US 20190150754A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2019/0150754 A1

Naik et al. (43) Pub. Date: May 23, 2019

(54) CIRCULATORY SYSTEM MONITOR

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(21) Appl. No.: **15/817,008**

(22) Filed: **Nov. 17, 2017**

Publication Classification

(51) **Int. Cl.**

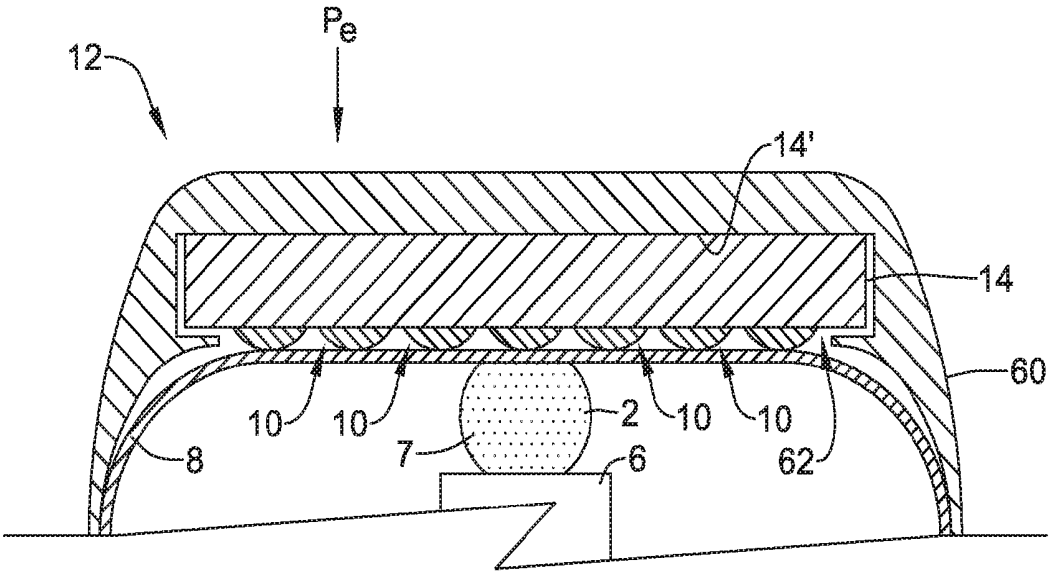
A61B 5/022	(2006.01)
A61B 5/021	(2006.01)
A61B 5/00	(2006.01)

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

CPC ***A61B 5/022*** (2013.01); *A61B 2560/0223* (2013.01); ***A61B 5/0004*** (2013.01); ***A61B 5/02108*** (2013.01)

(57) **ABSTRACT**

A circulatory system monitor may include a sensor array having a plurality of sensor assemblies and a controller in communication with the sensor array. The sensor array may be configured to be pressed against a patient's body and the controller may identify a sensor assembly of the plurality of sensor assemblies from which a signal is to be used to determine a circulatory system parameter of the patient's body. The controller may use a signal from the identified sensor assembly to determine the circulatory system parameter. The circulatory system monitor may include an inflatable member and a pump. The configuration of the sensor array and the inflatable member may facilitate ensuring alignment of at last one sensor assembly of the sensor array with a target artery to be monitored. The sensor assemblies may include a membrane that



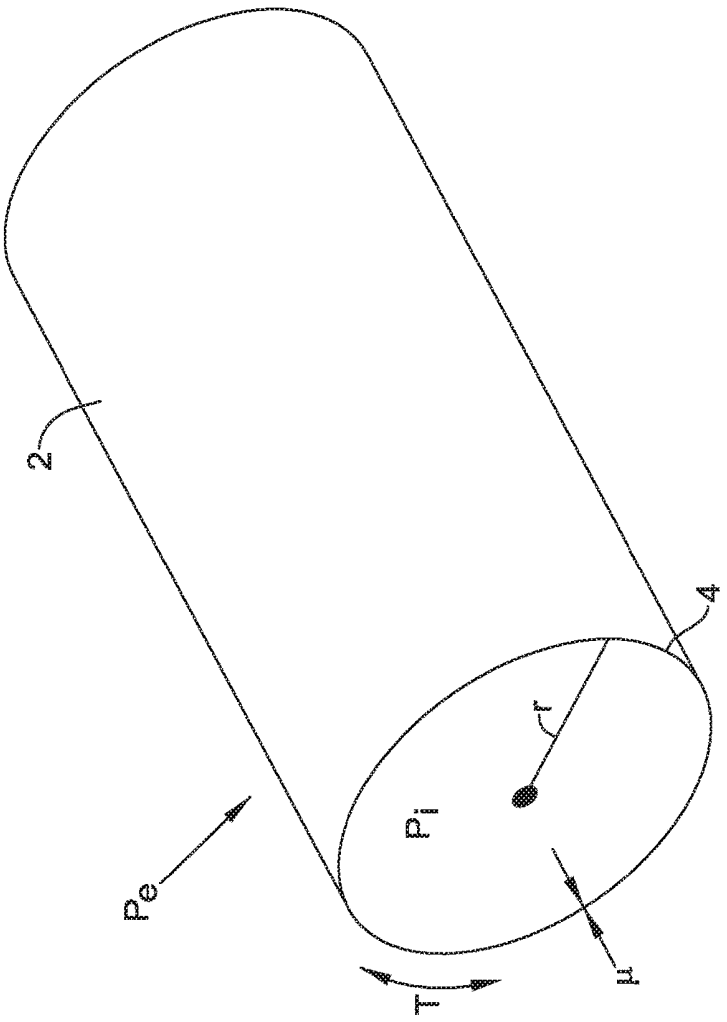


Figure 1

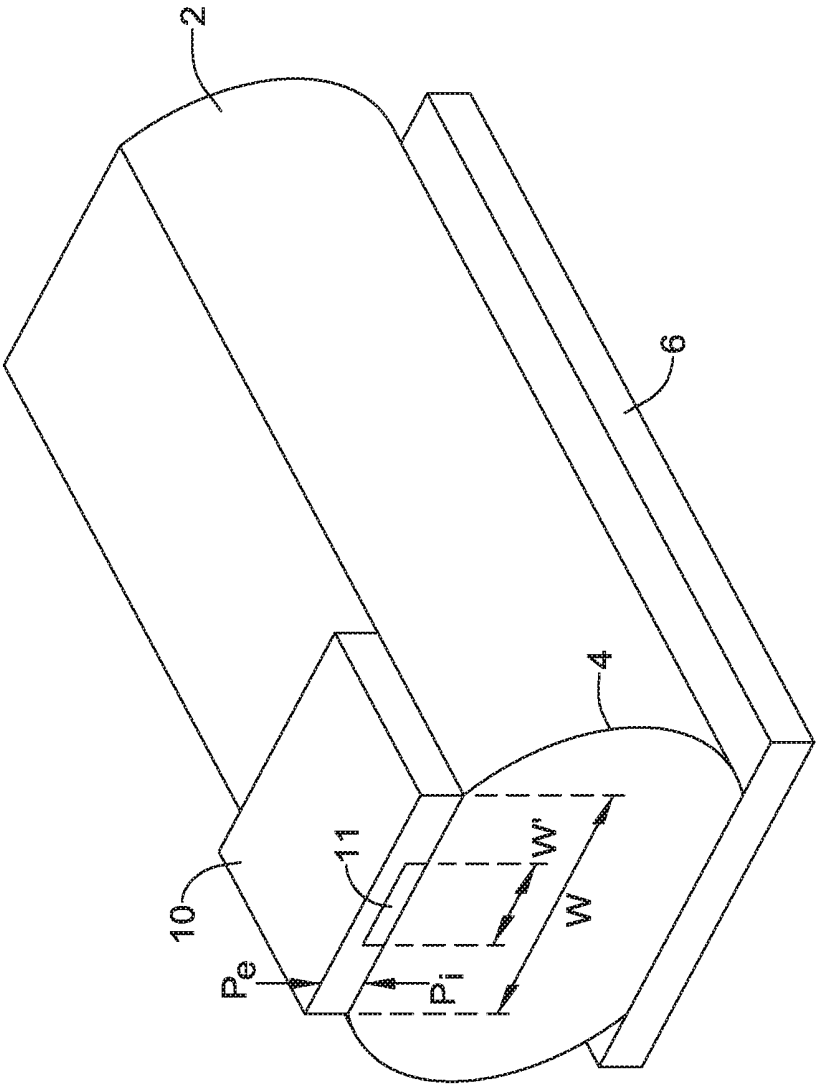


Figure 2

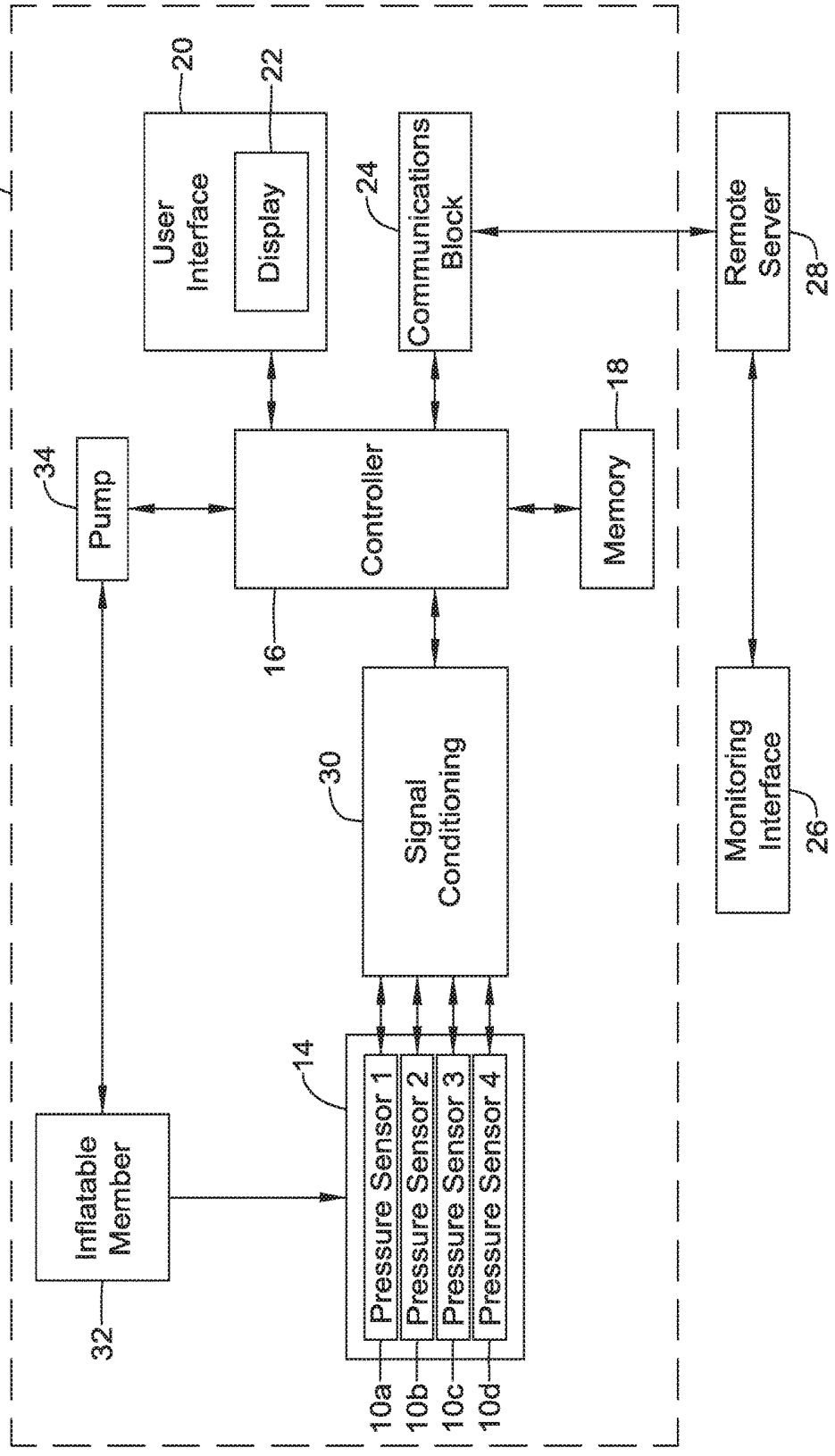

12
User Interface
20
Display
22
Communications Block
24
Remote Server
28
Pump
34
Controller
Memory
18
16
Signal Conditioning
30
Monitoring Interface
26
Inflatable Member
32
14
Pressure Sensor 1
Pressure Sensor 2
Pressure Sensor 3
Pressure Sensor 4
10a
10b
10c
10d

Figure 3

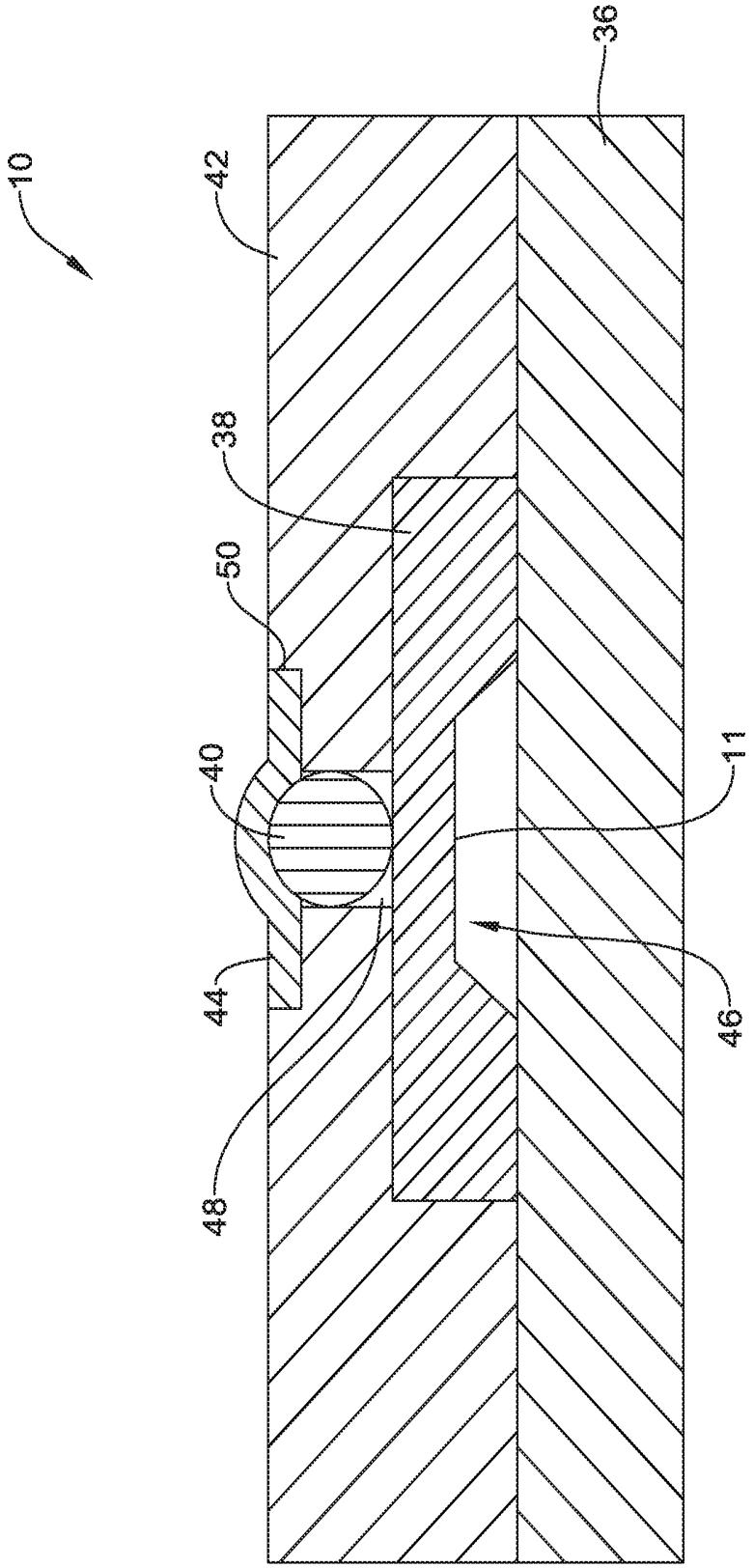


Figure 4

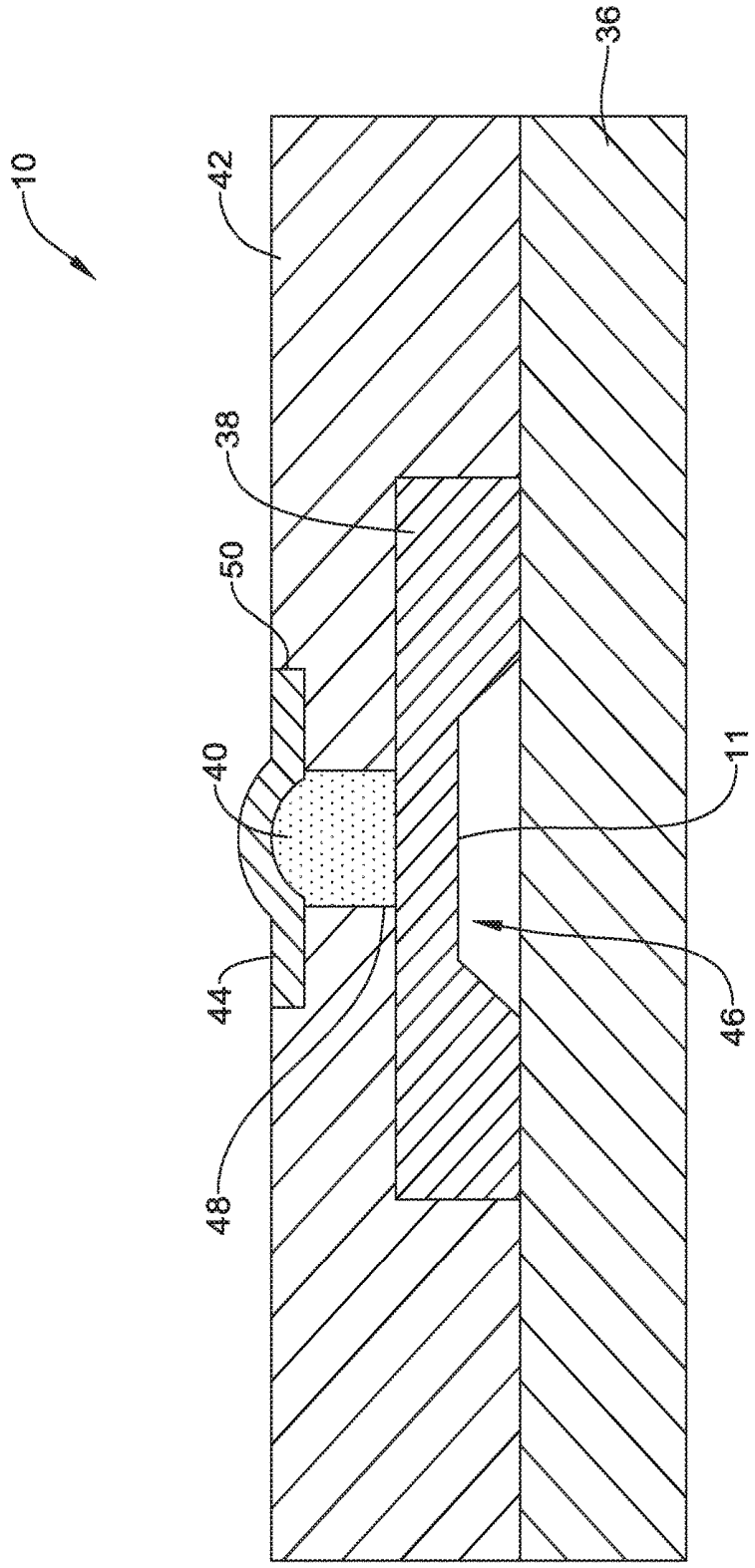


Figure 5

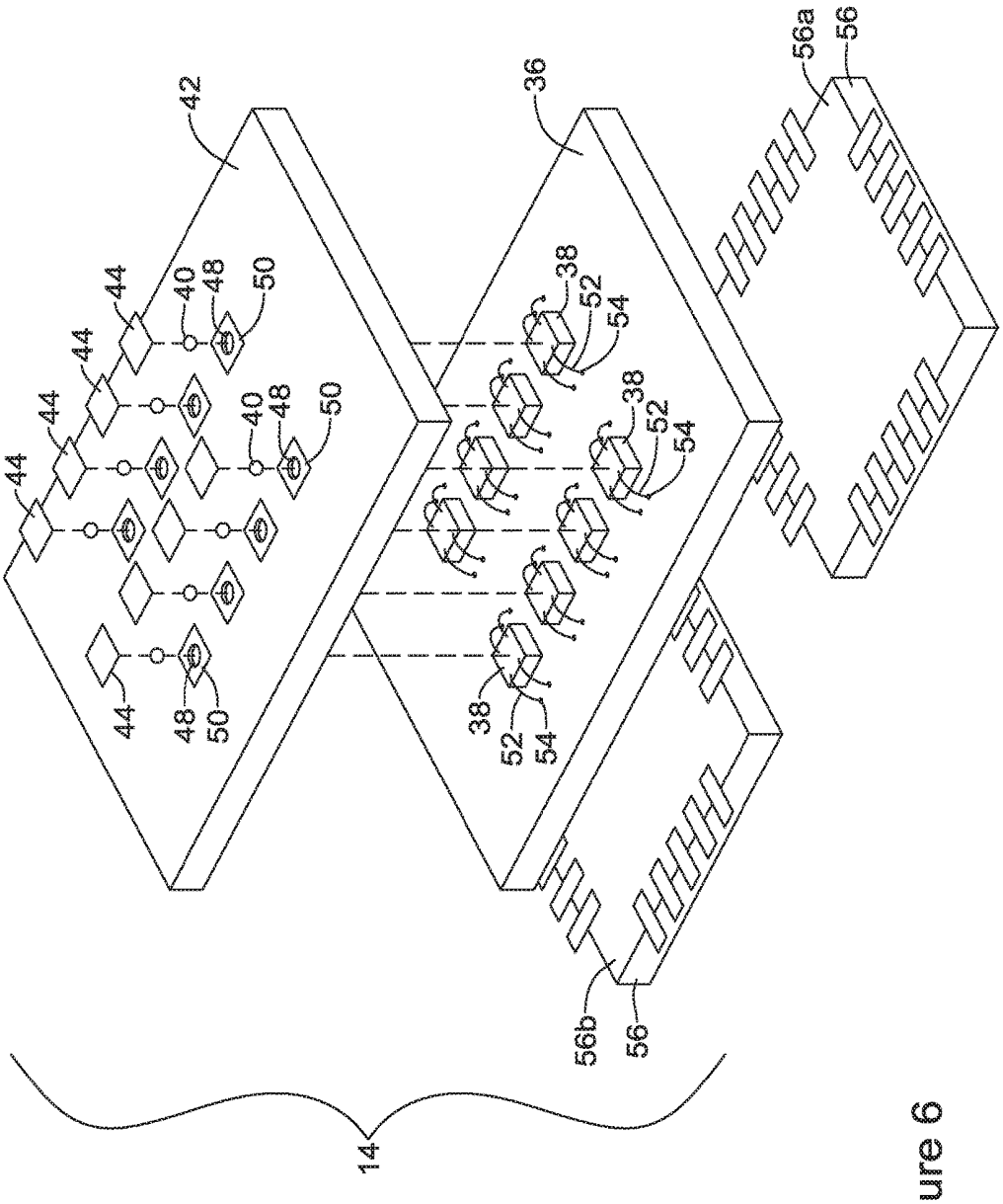
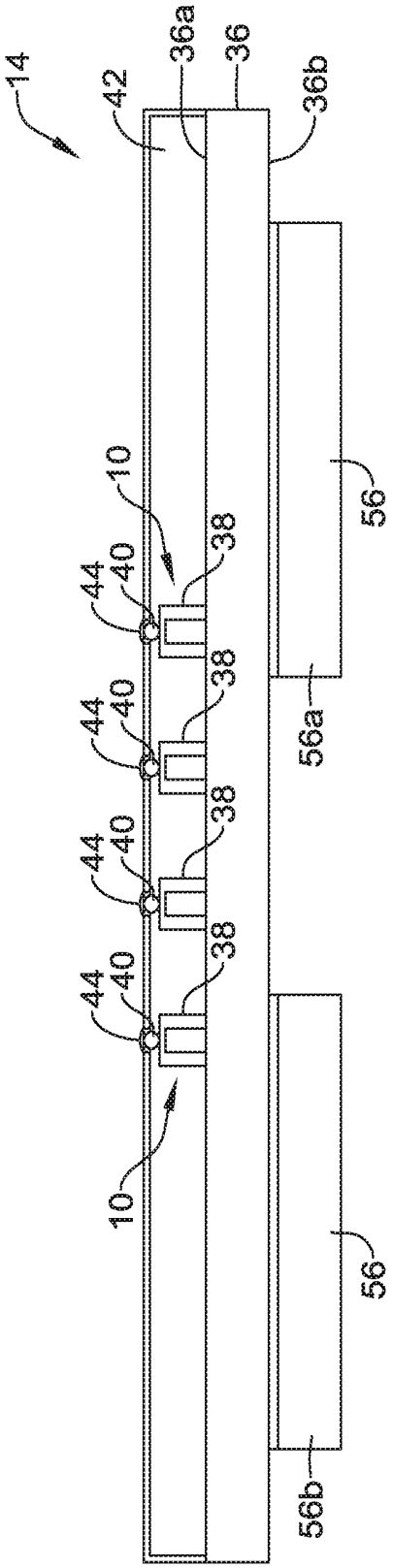


Figure 6


14
42
36a
36
36b
10
38
44
40
38
44
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40
38
44
40
10
56
56a
56
56b

Figure 7

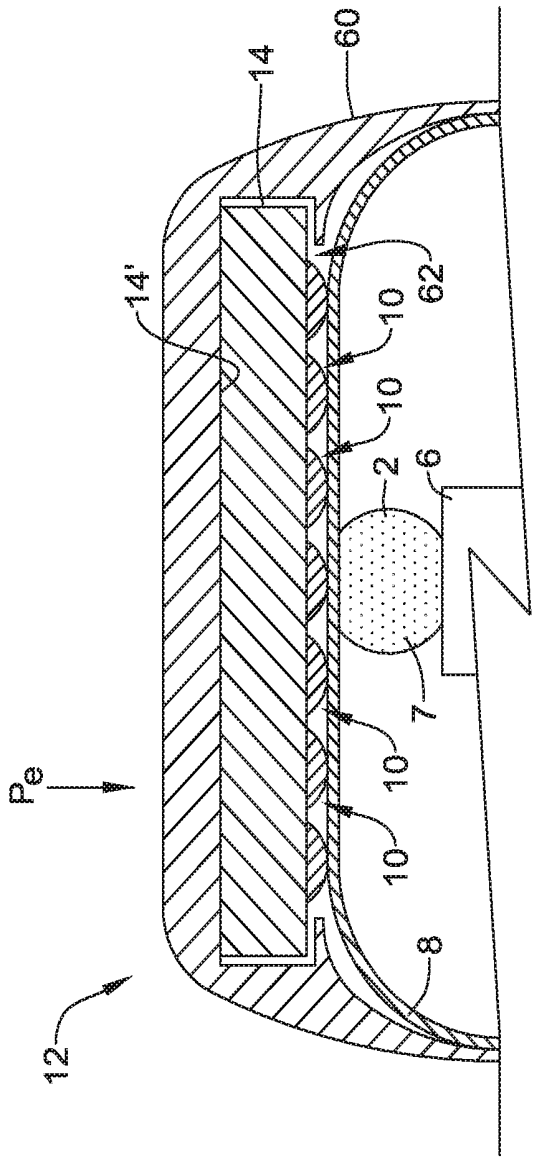

Figure 8

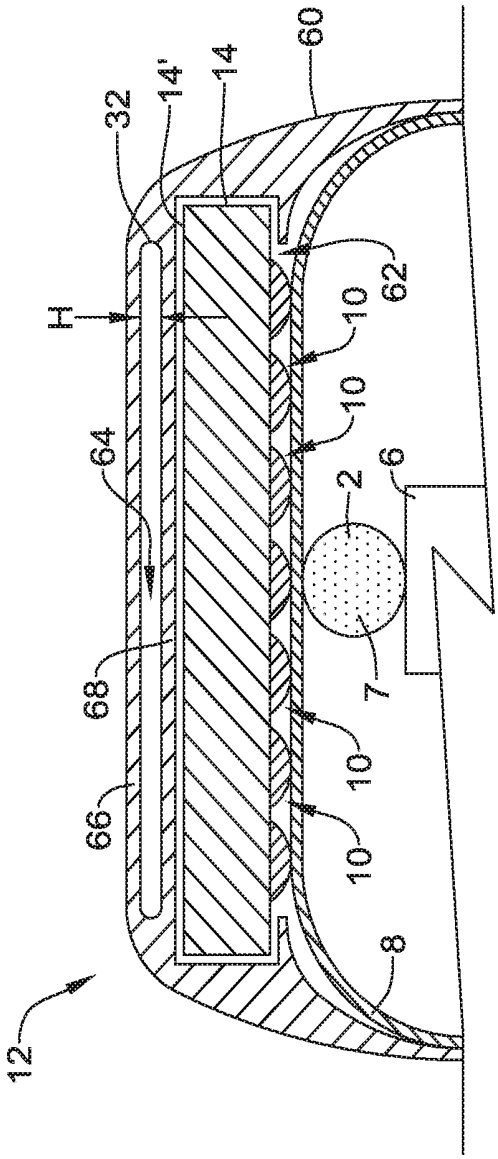

Figure 9

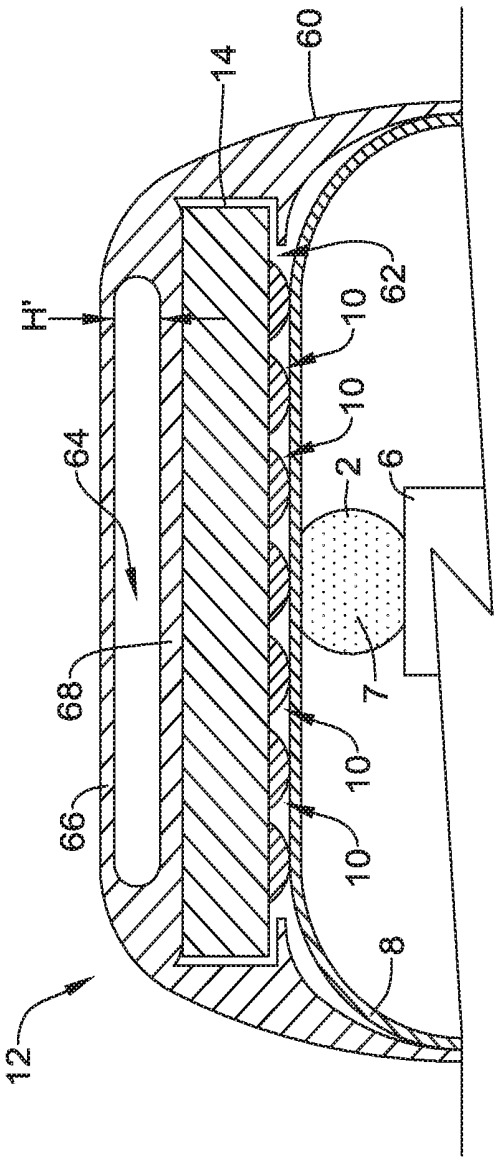

Figure 10

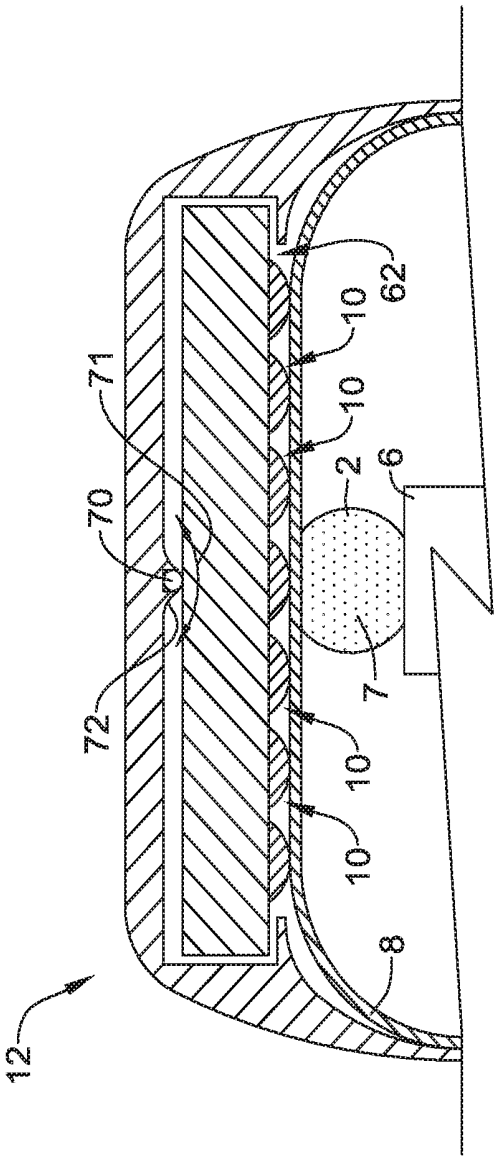

Figure 11

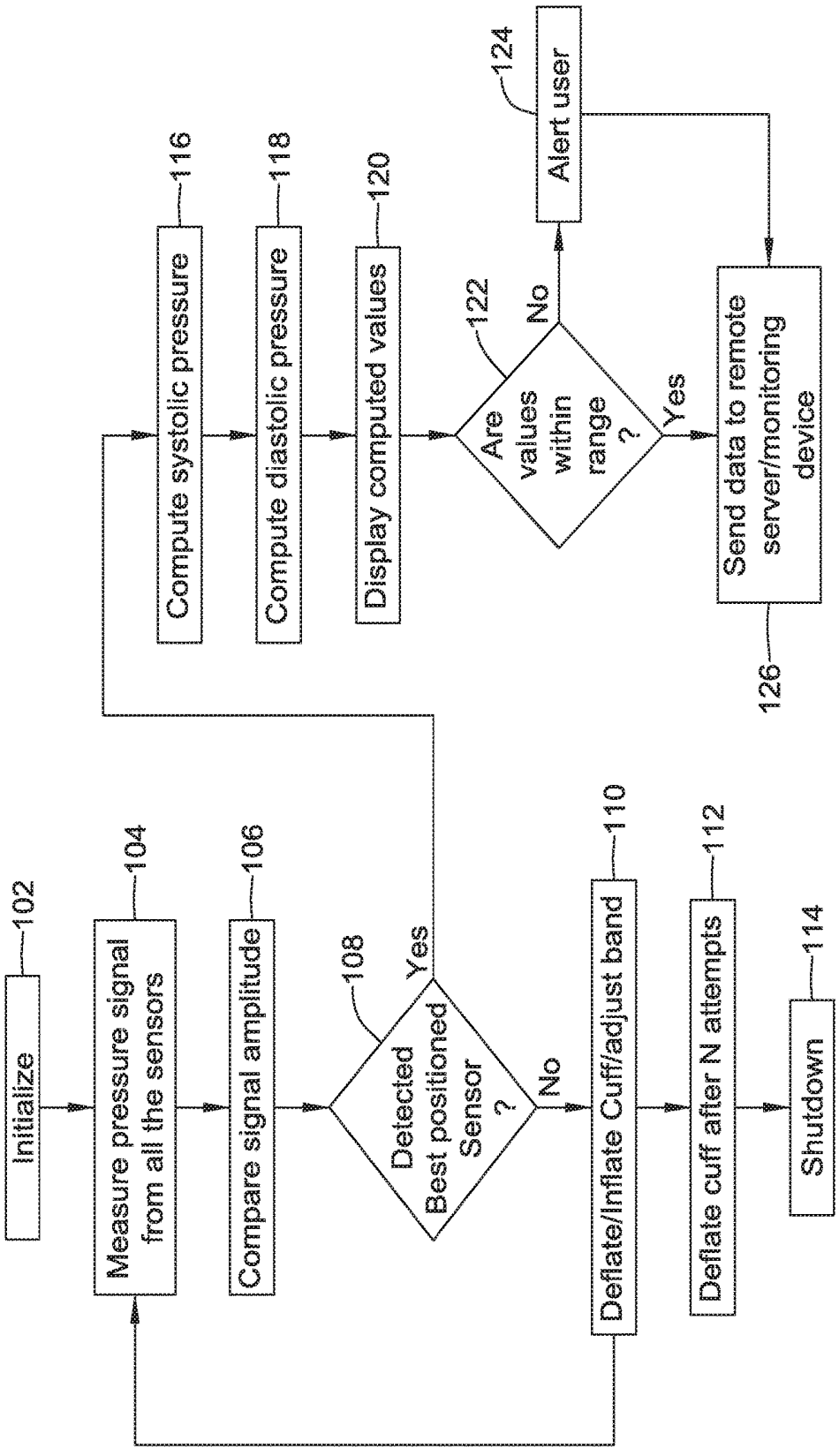
Initialize
102
Measure pressure signal from all the sensors
104
Compare signal amplitude
106
Detected Best positioned Sensor ?
108
Yes
No
Deflate/Inflate Cuff/adjust band
110
Deflate cuff after N attempts
112
Shutdown
114
Compute systolic pressure
116
Compute diastolic pressure
118
Display computed values
120
Are values within range ?
122
No
Yes
Alert user
124
Send data to remote server/monitoring device
126

Figure 12

CIRCULATORY SYSTEM MONITOR

TECHNICAL FIELD

[0001] The present disclosure relates generally to monitoring systems, and more particularly, to monitoring systems including sensors for sensing a force or pressure applied to the sensors.

BACKGROUND

[0002] Force sensors are often used to sense an external force applied to the sensors and provide an output signal representative of the applied force. Such sensors can be used in a wide variety of applications, including medical applications.

SUMMARY

[0003] The present disclosure relates generally to monitoring systems, and more particularly, to monitoring systems that include force sensors for sensing a force applied to the sensors. In one illustrative configuration, a monitoring system may be a circulatory monitoring system for monitoring and/or measuring, for example, blood pressure. The circulatory monitoring system may include a force sensor array and a controller in communication with the force sensor array. In some cases, the force sensor array is pressed against a patient's body, and the controller may be configured to identify a subset of force sensors of the plurality of force sensors from which a signal is to be used to determine a circulatory system parameter such as blood pressure.

[0004] An illustrative force sensor assembly that may be used in a monitoring system may include a substrate, a sense die secured relative to the substrate, a diaphragm, a cover secured relative to the substrate, a force transfer mechanism, and a film secured to or relative to the cover. The diaphragm may be part of the sense die and/or may be positioned relative to the sense die. The cover may have an opening that may be in registration with the diaphragm when the cover is secured relative to the substrate. The force transfer mechanism may extend at least partially into the opening of the cover and may be in contact with the diaphragm. The film, when provided, may be secured to the cover over the opening and the force transfer mechanism. The force transfer mechanism may interact with the film and the diaphragm such that force transfer mechanism transfers force applied to the film to the diaphragm.

[0005] An illustrative method of using a force sensor assembly may include applying a contact force to a force sensor array having a plurality of force sensors against a target area of a patient. Each force sensor of the force sensor array may be configured to provide a signal indicative of a corresponding force applied to a respective force sensor. While the contact force is applied to the force sensor array against the target area of a patient, a circulatory system parameter may be measured based on the signals from each force sensor in the force sensor array. The method may include determining which force sensor of the force sensor array is providing a strongest measure of the circulatory system parameter (e.g. blood pressure) and use a signal from the force sensor of the force sensor array that is determined to be providing the strongest measures of the circulatory system parameter during subsequent measures of the circulatory system parameter at the target area.

[0006] The preceding summary is provided to facilitate an understanding of some of the innovative features unique to the present disclosure and is not intended to be a full description. A full appreciation of the disclosure can be gained by taking the entire specification, claims, drawings, and abstract as a whole.

BRIEF DESCRIPTION

[0007] The disclosure may be more completely understood in consideration of the following description of various illustrative embodiments of the disclosure in connection with the accompanying drawings, in which:

[0008] FIG. **1** is a schematic perspective view of an artery depicting elements of Laplace's Law of Cylindrical Tubes;

[0009] FIG. **2** is a schematic perspective view of an artery depicting Tonometry principles based on Laplace's Law of Cylindrical Tubes;

[0010] FIG. **3** is a schematic block diagram of an illustrative circulatory system monitor;

[0011] FIG. **4** is a schematic cross-sectional view of an illustrative sensor assembly with a ball-shaped force transmitting member;

[0012] FIG. **5** is a schematic cross-sectional view of an illustrative sensor assembly with a force transmitting member formed from a fluid, gel, or semi-solid material;

[0013] FIG. **6** is a schematic exploded perspective view of an illustrative sensor array;

[0014] FIG. **7** is a schematic cross-sectional assembled view of the illustrative sensor array depicted in FIG. **6**;

[0015] FIG. **8** is a schematic cross-sectional view of an illustrative circulatory system monitor on a patient;

[0016] FIG. **9** is a schematic cross-sectional view of an illustrative circulatory system monitor on a patient, with an inflatable member in a deflated configuration;

[0017] FIG. **10** is a schematic cross-sectional view of an illustrative circulatory system monitor on a patient, with an inflatable member in an inflated configuration;

[0018] FIG. **11** is a schematic cross-sectional view of an illustrative circulatory system monitor on a patient, with a pivot element located between a sensor array and a band; and

[0019] FIG. **12** is a schematic flow diagram of an illustrative calibration and computing approach for use with a circulatory system monitor.

[0020] While the disclosure is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit aspects of the disclosure to the particular illustrative embodiments described herein. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure.

DESCRIPTION

[0021] The following description should be read with reference to the drawings wherein like reference numerals indicate like elements throughout the several views. The description and drawings show several embodiments which are meant to be illustrative of the disclosure.

[0022] Blood pressure is a fundamental measurement taken in healthcare. The monitoring of blood pressure may have strong applications in many clinical fields including

stroke prevention, obstetrics, neurology, vascular medicine, diabetes, and so on. Invasive measurements from an arterial line (e.g., invasive arterial blood pressure (IAP)) is generally considered to be the gold standard for blood pressure measuring. Non-invasive blood pressure (NBP) monitoring, however, may be a simpler measurement with limited, if any, patient discomfort.

[0023] The present disclosure pertains generally to sensing and monitoring circulatory system parameters, such as blood pressure, pulse, pulse wave velocity, and/or other circulatory system parameters. Although not required, the devices and methods of this disclosure may utilize or may be configured to utilize arterial tonometry to sense and monitor one or more circulatory system parameters. In some cases, the concepts of the present disclosure may be utilized for sensing and/or monitoring pressures or forces in other medical applications or non-medical applications. As such, although the disclosed concepts are described herein with respect to sensing and monitoring certain circulatory system parameters, these concepts may be applied to other medical and non-medical applications.

[0024] Arterial tonometry is a technique that may permit NBP monitoring within a superficial artery. An example superficial artery may be a radial artery of the wrist or other superficial artery of the circulatory system. The arterial tonometry technique is a way to detect blood pressure percutaneously by pressing a pressure/force sensor on a superficial artery (e.g., the radial artery near a person's wrist or other artery). In the arterial tonometry technique, part of the artery may be made flat or flatter (e.g., may be applanated) by applying a force to the skin adjacent the artery. A pressure/force sensor pressed against the skin may be used to sense the pressure/force exerted by the patient's blood against the inside of the artery wall, through the skin, and to the pressure/force sensor.

[0025] FIGS. **1** and **2** depict the physics of arterial tonometry. FIG. **1** depicts an artery **2** having an external pressure, P_e, applied thereto and an internal pressure, P_i. The artery **2** may have a wall **4** with a wall-thickness, μ, a radius of wall curvature, r, and a wall tension, T. Laplace's Law for a cylindrical tubes states:

$$T=(P_t*r)/\mu \quad (1)$$

and

$$P=P_i-P_e \quad (2)$$

Laplace's Law of Cylindrical Tube shows a relationship between wall tension, T, and transmural pressure, P_t, and the radius of wall curvature, r. Based on this relationship, when a sensor assembly **10** applanates the wall **4** of the artery **2**, as shown for example in FIG. **2**, the radius of the wall curvature, r, goes to infinity and external pressure, P_e, acting on the sensor assembly **10** to sandwich the artery **2** between the sensor assembly **10** and a bone, muscle or other anatomical structure **6** is equivalent to internal pressure, P within the artery **2**.

$$P_t = Pi - Pe = \frac{\mu T}{r} r \to \infty = 0 \quad (3)$$

As a result, the pressure acting on the sensor assembly **10** corresponds to the internal pressure and an output from the sensor assembly **10** reflects the internal pressure, P_i, of the artery **2** and thus, arterial tonometry techniques may be utilized for sensing blood pressure and/or other related parameters of the circulatory system in a non-invasive manner (e.g., from exterior the skin of a patient or at least exterior the vessel in which a pressure or other parameter is being monitored). For best measurements of pressure within the artery **2** using arterial tonometry, a diaphragm **11** of the sensor assembly **10** may have a width, W', that is less than a width, W, of the surface of the artery **2** that is applanated by the sensor assembly **10**.

[0026] Arterial tonometry may be sensitive to alignment of a diaphragm of the sensor assembly **10** with the flatter part (e.g., an applanated part) of the artery. The present disclosure discloses a circulatory system monitor **12** that may help address this sensitivity by facilitating optimal placement of one or more sensor assemblies **10** relative to the applanated part of the artery to obtain strong and accurate pressure/force measurements. For example, the disclosed circulatory system monitor **12** may facilitate placing a pressure sensor assembly **10** entirely or substantially entirely within the width, W, of the applanated surface of the artery.

[0027] A circulatory system monitor **12** may take on any suitable form. In some cases, the circulatory system monitor **12** may have a closed loop configuration. FIG. **3** depicts a schematic diagram of an illustrative closed loop circulatory system monitor **12**. Although the circulatory system monitor **12** is depicted as having a closed loop, such a closed loop configuration is not required in all cases.

[0028] As shown in FIG. **3**, the circulatory system monitor **12** may include a sensor array **14** having a plurality of sensor assemblies **10** (e.g., pressure and/or force sensor assemblies) and a controller **16** in communication with the sensor array **14**. The controller **16** may be configured to receive signals from the sensor assemblies **10** of the sensor array **14** and identify one (or more) of the sensor assemblies **10** from which a signal is to be used in current and/or future analyses, and then determine a circulatory system parameter based on the signal from the identified sensor assembly **10**. In some cases, the controller **16** may determine the circulatory system parameter based only on the signal from the identified sensor assembly **10** and/or the controller **16** may determine the circulatory system parameter based on signals from a plurality of sensor assemblies **10** including or excluding signals from the identified sensor assembly **10**. As is discussed in greater detail below, the identified sensor assembly **10** may be identified by the controller **16** in one or more manners including, but not limited to, by identifying the sensor assembly **10** with the strongest signal, most consistent signal, signal closest to an expected signal range, and/or one or more other signal related parameters. Circulatory system parameters sensed or determined by the controller **16** may include, but are not limited, to blood pressure, pulse rate, pulse wave velocity, etc.

[0029] In addition to performing analyses on signals received from the sensor array **14**, the controller **16** may be configured to control operation of the sensor array **14**. In one example, the controller **16** may be configured to turn on and/or off various sensor assemblies **10** of the sensor array **14** to limit noise and/or reduce power consumed by the sensor array **14** after one or more sensors have been identified for use in taking measurements. As shown for example in FIG. **3**, the sensor array **14** may include a first sensor assembly **10***a*, a second sensor assembly **10***b*, a third sensor

assembly **10***c*, and a fourth sensory assembly **10***d*. In such instances and when the controller **16** is monitoring blood pressure of a patient, the controller **16** may identify which sensor assembly **10** is best positioned with respect to the patient's artery based on signals from the sensor assemblies **10***a*, **10***b*, **10***c*, **10***d*, and then turn off and/or limit power supplied to one or more of the sensor assemblies **10** not identified as being in the best position for sensing the patient's blood pressure.

[0030] The controller **16** may include a microprocessor or microcontroller or the like, and may be operatively coupled to a memory **18**. The memory **18** may be used to store any desired information, such as control algorithms, set points, schedule times, diagnostic limits such as, for example, blood pressure limits, pulse rate limits, pulse wave form limits, and the like. The memory **18** may be any suitable type of storage device including, but not limited to, RAM, ROM, EPROM, flash memory, a hard drive, and/or the like. In some cases, the controller **16** may store information within the memory **18**, and may subsequently retrieve the stored information from the memory **18**. In some cases, the controller **16** may include and/or be in communication with a timer (not shown).

[0031] The illustrative circulatory system monitor **12** may optionally include signal conditioning circuitry **30**, as shown in FIG. **3**. In instances where signal condition circuitry **30** is included in circulatory system monitor **12**, the signal condition circuitry **30** may be mounted on a substrate (e.g., as discussed with respect to FIGS. **5** and **6**). In some cases, the signal conditioning circuitry **30** may include a microprocessor and/or a microcontroller, an application specific integrated circuit ("ASIC"), and/or an application specific standard product ("ASSP"). In some cases, the signal conditioning circuitry **30** may be (at least partially) incorporated into the controller **16**.

[0032] When provided, the signal conditioning circuitry **30** may include circuitry that receives an output signal from the sensor array **14**, and in response may generate output signals having magnitudes that are representative of a magnitude of a force or pressure applied to the sensor assemblies **10** of the sensor array **14**. The signal conditioning circuitry **30** may condition the output signals of the sensor assemblies **10** to correct for repeatable variations, such as offset, sensitivity, non-linearity, temperature effects, and/or other variations. Further, the signal conditioning circuitry **30** may condition the output signal to compensate for temperature-dependent variations in the electrical characteristics and/or to account for a nonlinear relationship between changes in the electrical characteristic and corresponding changes in the magnitude of the force. In some cases, the signal conditioning circuitry **30** may facilitate comparing measurement signals to reference signals from the sensor assemblies **10** of the sensor array **14**.

[0033] The circulatory system monitor **12** may include a user interface **20** operatively coupled to the controller **16**, but this is not required, where the user interface **20** may include a display **22** in communication with the controller **16** to display information related to monitored circulatory system parameters. The user interface **20**, when provided, may be any suitable user interface that permits the circulatory system monitor **12** to display and/or solicit information, as well as accept one or more user interactions with the circulatory system monitor **12**. For example, the user interface **20** may permit a user to locally enter data such as diagnostic limits, configuration settings, response configurations for responding to alerts, and the like. The user interface **20** may take the form of a watch face-like user interface or may be a user interface on a device remote from the sensor array **14**.

[0034] In one example, the user interface **20** may be a physical user interface that is accessible at the circulatory system monitor **12**, and may include a display **22** and/or a distinct keypad. The display **22** may be any suitable display and in some cases may be backlit or have a different lighting configuration. In some instances, a display may include or may be a liquid crystal display (LCD), and in some cases an e-ink display, fixed segment display, a light emitting diode (LED) display, or a dot matrix LCD display. Alternatively or in addition, the user interface **20** may be a touch screen LCD and/or LED panel or other touch sensitive screen that functions as both display and keypad. The touch screen panel may be adapted to solicit values and/or selections for a number of operating parameters and/or to receive such values, but this is not required. In still other cases, the user interface **20** may be a dynamic graphical user interface.

[0035] The circulatory system monitor **12** may be a connected device that is capable of connecting to one or more networks (e.g., wired and/or wireless local area network (LAN), wide area network or global network (WAN) including, for example, the Internet). In some cases, the circulatory system monitor **12** may be accessed from, controlled from, and/or have data therefrom analyzed at a remote location over the network using a remote wired or wireless device such as, for example, a smart phone, a tablet computer, a laptop or personal computer, a wireless network-enabled key fob, an e-reader, a remote server, and/or the like.

[0036] To facilitate connecting to other devices, the circulatory system monitor **12** may include a communications block **24** (e.g., a communications component) in communication with the controller **16** and having one or more communication ports. The communications block **24** may facilitate connecting to other devices via a wired or wireless communication link. In one example, the communications block **24** may facilitate communicating with and/or connecting to other devices via one or more communication protocols including, but not limited to, cellular communication, ZigBee, Bluetooth, WiFi, IrDA, dedicated short range communication (DSRC), EnOcean, and/or any other suitable common or proprietary wireless protocol, as desired.

[0037] The circulatory system monitor **12** may be in communication with a remote computing device(s) (e.g., a monitoring interface **26**, remote server **28**, and/or other device) via the communications block **24** and communicate information (e.g., data, analyses, alerts, etc.) from the controller **16** to the remote computing device(s). In some cases, the circulatory system monitor **12** may communicate directly to the remote server **28**. The remote server **28** may analyze information and/or data received from the circulatory system monitor **12** and send results and/or alerts back to the circulatory system monitor **12** or to the monitoring interface **26**. Alternatively or in addition, when an alert is identified, the remote server **28** may send the alert to the monitoring interface **26** and/or the circulatory system monitor **12**. The circulatory system monitor **12** may display the alert on the user interface **20** of the circulatory system monitor **12**.

[0038] The monitoring interface **26** may include any suitable computing device. In one example, the monitoring

interface **26** may be a remote or local user device including, but not limited to a smart phone, a tablet computer, a laptop or personal computer, a wireless network-enabled key fob, an e-reader, and/or the like.

[0039] To facilitate applanating of the patient's artery with the sensor array **14**, the circulatory system monitor **12** may include, for example, an inflatable member **32** and a pump **34** in communication with the inflatable member **32** for inflating and/or deflating the inflatable member **32**, The inflatable member **32**, when inflated, may provide an inward force to the sensor array **14** and against the artery. The inflatable member **32** may be part of a strap, band or other mechanism that extends around the patient's wrist or the like, with the sensor array **14** between the inflatable member **32** and the patient's skin. Alternatively or in addition, the circulatory system monitor **12** may include one or more other mechanisms for applanating a patient's artery including, but not limited to, adjustable straps and/or other manual or automated adjustable mechanisms configured to provide a radially inward force on a portion of a patient's skin.

[0040] When provided, the inflatable member **32** may be in mechanical communication with the sensor array **14** and may be configured to apply a force to the sensor array **14** against the patient's body. In some cases, the inflatable member **32** may be in direct contact with the sensor array **14** (e.g., the inflatable member **32** may contact a portion of the sensor array **14**) or indirect contact with the sensor array **14** (e.g., the inflatable member **32** may interact with the sensor array **14** through a membrane or the like, by causing a tightness of a band including the sensor array **14** to change based on inflating or deflating the inflatable member **32**).

[0041] A pump **34** may be any suitable type of pump. The pump **34** may be a manual operated pump, or may include a motor or the like to operate the pump. The pump **34** may be connected to the inflatable member **32** or configured to be selectively connected to the inflatable member **32**. The pump **34** may be manually actuated or actuated in an automated manner to inflate and/or deflate the inflatable member **32**. In some cases, the pump **34** and/or the inflatable member **32** may be connected to and/or in communication with the controller **16** to monitor an amount of force applied to the sensor assembly **10** by the inflatable member **32** and/or to actuate the pump **34**.

[0042] FIGS. **4** and **5** depict a schematic cross-sectional views of the illustrative sensor assembly **10**. The illustrative sensor assembly **10** includes a substrate **36**, a sense die **38** defining or including the diaphragm **11**, a force transmitting member **40** (e.g., a force transfer mechanism) configured to transmit a force acting thereon to the diaphragm **11**, a cover **42** extending over at least a portion of the substrate **36** and the sense die **38**, and a membrane **44** extending over the force transmitting member **40** to help provide a seal over the force transmitting membrane. Additionally or alternatively, the sensor assembly **10** may include one or more other features including, but not limited to, structural supports, wire bonds, electrical traces, bond pads, one or more constraints, and/or other features facilitating sensing and/or monitoring a force or pressure.

[0043] The substrate **36** may be a suitable type of substrate configured to support the sense die **38**. In some cases, the substrate **36** may be a printed circuit board (PCB), a printed wiring assembly (PWA), a printed wiring board (PWB), and/or other device configured to facilitate supporting the sense die **38** and/or other electronic components. In some cases, the substrate **36** may be a thick film printed ceramic board, but this is not required. In one example, the substrate **36** may be made, at least in part, of FR **4** laminate and/or other material. Alternatively or in addition, the substrate **36** may be a flexible PCB.

[0044] The sense die **38** of the sensor assembly **10** may be arranged to sense an absolute pressure, where a pressure or force acting on the force transmitting member **40** and the diaphragm **11** is referenced against a vacuum pressure. When sensing an absolute pressure, the sense die **38** may be fabricated to include a vacuum or reference cavity **46** immediately behind the diaphragm **11**, such that a pressure or force acting on the force transmitting member **40** and/or the diaphragm **11** is referenced against a vacuum (not specifically shown) or other reference pressure. Alternatively, the sense die **38** may be arranged to sense a gauge pressure. In such a gauge pressure sensor, the substrate **36** may include an opening **48** extending from the sense die **38** through the substrate **36** (e.g., extending through the substrate **36** from a first side to a second side of the substrate **36**) to allow a reference pressure (e.g. atmosphere) to reach the back side of the sense die **38**. Example sensor die may include, but are not limited to, those described in U.S. Pat. Nos.: 7,503,221; 7,493,822; 7,216,547; 7,082,835; 6,923,069; 6,877,380, and U.S. patent application publications: 2010/0180688; 2010/0064818; 2010/00184324; 2007/0095144; and 2003/0167851, all of which are hereby incorporated by reference.

[0045] The cover **42** may be any suitable type of cover configured to help protect the sense die **38** from external forces and material (e.g. fluids) that may affect the sensing and/or monitoring capabilities of the sensor assembly **10**. In some cases, the cover **42** may be made of metal, polymer, and/or other suitable material. In some cases, the cover **42** may include an opening **48** for receiving the force transmitting member **40**, at least partially containing the force transmitting member **40**, and allowing the force transmitting member **40** to contact the diaphragm **11**.

[0046] The force transmitting member **40** may have any suitable configuration for transferring a force or pressure acting on the force transmitting member **40** to the diaphragm **11**. In some cases, the force transmitting member **40** may include a spherical object, as shown in FIG. **4**, a pin, an extender, a button, any other force transmitting device, and/or a combination thereof. If desired, only part of the outside surface of the force transmitting member **40** may be spherical in shape or take on a particular shape. The force transmitting member **40** may be made of any material. For example, the force transmitting member **40** may include stainless steel, other suitable metal and/or other suitable material. In some cases, the force transmitting member **40** may include a ball bearing (e.g., a stainless steel ball bearing or other ball bearing). It is contemplated, however, that other generally spherical and other shaped elements may be used as or as part of the force transmitting member **40**, if desired, including polymer based objects.

[0047] In some cases, the force transmitting member **40** may be made from a suitable fluid, gel, or semi-solid material, as shown in FIG. **5**. Example types of fluid, gel, or semi-solid materials may include dielectric material, non-compressible material, biocompatible material, colored material, non-colored material, and/or one or more other types of material. Example materials acceptable for use as or in fluid, gel, or semi-solid force transmitting members **40**

may include fluoro-silicone gel, a cured silicone rubber or silicone elastomer, a cured liquid silicone rubber, an oil and/or any other suitable material. When the force transmitting member **40** is a non-compressible fluid or gel, it may be at least partially contained in the opening **48** of the cover **42** by the membrane **44**.

[0048] Silicone elastomers may be polysiloxanes and/or polydimethylsiloxanes. Example silicone elastomers may include SILASTIC® MDX4-421 Biomedical grade elastomer from Dow Corning Corporation, SILPURAN® 2430 (e.g., an addition curing RTV silicone rubber curing to a silicon elastomer) from Wacker Chemie AG, and/or one or more other silicone elastomers.

[0049] The membrane **44** may extend over the force transmitting member **40** and the opening **48** to protect the force transmitting member **40** and the sense die **38** from contaminants (e.g. sweat and/or other body fluids or the like). In some cases, the membrane **44** may form a hermetic seal with the cover **42**. The membrane **44** may be made from a suitable material and have a suitable thickness that allows for a force or pressure to be transferred to the force transmitting member **40** while still protecting the force transmitting member **40** and the sense die **38** from contaminants. Illustrative membranes **44** may be made from polymers, nylon, a cured silicon elastomer, and/or other materials. In some case, the material of the membrane **44** may be a film element. In one example, the membrane **44** may be a nylon film. Although a thickness of the membrane **44** may differ based on the material of the membrane **44**, the membrane **44** may generally have a thickness between about 0.01 millimeter (mm) or thinner and 1.0 mm or thicker. In one example, a membrane may have a thickness between about 0.1 mm and 0.2 mm. The membrane **44** may be connected to the cover **42** in any suitable manner. In some cases, the membrane **44** may be secured to the cover **42** with an adhesive, a welding technique, a laser welding technique, a molding technique, and/or other suitable techniques.

[0050] To facilitate a connection between the membrane **44** and the cover **42**, the cover **42** may have a recess or an indentation **50** extending entirely or at least partially around a perimeter of the opening **48** for receiving the membrane **44**, but this is not required. When included, the indentation **50** may have a depth equal to or substantially equal to a thickness of the membrane **44** or other depth.

[0051] In some cases, the membrane **44** and the cover **42** may interact to render the sensor assembly **10** compliant with at least an ingress protection (IP) **67** rating, as defined by international standard 60529 of the International Electrotechnical Commission (i.e., IEC 60529).

[0052] The first digit in an IP 67 rating (i.e., the "6") indicates such a sensor assembly **10** is dust tight (e.g., there is no ingress of dust to the sense die **38** and there is complete protection against contact). The second digit in an IP 67 rating (i.e., the "7") indicates such a sensor assembly **10** may be immersed in up to one (1) meter (m) of water without harm to the sense die **38**. One example membrane **44** and cover **42** that would receive the IP 67 rating may be a nylon membrane **44** having a thickness between about 0.1 mm and about 0.2 mm, where the membrane **44** is laser welded to the cover **42** around an entirety or substantially an entirety of a perimeter of the opening **48** in the cover **42**.

[0053] FIG. **6** is a perspective exploded view of a packaging of the sensor array **14**, including the substrate **36**, a plurality of sense die **38** (e.g., two rows of four sense die **38** in each row or any other suitable sense die **38** configuration), the cover **42**, a plurality of force transmitting members **40** configured to be received within corresponding openings **48** of the cover **42**, and a plurality of membranes **44** each configured to be received within a corresponding recess or indentation **50** in the cover **42**. Alternatively, the sensor array **14** may take on one or more other configurations. In one example of a different configuration, one or more of the sense die **38** may have its own cover **42** and/or own substrate **36** separate from a cover **42** and/or substrate **36**, respectively, of one of the other sense die **38**. A layout of the plurality of sense die **38** may have any suitable configuration and may be configured to position at least one sense die **38** directly over an artery or other vessel of the circulatory system for monitoring, and at least one other sense die **38** spaced sufficiently far so as to not be directly over the same artery or other vessel of the circulatory system.

[0054] Components of the sensor array **14** may be connected to one another with one or more suitable connections including, but not limited to welding, soldering, adhesives, and/or one or more other connections. In some cases, the components of the sensor array **14** may be connected to one another using an adhesive such as a silicone, RTV, a silicone-epoxy, a soft epoxy, or a regular or hard epoxy. The adhesive may include a conductive adhesive, a nonconductive adhesive, or a combination of conductive and nonconductive adhesives. Any suitable conductive adhesive and nonconductive adhesive may be used. One example nonconductive adhesive is RTV6424, which is available from Momentive Performance Materials Inc. of Waterford, N.Y. One example conductive adhesive may be SDC5000, which is available from Momentive Performance Materials Inc. of Waterford, N.Y. These are just examples, and it is contemplated that any other suitable conductive and/or nonconductive adhesive may be used, as desired. When provided, the combination of conductive and nonconductive adhesives may be provided in a pattern to electrically connect electronic components of the sensor array **14**.

[0055] The sense die **38** may be connected to the substrate **36** in any suitable manner such that sense die **38** provides electrical signals to electrically conducive components in the substrate **36**. In one example, as shown in FIG. **6**, the sense die **38** may be electrically connected to bond pads **54** on the substrate **36** via wire bonds **52**.

[0056] In some cases, the substrate **36** may also include signal conditioning circuitry **30** that incorporates one or more ASSPs or ASICs **56**. The one or more ASSPs or ASICs **56** may be attached to a same side of the substrate **36** to which the sense dies **38** are attached and/or to an opposite of the substrate **36** to which the sense dies **38** are attached. In some cases, and as shown in FIG. **6**, the sensor array **14** may include a first ASIC **56***a* and a second ASIC **56***b* configured to condition signals received from the sense die **38**. The ASICs **56***a*, **56***b* are shown electrically connected to the back side of the substrate **36** via wire bonds, bump bonds, electrical terminals, and/or any other suitable electrical connections. Although not particularly shown in

[0057] FIG. **6**, the controller **16**, the communications block **24**, and/or other electronic components may be on and/or electrically connect to the substrate **36**, as desired.

[0058] The sensor assemblies **10** of the sensor array **14** may be split into at least a first set of sensor assemblies **10** (e.g., a first row of sensor assemblies **10**) and a second set of sensor assemblies **10** (e.g., a second row of sensor

assemblies **10**). The first set of sensor assemblies **10** may be configured to output signals to the ASICs **56** (e.g., to the first ASIC **56**a) and the second set of sensor assemblies **10** may be configured to output signals to the ASICs **56** (e.g., to the second ASIC **56***b*). In some cases, the controller **16** may compare an output of certain sensor assemblies **10** with the output of certain other sensor assemblies **10** to help identify which sensor assemblies **10** to use when determining certain circulatory system parameters.

[0059] In some instances, the ASICs **56** and/or other circuitry of the substrate **36** may include circuitry that is configured to format one or more output signals provided by the sensor assemblies **10** into a particular output format. For example, circuitry of the ASICs **56** and/or the substrate **36** may be configured to format the output signal provided by sensor assemblies **10** into a ratio-metric output format, a current format, a digital output format and/or any other suitable format. In some cases, the ASICs **56** and/or other circuitry of the substrate **36** may be configured to regulate an output voltage. The ASICs **56** and/or other circuitry on the substrate **36** may include traces and/or other circuitry that may serve as a conduit to test pads, and/or for providing ratio-metric (or other) output to one or more electrical terminals facilitating electrical connections with electronic components of one or more devices used with the sensor array **14**.

[0060] FIG. **7** is a schematic cross-sectional view of the packaging of the sensor array **14** taken along a row of sensor assemblies **10**. In the example of FIG. **7**, the sense dies **38** and the cover **42** are attached to a first side **36***a* of the substrate **36** and the ASICs **56***a*, **56***b* are attached to a second side **36***b* of the substrate **36**. Further, the force transmitting members **40** are received within apertures of the cover **42** and may cause the membrane **44** to protrude out from an outer surface of cover **42**. Such protrusion may facilitate interaction with a pressure or force exterior (e.g. artery force) to the corresponding sensor of the sensor array **14**.

[0061] FIGS. **8-11** depict a schematic cross-sectional views of the circulatory system monitor **12** with the sensor array **14** incorporated into a band **60** (e.g., a wrist band, head band, arm band, watch band, cuff, an ankle band, a neck band, etc.) extending around a suitable portion of a patient's body (e.g., wrist, arm, head, ankle, leg, neck, etc.) for monitoring circulatory system parameters. When the sensor array **14** is incorporated into the band **60**, the user interface **20** may be a watch face-like user interface in the band **60** and/or the user interface **20** may be separate from the band **60** (e.g. on the user's smartphone or the like). Although the circulatory system monitor **12** is depicted in FIGS. **7-10** with the sensor array **14** being incorporated into the band **60**, the circulatory system monitor **12** may take on one or more other configurations suitable for being used to monitor circulatory system parameters. Whether having a band configuration or other configuration, it is contemplated that the circulatory system monitor **12** may be incorporated into a garment or the like that can be worn by a patient (e.g., a shirt, pants, a belt, or the like), but this is not required.

[0062] In the example shown, the band **60** may be configured to extend around a portion of a patient's body. Although not particularly shown in the Figures, the band **60** may be a continuous single strap, a strap having two ends, a stretchable strap, an elastic strap, and/or other strap configuration. In some cases, ends of the band **60** may be connectable with a buckle, hook and loop fasteners, magnets, knots, and/or other connector. The band **60** may be manually tightened or loosened around a patient and/or tightened or loosened in an automated manner (e.g. inflatable member **32**).

[0063] The band **60** may have an opening **62** for receiving the sensor array **14**. In some cases, the opening **62** in the band **60** may be sized to have a volume greater than the volume of the sensor array **14** to allow for adjustment of the sensor array **14** within the opening **62** as the band **60** is tightened around the portion of the patient. Such potential for adjustment of the sensor array **14** relative to the band **60** may facilitate one or more of the sensor assemblies **10** being in good contact with an artery **2** of the patient having blood **7** passing therethrough. In other cases, the band or cuff may be moved relative to the patient's body to facilitate one or more of the sensor assemblies **10** being in good contact with an artery **2** of the patient having blood **7** passing therethrough.

[0064] The sensor array **14** may be positioned within the opening **62** of the band **60** such that the sensor assemblies **10** may extend out of the opening **62** in a manner configured to interact with a patient's skin **8**. When the band **60** has been tightened around a portion of the patient, a wall of the opening **62** is configured to act on a top side **14'** of the sensor array **14** and cause the sensor assembly **10** to apply an exterior force or pressure, P_e, to the patient's skin **8** and the patient's artery **2** (e.g., a radial artery or other artery) resulting in applanation of the artery **2**, as shown in FIG. **8**. In some cases, the application of the exterior force or pressure, P_e, to the skin may result in applanating a surface of the artery **2** against the skin **8** and against the bone (e.g., a radial bone), muscle or other anatomical structure **6**, as shown in FIG. **8**. Once, the band is properly tightened around a portion of a patient, the sensor assemblies **10** may begin sensing circulatory system parameters.

[0065] FIGS. **9** and **10** depict the circulatory system monitor **12** with the sensor array **14** within an opening **62** of a band **60** having an inflatable member **32**. The inflatable member **32** may be configured to inflate in order to apply an inward pressure against the sensor array **14** to applanate the artery **2**, as shown for example in FIG. **10**, and deflate to remove pressure applied by the circulatory system monitor **12** and allow the artery **2** to take its natural form due to blood **7** passing there through, as shown for example in FIG. **9**. As discussed above, but not shown in FIGS. **8** and **9**, the inflatable member **32** may be in communication with a pump (manual or motor driven) to allow the pump to inflate the inflatable member **32** to an inflated configuration having a height, H', and/or deflate the inflatable member **32** to a deflated configuration having a height, H. The pump may be incorporated into the band **60** or may be separate from the band **60**. In some cases, the inflatable member **32** may be in communication with an exhaust valve (not shown) that facilitates releasing fluid (e.g. air) from the inflatable member **32** to deflate the inflatable member **32** to the deflated configuration seen in FIG. **9**. The inflatable member **32** may be formed from a cavity **64** in the band **60** or may be a separate inflatable component that is positioned within a cavity **64** in the band **60**. In some cases, the inflatable member **32** may have and/or may abut a more stiff side and a less stiff side of the cavity **64**, where the less stiff side may form a side of the opening **62** in the band **60** and may act on the sensor array **14** when the inflatable member **32** is inflated. As shown in FIGS. **8** and **9**, the inflatable member

32 may be formed by cavity 64 in the band 60, where the cavity 64 is defined by at least a first side 66 (e.g., a more stiff side) and a second side 68 (e.g., a less stiff side) that is configured to flex more than the first side 66 when the inflatable member 32 is inflated or in an inflated configuration.

[0066] FIG. 11 depicts a cross-sectional view of the circulatory system monitor 12 having a sensor array 14 within a band 60 configuration around a portion of a patient and applanating the artery 2 of the patient. FIG. 11 depicts a pivot element 70 in contact with a surface of the sensor array 14 that is opposed to a surface of the circulatory system monitor 12 from which the sensor assemblies 10 extend. The pivot element 70 also engages or extend from a wall of the opening 62 in the band 60 and may facilitate movement of the sensor array 14 within the opening 62 of the band 60. Utilization of a pivot element (e.g., the pivot element 70) may allow an orientation of the sensor array 14 within the opening 62 to adjust, at least partially, about the pivot element 70 in a direction of arrows 71 (and in some cases other directions) to allow the sensor assemblies 10 to make good contact with the patient's skin even when the band 60 is not itself perfectly aligned with the patient's skin.

[0067] The pivot element may be any suitable element for allowing the sensor array 14 to orient itself relative to the patient's skin. In some cases, the pivot element 70 may include a rounded portion or may be a spherical ball about which the sensor array 14 may be able to pivot. Alternatively or in addition, the pivot element 70 may be an extension or protrusion of the band 60 about which the sensor array 14 may pivot. When the pivot element 70 is at least partially separate from the band 60, the pivot element 70 may be secured within a pocket 72 of the band 60. In some cases, the pivot element 70 may be snap fitted into the pocket 72. Alternatively or in addition, the pivot element 70 may be rigidly secured to the band 60 such that the pivot element 70 cannot be naturally separated from the band 60. While the band shown in FIG. 11 does not explicitly show an inflatable member 32, it is contemplated that the pivot element 70 may be used in conjunction with an inflatable member 32.

[0068] The illustrative circulatory system monitor 12 described herein may use a calibration and computing approach 100, as shown in FIG. 12 for example, to automatically detect which sensor assembly 10 (e.g., sensor assembly 10 or other sensor assembly) of a sensor array (e.g., the sensor array 14 or other sensor array) is in good contact and aligned with an artery or other target vessel of the circulatory system. The first step of the calibration and computing approach 100 may be to initialize 102 the circulatory system monitor 12 on a portion of a patient (e.g., on an arm, ankle, neck, head, wrist, etc. of a patient). When the circulatory system monitor 12 includes a band (e.g., the band 60 or other band), initializing 102 may entail, among other steps, placing the band around the portion of the patient and adjusting the circulatory system monitor 12 to a desired fit around the portion of the patient, such as by adjusting a length of the band, inflating/deflating an inflatable member 32, etc.). The desired fit may apply a contact force against a target area of a patient (e.g., adjacent an artery or other vessel) to the sensor array 14 having a plurality of sensor assemblies 10, wherein each sensor assembly 10 of the sensor array 14 may be configured to provide a signal indicative of a corresponding force. In some cases, initializing the circulatory system monitor 12 may also include booting up or turning on the electronic components of the circulatory system monitor 12.

[0069] Once the circulatory system monitor 12 has been initialized, a circulatory system parameter may be measured based on the signals from each sensor assembly 10 in the sensor array 14 while the contact force is applied to the sensor array 14 against the target area of a patient. For example, signals from all or substantially all of the sensor assemblies 10 of the sensor array 14 may be measured at 104, and the amplitudes of the signals from each indicative of a circulatory system parameter may be compared 106 to determine which sensor assembly 10 is providing the best or strongest signal.

[0070] Once the measures of the signals have been compared, the circulatory system monitor 12 may determine which sensor assembly 10 of the sensor array 14 is providing a best signal and/or strongest measure of the circulatory system parameter, as shown at 108. The best signal may be based on one or more factors in addition to or as an alternative to the greatest signal amplitude including, but not limited to, most consistent signal, a signal closest to an expected signal, a signal with the highest signal-to-noise ratio, and/or one or more other signal related factors. This may identify a best positioned sensor relative to a target artery or other vessel for taking pressure measurements and/or other measurements within the target artery or other vessel.

[0071] If no best-positioned sensor is detected and/or no sensor signals meet a baseline requirement, the calibration and computing approach 100 may include manually and/or automatically adjusting 110 the position or tightness of the band. In some cases, adjusting the band of the circulatory system monitor 12 may include inflating an inflatable member (e.g., the inflatable member 32 or other inflatable member), deflating the inflatable member 32, adjusting straps of the band, and/or otherwise physically adjusting the circulatory system monitor 12. After the band has been adjusted 110, steps 104-110 may be repeated until a best-positioned sensor is identified at step 108.

[0072] In some cases, after N number of attempts at determining a best-positioned sensor with a best signal that meets a baseline reading without identifying the sensor with a best signal, the circulatory system monitor 12 may determine a best-positioned sensor cannot be identified at this time and deflate 112 the inflatable member 32 and shut down 114 the circulatory system monitor 12. In some case, the N number of attempts at determining a best-positioned sensor with a best signal that meets a baseline reading may be pre-set or set by a user through a user interface. The shutdown of the circulatory system monitor 12 may facilitate saving power for later uses of the circulatory system monitor 12 and/or to prolong the life of the components of the circulatory system monitor 12 (e.g., to prevent a motor of the pump from burning out due to overuse, etc.).

[0073] If a best-positioned sensor assembly 10 meeting a baseline signal measurement requirement is identified at step 108, the circulatory system monitor 12 may use a signal from the best-positioned sensor assembly 10 during measurements (e.g., current and/or subsequent measurements) of the circulatory system parameter at the target area. For example, the circulatory system monitor 12 may use the signal from the identified or determined best-positioned sensor assembly 10 to compute 116 a systolic pressure and compute 118 a diastolic pressure. In some cases, once the

best-positioned sensor assembly **10** meeting a baseline signal measurement requirement is determined, the other sensor assemblies **10** of the sensor array **14** may be turned off, however, this is not required. In some cases, it may be useful to use more than one sensor assembly **10** but less than all when determining one or more circulatory system parameters. For example, two of the sensor assemblies **10** may both return good signals, in which cases both signals may be processes and an average may be taken to identify the circulatory system parameter. In another example, two of the sensor assemblies **10** that are both determined to be in registration with the same artery, one upstream of the other, signals from both sensors may be used to determine a time of flight (e.g. velocity) of a heart beat pressure pulse through the artery. These are just examples.

[0074] Once the systolic pressure and the diastolic pressures are computed **116**, **118**, the circulatory system monitor **12** may display **120** the computed values on a display (e.g., the display **22** or other display) on a user interface (e.g., the user interface **20** or other user interface). The circulatory system monitor **12** may further determine **122** if the computed systolic and diastolic pressures are within a desired or preset range. If the computed pressures are not within a desired or preset range of values, the circulatory system monitor **12** may alert a user (e.g., the patient, a medical practitioner, and/or other user) to the computed pressures that are not within a desire range and send **126** the computed pressures to one or more remote servers (e.g., the remote server **28** or other remote servers) and/or one or more monitoring devices (e.g., a monitoring interface **26**) for storage and possible further analyses. If it is determined **122** the values are within a desired or present range, the circulatory system monitor **12** may send the computed pressures to one or more remote servers and/or one or more monitoring devices for storage and possible further analyses. A controller (e.g., the processor or controller **16** or other controller) of the circulatory system monitor **12** may implement the approach **100** in an automated manner with or without manual or electronic prompting from a user.

[0075] The circulatory system monitor **12** may re-calibrate from time-to-time, periodically, whenever a value of the signal from the current best-positioned sensor assembly **10** changes by a predetermined amount, or at any other suitable time. In some cases, the circulatory system monitor **12** may re-calibrate (e.g. determine which pressure/force sensor of the pressure/force sensor array **14** is providing a strongest measure of the blood pressure at the target area based on the measured parameters) at each interval for computing systolic pressure and diastolic pressure. The intervals for computing systolic pressure and diastolic pressure may be preset automatically, preset by user entry, manually entered by a user, and/or set in one or more other manners.

[0076] In some cases, the circulatory system monitor **12** may be configured to determine a pulse and/or pulse wave velocity in the artery, which may be useful in detecting the onset of cardiovascular disease and/or cardiovascular risks of the patient. When detecting a pulse wave velocity, the circulatory system monitor **12** may, for example, determine a first sensor assembly (e.g., a first sensor assembly **10** or other first sensor assembly) and a second sensor assembly (e.g., a second sensor assembly **10** or other second sensor assembly) are both in good contact with a desired artery or other vessel, and then a controller and/or conditioning circuitry may utilize signals from the first sensor assembly **10** and the second sensor assembly **10**, along with a timer and a known distance between the first sensor assembly **10** and the second sensor assembly **10**, to determine a measure of the pulse wave velocity in an artery of the patient (i.e., a speed at which a pulse is traveling through the artery). A controller (e.g., the controller **16** or other controller) of the circulatory system monitor **12** may implement the approach for determining a pulse wave velocity in an automated manner with or without manual or electronic prompting from a user.

[0077] Having thus described several illustrative embodiments of the present disclosure, those of skill in the art will readily appreciate that yet other embodiments may be made and used within the scope of the claims hereto attached. It will be understood that this disclosure is, in many respects, only illustrative. Changes may be made in details, particularly in matters of shape, size, and arrangement of parts without exceeding the scope of the disclosure. The disclosure's scope is, of course, defined in the language in which the appended claims are expressed

What is claimed is:

1. A circulatory sensor monitor, comprising:

a force sensor array having a plurality of force sensors;

a controller in communication with the force sensor array; and

wherein with the force sensor array pressed against a patient's body, the controller is configured to identify a force sensor of the plurality of force sensors from which a signal is to be used to determine a circulatory system parameter of the patient's body and determine the circulatory system parameter of the patient's body based on the signal from the identified force sensor.

2. The circulatory sensor monitor of claim **1**, further comprising:

an inflatable member in mechanical communication with the force sensor array, the inflatable member configured to apply a force to the force sensor array against the patient's body when inflated;

a pump in communication with the inflatable member for inflating the inflatable member.

3. The circulatory sensor monitor of claim **1**, wherein the circulatory system parameter is blood pressure.

4. The circulatory sensor monitor of claim **1**, wherein the controller is configured to run a calibration procedure to determine which force sensor of the force sensor array is in a best position to sense the circulatory system parameter of the patient's body.

5. The circulatory sensor monitor of claim **4**, wherein the controller is configured to effect the calibration procedure by:

receiving signals from each force sensor of the force sensor array; and

determining which force sensor of the force sensor array is providing a strongest signal relative to the circulatory system parameter based on the received signals from each force sensor of the force sensor array.

6. The circulatory sensor monitor of claim **5**, wherein the controller is configured to use the force sensor of the force sensor array that is providing the strongest signal relative to the circulatory system parameter for at least one subsequent determinations of the circulatory system parameter.

7. The circulatory sensor monitor of claim **6**, wherein the controller is configured to turn off those force sensors of the

force sensor array that are not providing the strongest signal relative to the circulatory system parameter.

8. The circulatory sensor monitor of claim **1**, wherein:

the force sensor array has a first force sensor and a second force sensor; and

the controller is configured to use signals from the first force sensor and signals from the second force sensor to determine a pulse wave velocity in an artery of the patient's body.

9. The circulatory sensor monitor of claim **1**, wherein:

the force sensor array has a first set of force sensors and a second set of force sensors;

the first set of force sensors are configured to output signals to a first sensor input of an application-specific integrated circuit (ASIC); and

the second set of force sensors are configured to output signals to a second sensor input of the ASIC.

10. The circulatory sensor monitor of claim **1**, further comprising:

a display in communication with the controller, the controller is configured to provide information related to the circulatory system parameter to the display for displaying thereon.

11. The circulatory sensor monitor of claim **1**, further comprising:

a communications component in communication with the controller, the communications component is configured to communicate information related to the signals from the force sensor array to a remote computing device.

12. A force sensor assembly, comprising:

a substrate;

a sense die having a diaphragm, the sense die secured relative to the substrate;

a cover secured relative to the substrate, the cover having an opening that is in registration with the diaphragm when the cover is secured relative to the substrate;

a force transfer mechanism extending at least partially into the opening of the cover and is in contact with the diaphragm of the sense die;

a film secured to the cover over the opening and in contact with the force transfer mechanism; and

wherein the force transfer mechanism is configured to transfer force applied to the film to the diaphragm of the sense die.

13. The force sensor assembly of claim **12**, wherein the film comprises a nylon film.

14. The force sensor assembly of claim **12**, wherein the film has a thickness between 0.1 millimeters (mm) and 0.2 mm.

15. The force sensor assembly of claim **12**, wherein the film is laser welded to the cover.

16. The force sensor assembly of claim **12**, wherein the force transfer mechanism comprises a ball bearing.

17. The force sensor assembly of claim **12**, wherein the force transfer mechanism comprises a non-compressible fluid or gel contained in a defined cavity defined at least in part by the film.

18. The force sensor assembly of claim **12**, wherein:

the sense die is one of a plurality of sense die secured relative to the substrate and forming a sense die array;

each sense die has a corresponding opening in the cover when the cover is secured relative to the substrate;

each opening has a corresponding force transferring mechanism extending at least partially into the corresponding opening; and

each opening in the cover has a corresponding film secured to the cover over the opening.

19. The force sensor assembly of claim **12**, further comprising:

signal conditioning circuitry secured relative to the substrate and in communication with the sense die.

20. A method of using a force sensor assembly, the method comprising:

applying a contact force to a force sensor array having a plurality of force sensors against a target area of a patient, wherein each force sensor of the force sensor array is configured to provide a signal indicative of a corresponding force;

measuring a circulatory system parameter based on the signals from each force sensor in the force sensor array while the contact force is applied to the force sensor array against the target area of a patient;

determining which force sensor of the force sensor array is providing a strongest measure of the circulatory system parameter; and

using a signal from the force sensor of the force sensor array that is determined to be providing the strongest measure of the circulatory system parameter during subsequent measures of the circulatory system parameter at the target area.

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专利名称(译)	循环系统监测		
公开(公告)号	US20190150754A1	公开(公告)日	2019-05-23
申请号	US15/817008	申请日	2017-11-17
[标]申请(专利权)人(译)	霍尼韦尔国际公司		
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IPC分类号	A61B5/022 A61B5/021 A61B5/00		
CPC分类号	A61B5/022 A61B5/02108 A61B5/0004 A61B2560/0223		
外部链接	Espacenet USPTO		

摘要(译)

循环系统监测器可包括具有多个传感器组件的传感器阵列和与传感器阵列通信的控制器。传感器阵列可以被配置为压靠患者的身体，并且控制器可以识别多个传感器组件的传感器组件，信号将从该传感器组件用于确定患者身体的循环系统参数。控制器可以使用来自所识别的传感器组件的信号来确定循环系统参数。循环系统监测器可包括可充气构件和泵。传感器阵列和可充气构件的配置可有助于确保传感器阵列的最后一个传感器组件与待监测的目标动脉对准。传感器组件可包括膜