1**A. In other examples, however, the technique of FIG. **6** may be used with a system other than system **10** of FIG. **1**A, such as with system **40** of FIG. **1**B.

[0089] The technique of FIG. **6** includes imaging tissue associated with bladder **24** (**120**). In some examples, imaging tissue associated with bladder **24** includes delivering ultrasound energy **32** to the tissue associated with bladder **24** and receiving reflected ultrasound energy (e.g., mechanical waves resulting from initial ultrasound waves bouncing off tissues in patient **12**) from tissue associated with bladder **24** and/or other tissues of patient **12**. In some cases, imaging tissue associated with bladder **24** may be performed during delivery of ultrasound energy **32** for therapeutic purposes (e.g., monitoring patient activity or changes to anatomical structures that may inform changes to one or more ultrasound parameter values). In other cases, imaging tissue associated with bladder **24** may include delivering ultrasound energy **32** configured of a frequency and/or intensity specific for imaging. For example, prior to delivering therapeutic ultrasound energy **32**, a burst of imaging ultrasound energy **32** may be delivered to patient **12**, and reflected

ultrasound waves may be detected to generate information about the current physiological or anatomical state of the patient.

[0090] In some examples, imaging tissue associated with bladder **24** may be used to detect a physiological event, such as a size of bladder **24**, nerve activity, an anxiety level, a patient orientation, a sleep state, a breathing rate, a time of day, an activity level, a blood pressure, EMG information, or a heart rate of patient **12**. The wearable ultrasound device **30** may, in some examples, contextualize the imaging information with other physiological information detected from other sensors (non-ultrasound sensors) associated with patient **12**.

[0091] The technique of FIG. **6** further includes determining at least one parameter value of a set of parameter values based on the image of the tissue associated with bladder **24** (**122**). In some examples, imaging including detection of a physiological event may be used to determine a parameter value of the set of parameter values that define ultrasound energy **24**. For example, imaging associated with the activity of bladder **24** or tissue associated with bladder **24** may be used to detect the size of bladder **24**, which, in turn may be used to determine a parameter value of the set of parameter values defining ultrasound energy **32**. In other examples, the image of tissue associated with bladder **24** may be used in a manner other than to detect a physiological event to determine at least one parameter value of a set of parameter values based on the image of the tissue associated with bladder **24**. As one example, the image of tissue associated with bladder **24** may be used to map the location of bladder **24** and/or nerve tissue. In turn, such mapping information may be used to determine a parameter value such as a selection of a set of ultrasound transducers. For example, wearable ultrasound device **30** may use ultrasound imaging to identify nerve activity associated with the bladder dysfunction and then target ultrasound energy to that nerve tissue of the activity in order to modulate the bladder activity.

[0092] FIG. **7** is a flow diagram illustrating an example technique of delivering ultrasound energy to nerve tissue of a patient based on detection of a physiological event, such as a trigger event. The example technique of FIG. **7** will be described with respect to system **10** of FIG. **1**A. In other examples, however, the technique of FIG. **7** may be used with a system other than system **10** of FIG. **1**A, such as with system **40** of FIG. **1**B.

[0093] The technique of FIG. **7** includes detecting a first physiological event associated with bladder activity (**130**). In some examples, detecting the first physiological event associated with bladder activity may include one or more of detecting a size of bladder **24**, nerve activity associated with bladder **24**, an anxiety level, a patient orientation, a sleep state, a breathing rate, a time of day, an activity level, a blood pressure, EMG information, or a heart rate of patient **12**. For example, an increased anxiety level or change in patient orientation (e.g., standing from a lying down position) may indicate that the patient **12** is expecting an upcoming incontinence event. The first physiological event may be detected via imaging by wearable ultrasound device **30**, one or more non-ultrasound sensors carried by wearable ultrasound device **30**, one or more sensors attached to or implanted within patient **12**, and/or by one or more external devices, such as interface device **34**.

[0094] Wearable ultrasound device **30** may also determine a set of parameters that at least partially defines ultrasound energy **32** configured to modulate nerve tissue that at least partially innervates bladder **24** of patient **12**. Determining the set of parameters may be based on the detected first physiological event in some cases. In other examples, wearable ultrasound device **30** may refer to stored parameter values preselected for delivery of ultrasound energy. In response to detecting the first physiological event (**130**), wearable ultrasound device **30** controls delivery of ultrasound energy **32** to the nerve tissue associated with activity of the bladder **24** to modulate activity of the bladder (**136**).

[0095] The technique of FIG. **7** additionally includes monitoring one or more physiological events associated with bladder **24** (**138**) and detecting a second physiological event associated with bladder activity (**140**) that may indicate ultrasound energy may be stopped. For example, wearable ultrasound device **30** may be configured to image one or more structures of patient **12**, receive information from one or more sensors of wearable ultrasound device **30**, receive information from one or more sensors externally worn by or implanted within patient **12**, and/or one or more external devices, such as interface device **34** to monitor one or more physiological events. Example physiological events may include a size of bladder **24**, nerve activity associated with bladder **24**, an anxiety level, a patient orientation, a sleep state, a breathing rate, a time of day, an activity level, a blood pressure, EMG information, a heart rate of patient **12**, a temperature of tissue of patient **12**, or the like. In some examples, monitoring such physiological events and detecting the second physiological event associated with activity of bladder **24** may enable system **10** to utilize closed loop feedback.

[0096] If wearable ultrasound device **30** does not detect a second physiological event ("NO" branch of block **140**), wearable ultrasound device **30** may continue to control delivery of ultrasound energy (**134**). During delivery of ultrasound energy, wearable ultrasound device **30** may monitor other physiological information to detect one or more additional events that may trigger wearable ultrasound device **30** to change one or more ultrasound parameter values to accommodate changing physiology, such as changes in patient orientation (e.g., posture), changes to bladder volume, detecting of stretch receptor activity, or any other events related to bladder activity. As one example, detection of another physiological event may indicate ultrasound energy **32** is not reaching the intended target, is not efficacious, or the like. As one example, imaging information and/or ultrasound energy **32** reflection information may be monitored to determine if ultrasound energy **32** is having a desired effect, such as, increasing the temperature of nerve tissue associated with bladder **24**, inhibiting stretch receptors **22**, or other desired effects from the delivery of ultrasound energy **32**. In response to wearable ultrasound device **30** determining that ultrasound therapy is not effective, wearable ultrasound device **30** may adjust one or more ultrasound parameter values (e.g., change ultrasound intensity, ultrasound frequency, targeted location, or the ultrasound transducers used to deliver ultrasound energy).

[0097] In some examples, the one or more physiological events associated with bladder **24** may be monitored for a predetermined amount of time. For example, the one or

more physiological events may be monitored for a predetermined amount of time after delivery of ultrasound energy **32** (**136**).

[0098] If wearable ultrasound device **30** detects a second physiological event ("YES" branch of block **140**), wearable ultrasound device **30** ceases delivery of ultrasound energy **32**. For example, the physiological event may be a determined voiding event by patient **12**. The second physiological event may be indicated via a user input to interface device **32** representative of a desired voiding event. Alternatively, wearable ultrasound device **30** may use an accelerometer and/or EMG signals to determine that patient **12** is attempting to sleep, and wearable ultrasound device **30** may be configured to turn off ultrasound therapy under these conditions. In other examples, wearable ultrasound device **30** may cease ultrasound delivery after a predetermined timer elapses or according to a certain time of day. After ultrasound energy has been stopped (**142**), wearable ultrasound device **30** may then determine if a new physiological event (e.g., the first physiological event or another event) is detected (**144**). If no new physiological event is detected ("NO" branch of block **144**), wearable ultrasound device **30** may continue to refrain from delivering ultrasound energy (**142**). If wearable ultrasound device **30** detects the new physiological event ("YES" branch of block **144**), wearable ultrasound device **30** may again control delivery of ultrasound energy (**143**).

[0099] Although FIG. **7** is described with respect to detecting a physiological event and controlling delivery of ultrasound therapy based on the detected physiological event, other events may be used by system **10** to control ultrasound delivery. For example, wearable ultrasound device **30** may be configured to detect two or more different physiological events (e.g., events of different physiological aspects from a single sensor or events from different sensors) before beginning to deliver ultrasound energy). In addition, or alternatively, wearable ultrasound device **30** may begin or stop delivering ultrasound energy in response to a user input based trigger event. For example, interface device **32** may receive user input requesting therapy to avoid an urge incontinence event, and wearable ultrasound device **30** may begin delivering ultrasound therapy in response to receiving an indication of the received user input.

[0100] The following examples are examples described herein.

Example 1

[0101] A method for modulating bladder activity, the method comprising: determining, by processing circuitry, a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with activity of a bladder of a patient; and controlling, by processing circuitry and according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the activity of the bladder of the patient.

Example 2

[0102] The method of example 1, further comprising delivering, by the set of ultrasound transducers, the ultrasound energy to the nerve tissue associated with the activity of the bladder.

Example 3

[0103] The method of any of examples 1 and 2, wherein the nerve tissue comprises one or more stretch receptors associated with the bladder, and wherein determining the set of parameter values comprises determining the set of parameter values that at least partially defines ultrasound energy configured to inhibit the one or more stretch receptors.

Example 4

[0104] The method of any of examples 1 through 3, wherein the nerve tissue comprises at least one of a pudendal nerve, a pelvic nerve, a hypogastric nerve, an afferent nerve, a sciatic nerve, a tibial nerve, a sacral nerve, a sacral dermatome, a dorsal root ganglion, a spinal root, or a spinal cord.

Example 5

[0105] The method of any of examples 1 through 4, wherein the set of parameter values comprises an ultrasound frequency in a range from 300 kHz to 2.0 MHz.

Example 6

[0106] The method of any of examples 1 through 5, wherein the set of parameter values comprises an energy level of less than 0.7 watts per square centimeters.

Example 7

[0107] The method of any of examples 1 through 6, further comprising detecting a physiological event associated with bladder activity, and wherein controlling delivery of the ultrasound energy comprises, responsive to detecting the physiological event, controlling the set of ultrasound transducers to begin delivering the ultrasound energy to the nerve tissue.

Example 8

[0108] The method of example 7, wherein a plurality of ultrasound transducers comprises the set of ultrasound transducers, and wherein detecting the physiological event comprises detecting, via at least one ultrasound transducer of the plurality of ultrasound transducers, a size of the bladder exceeding a bladder size threshold.

Example 9

[0109] The method of any of examples 7 and 8, wherein detecting the physiological event comprises detecting, via a sensor, at least one of an anxiety level, a patient orientation, a sleep state, a breathing rate, electromyography (EMG) information, or a heart rate.

Example 10

[0110] The method of any of examples 1 through 9, wherein a plurality of ultrasound transducers comprises the set of ultrasound transducers, and wherein the method further comprises imaging, with at least one ultrasound transducer of the plurality of ultrasound transducers, tissue associated with the bladder, and wherein determining the set of parameter values comprises determining, based on the imaging of the tissue associated with the bladder, at least one parameter value of the set of parameter values.

Example 11

[0111] The method of example 10, wherein the at least one parameter value identifies, from a plurality of selectable ultrasound transducers, the set of ultrasound transducers for delivering the ultrasound energy to the nerve tissue.

Example 12

[0112] The method of any of examples 1 through 11, wherein an external patch comprises the set of ultrasound transducers and the processing circuitry, and wherein the external patch is configured to be attached to an external skin surface of the patient.

Example 13

[0113] A system for modulating bladder activity, the system comprising: processing circuitry configured to: determine a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with activity of a bladder of a patient; and control, according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the activity of the bladder of the patient.

Example 14

[0114] The system of example 13, further comprising the set of ultrasound transducers configured to deliver the ultrasound energy to the nerve tissue associated with the activity of the bladder.

Example 15

[0115] The system of any of examples 13 and 14, wherein the nerve tissue comprises one or more stretch receptors associated with the bladder, and wherein the processing circuitry is configured to determine the set of parameter values that at least partially defines ultrasound energy configured to inhibit the one or more stretch receptors.

Example 16

[0116] The system of any of examples 14 through 15, wherein the nerve tissue comprises at least one of a pudendal nerve, a pelvic nerve, a hypogastric nerve, an afferent nerve, a sciatic nerve, a tibial nerve, a sacral nerve, a sacral dermatome, a dorsal root ganglion, a spinal root, or a spinal cord.

Example 17

[0117] The system of any of examples 13 through 16, wherein the set of parameter values comprises an ultrasound frequency in a range from 300 kHz to 2.0 MHz.

Example 18

[0118] The system of any of examples 13 through 17, wherein the processing circuitry is configured to: detect a physiological event associated with bladder activity; and responsive to detecting the physiological event, control the set of ultrasound transducers to begin delivering the ultrasound energy to the nerve tissue.

Example 19

[0119] The system of example 18, wherein a plurality of ultrasound transducers comprises the set of ultrasound transducers, and wherein the processing circuitry is configured to detect, via at least one ultrasound transducer of the plurality of ultrasound transducers, a size of the bladder exceeding a bladder size threshold.

Example 20

[0120] The system of any of examples 18 and 19, wherein the processing circuitry is configured to detect, via a sensor, at least one of an anxiety level, a patient orientation, a sleep state, a breathing rate, electromyography (EMG) information, or a heart rate.

Example 21

[0121] The system of any of examples 13 through 20, wherein a plurality of ultrasound transducers comprises the set of ultrasound transducers, and wherein the processing circuitry is further configured to: image, with at least one ultrasound transducer of the plurality of ultrasound transducers, tissue associated with the bladder; and determine, based on the imaging of the tissue associated with the bladder, at least one parameter value of the set of parameter values.

Example 22

[0122] The system of any of examples 13 through 21, further comprising an external patch comprising the set of ultrasound transducers and the processing circuitry, and wherein the external patch is configured to be attached to an external skin surface of the patient.

Example 23

[0123] A non-transitory computer readable medium comprising instructions that, when executed, cause processing circuitry to: determine a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with activity of a bladder of a patient; and control, according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the activity of the bladder of the patient.

Example 24

[0124] A system for modulating bladder activity, the system comprising: means for determining a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with activity of a bladder of a patient; and means for controlling, according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the activity of the bladder of the patient.

Example 25

[0125] The system of example 24, further comprising the set of ultrasound transducers configured to deliver the ultrasound energy.

[0126] The techniques described in this disclosure, including those attributed to system **10**, system **40**, wearable

ultrasound device **30**, wearable ultrasound device **42**, and wearable ultrasound device **60**, and various constituent components, may be implemented, at least in part, in hardware, software, firmware or any combination thereof. For example, various aspects of the techniques may be implemented within one or more processors or processing circuitry, including one or more microprocessors, DSPs, ASICs, FPGAs, or any other equivalent integrated or discrete logic circuitry, as well as any combinations of such components, remote servers, remote client devices, or other devices. The term "processor" or "processing circuitry" may generally refer to any of the foregoing logic circuitry, alone or in combination with other logic circuitry, or any other equivalent circuitry.

[0127] Such hardware, software, firmware may be implemented within the same device or within separate devices to support the various operations and functions described in this disclosure. In addition, any of the described units, modules or components may be implemented together or separately as discrete but interoperable logic devices. Depiction of different features as modules or units is intended to highlight different functional aspects and does not necessarily imply that such modules or units must be realized by separate hardware or software components. Rather, functionality associated with one or more modules or units may be performed by separate hardware or software components, or integrated within common or separate hardware or software components.

[0128] The techniques or processes described in this disclosure may also be embodied or encoded in an article of manufacture including a computer-readable storage medium encoded with instructions. Instructions embedded or encoded in an article of manufacture including a computer-readable storage medium encoded, may cause one or more programmable processors, or other processors, to implement one or more of the techniques described herein, such as when instructions included or encoded in the computer-readable storage medium are executed by the one or more processors. Example computer-readable storage media may include random access memory (RAM), read only memory (ROM), programmable read only memory (PROM), erasable programmable read only memory (EPROM), electronically erasable programmable read only memory (EEPROM), flash memory, a hard disk, a compact disc ROM (CD-ROM), a floppy disk, a cassette, magnetic media, optical media, or any other computer readable storage devices or tangible computer readable media. The computer-readable storage medium may also be referred to as storage devices.

[0129] In some examples, a computer-readable storage medium comprises non-transitory medium. The term "non-transitory" may indicate that the storage medium is not embodied in a carrier wave or a propagated signal. In certain examples, a non-transitory storage medium may store data that can, over time, change (e.g., in RAM or cache).

[0130] Various examples have been described herein. Any combination of the described operations or functions is contemplated. These and other examples are within the scope of the following claims.

What is claimed is:

1. A method for modulating bladder activity, the method comprising:

determining, by processing circuitry, a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with activity of a bladder of a patient; and

controlling, by processing circuitry and according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the activity of the bladder of the patient.

2. The method of claim **1**, further comprising delivering, by the set of ultrasound transducers, the ultrasound energy to the nerve tissue associated with the activity of the bladder.

3. The method of claim **1**, wherein the nerve tissue comprises one or more stretch receptors associated with the bladder, and wherein determining the set of parameter values comprises determining the set of parameter values that at least partially defines ultrasound energy configured to inhibit the one or more stretch receptors.

4. The method of claim **1**, wherein the nerve tissue comprises at least one of a pudendal nerve, a pelvic nerve, a hypogastric nerve, an afferent nerve, a sciatic nerve, a tibial nerve, a sacral nerve, a sacral dermatome, a dorsal root ganglion, a spinal root, or a spinal cord.

5. The method of claim **1**, wherein the set of parameter values comprises an ultrasound frequency in a range from 300 kHz to 2.0 MHz.

6. The method of claim **1**, wherein the set of parameter values comprises an energy level of less than 0.7 watts per square centimeters.

7. The method of claim **1**, further comprising detecting a physiological event associated with bladder activity, and wherein controlling delivery of the ultrasound energy comprises, responsive to detecting the physiological event, controlling the set of ultrasound transducers to begin delivering the ultrasound energy to the nerve tissue.

8. The method of claim **7**, wherein a plurality of ultrasound transducers comprises the set of ultrasound transducers, and wherein detecting the physiological event comprises detecting, via at least one ultrasound transducer of the plurality of ultrasound transducers, a size of the bladder exceeding a bladder size threshold.

9. The method of claim **7**, wherein detecting the physiological event comprises detecting, via a sensor, at least one of an anxiety level, a patient orientation, a sleep state, a breathing rate, electromyography (EMG) information, or a heart rate.

10. The method of claim **1**, wherein a plurality of ultrasound transducers comprises the set of ultrasound transducers, and wherein the method further comprises imaging, with at least one ultrasound transducer of the plurality of ultrasound transducers, tissue associated with the bladder, and wherein determining the set of parameter values comprises determining, based on the imaging of the tissue associated with the bladder, at least one parameter value of the set of parameter values.

11. The method of claim **10**, wherein the at least one parameter value identifies, from a plurality of selectable ultrasound transducers, the set of ultrasound transducers for delivering the ultrasound energy to the nerve tissue.

12. The method of claim **1**, wherein an external patch comprises the set of ultrasound transducers and the processing circuitry, and wherein the external patch is configured to be attached to an external skin surface of the patient.

13. A system for modulating bladder activity, the system comprising:

processing circuitry configured to:

determine a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with activity of a bladder of a patient; and

control, according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the activity of the bladder of the patient.

14. The system of claim **13**, further comprising the set of ultrasound transducers configured to deliver the ultrasound energy to the nerve tissue associated with the activity of the bladder.

15. The system of claim **13**, wherein the nerve tissue comprises one or more stretch receptors associated with the bladder, and wherein the processing circuitry is configured to determine the set of parameter values that at least partially defines ultrasound energy configured to inhibit the one or more stretch receptors.

16. The system of claim **13**, wherein the nerve tissue comprises at least one of a pudendal nerve, a pelvic nerve, a hypogastric nerve, an afferent nerve, a sciatic nerve, a tibial nerve, a sacral nerve, a sacral dermatome, a dorsal root ganglion, a spinal root, or a spinal cord.

17. The system of claim **13**, wherein the set of parameter values comprises an ultrasound frequency in a range from 300 kHz to 2.0 MHz.

18. The system of claim **13**, wherein the processing circuitry is configured to:

detect a physiological event associated with bladder activity; and

responsive to detecting the physiological event, control the set of ultrasound transducers to begin delivering the ultrasound energy to the nerve tissue.

19. The system of claim **18**, wherein a plurality of ultrasound transducers comprises the set of ultrasound transducers, and wherein the processing circuitry is configured to detect, via at least one ultrasound transducer of the plurality of ultrasound transducers, a size of the bladder exceeding a bladder size threshold.

20. The system of claim **18**, wherein the processing circuitry is configured to detect, via a sensor, at least one of an anxiety level, a patient orientation, a sleep state, a breathing rate, electromyography (EMG) information, or a heart rate.

21. The system of claim **13**, wherein a plurality of ultrasound transducers comprises the set of ultrasound transducers, and wherein the processing circuitry is further configured to:

image, with at least one ultrasound transducer of the plurality of ultrasound transducers, tissue associated with the bladder; and

determine, based on the imaging of the tissue associated with the bladder, at least one parameter value of the set of parameter values.

22. The system of claim **13**, further comprising an external patch comprising the set of ultrasound transducers and the processing circuitry, and wherein the external patch is configured to be attached to an external skin surface of the patient.

23. A non-transitory computer readable medium comprising instructions that, when executed, cause processing circuitry to:

determine a set of parameter values that at least partially defines ultrasound energy configured to modulate nerve tissue associated with activity of a bladder of a patient; and

control, according to the set of parameter values, delivery of the ultrasound energy from a set of ultrasound transducers external to the patient and to the nerve tissue associated with the activity of the bladder of the patient.

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摘要(译)

本公开描述了用于递送配置成治疗膀胱功能障碍的疗法的装置，系统和技术。例如，系统可以被配置为通过确定一组参数值来调节膀胱活动，所述参数值至少部分地定义被配置为调节与患者的膀胱活动相关的神经组织的超声能量。然后，系统可以根据该组参数值控制超声能量从患者体外的一组超声换能器输送到与患者膀胱相关的神经组织，以调节膀胱活动并影响患者排尿。