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(54) **MONITORING PLATFORM FOR WOUND AND ULCER MONITORING AND DETECTION**

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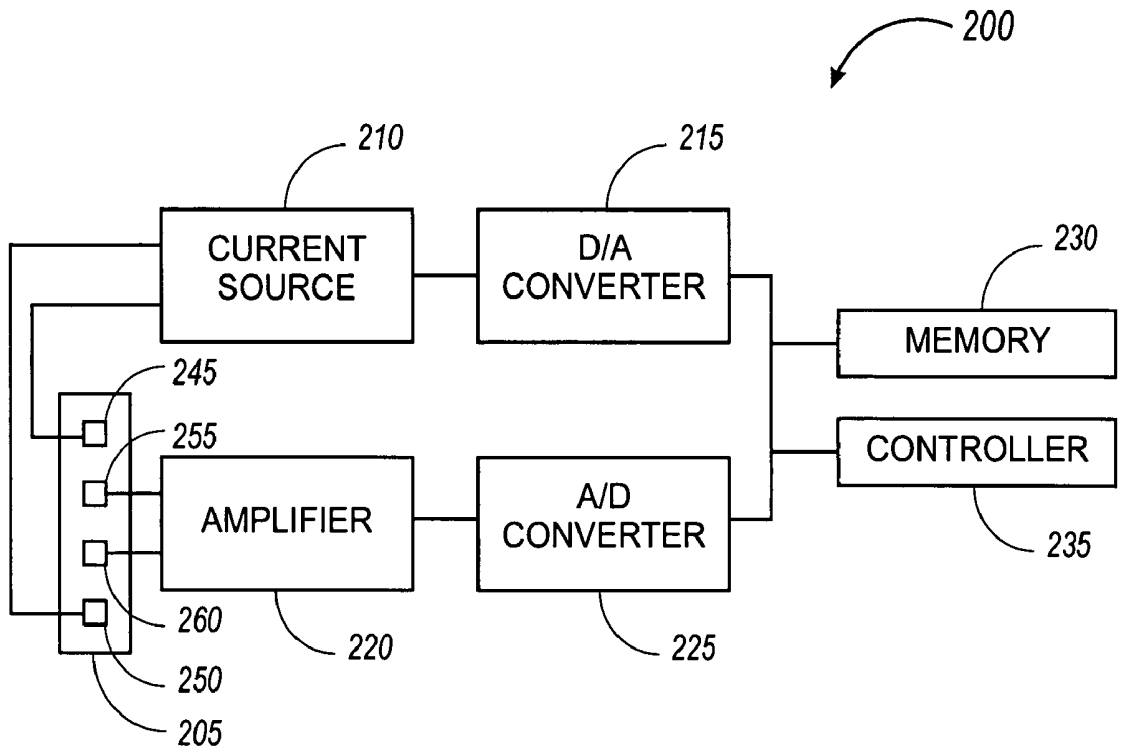
(57) **ABSTRACT**

Systems and techniques for monitoring hydration. In one implementation, a method includes measuring an electrical impedance of a region of a subject to generate an impedance measurement result, and wirelessly transmitting the data to a remote apparatus. The probe with which impedance is measured may in the form of a patch adhesively secured to the subject.



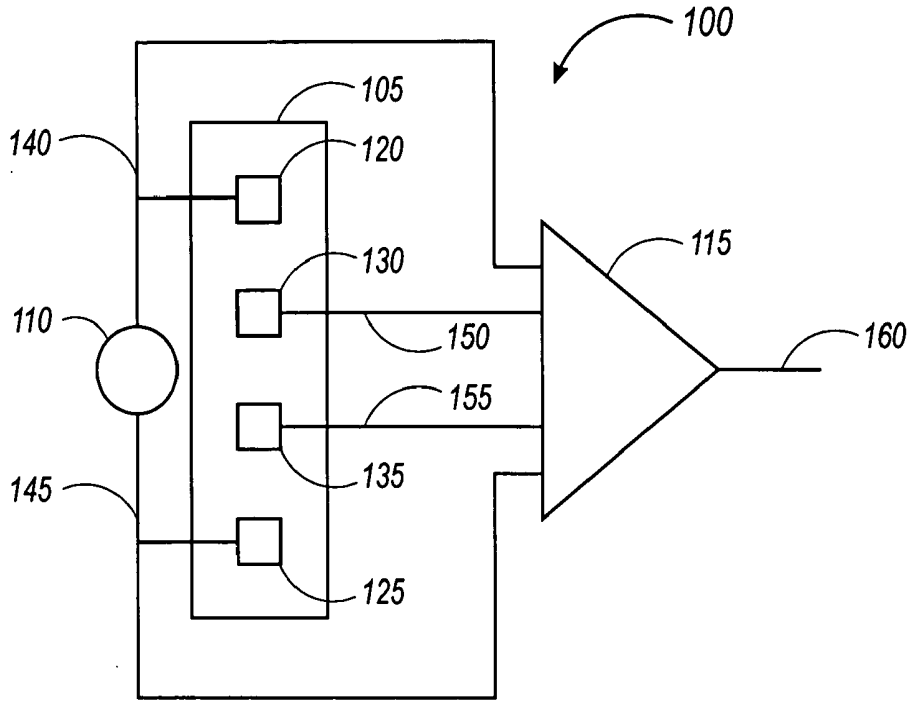

100
105
140
120
130
115
110
150
160
155
135
145
125

FIG. 1

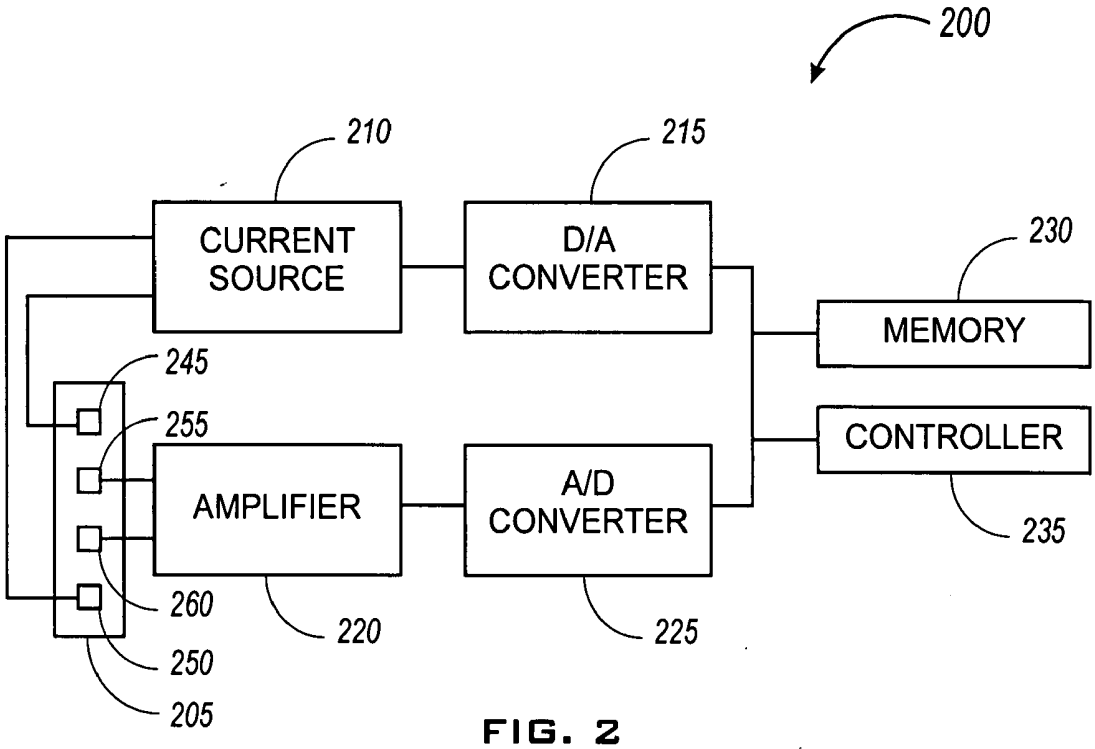

200
210
215
CURRENT SOURCE
D/A CONVERTER
230
MEMORY
245
255
CONTROLLER
AMPLIFIER
A/D CONVERTER
235
260
220
225
250
205

FIG. 2

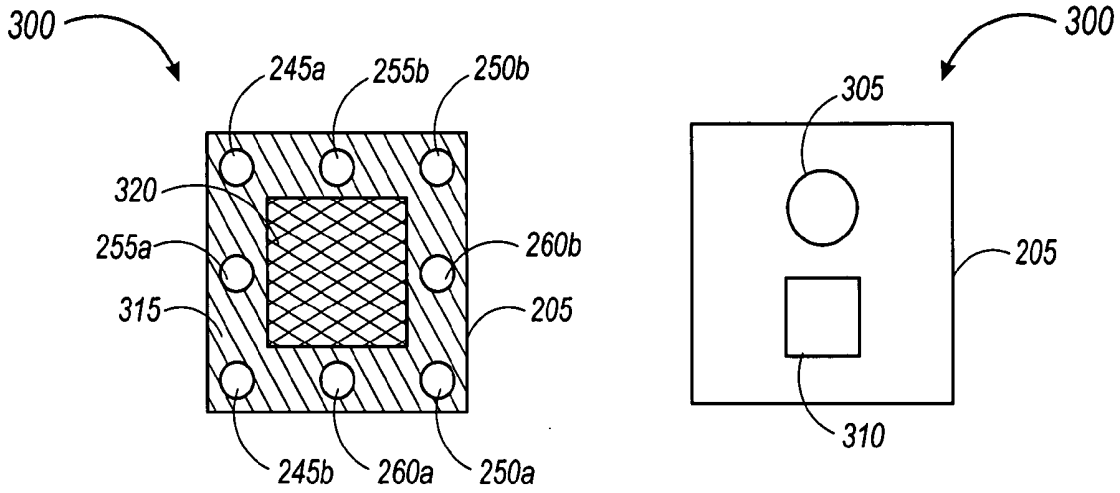

300
245a
255b
250b
320
255a
260b
315
205
245b
260a
250a
300
305
205
310

FIG. 3A

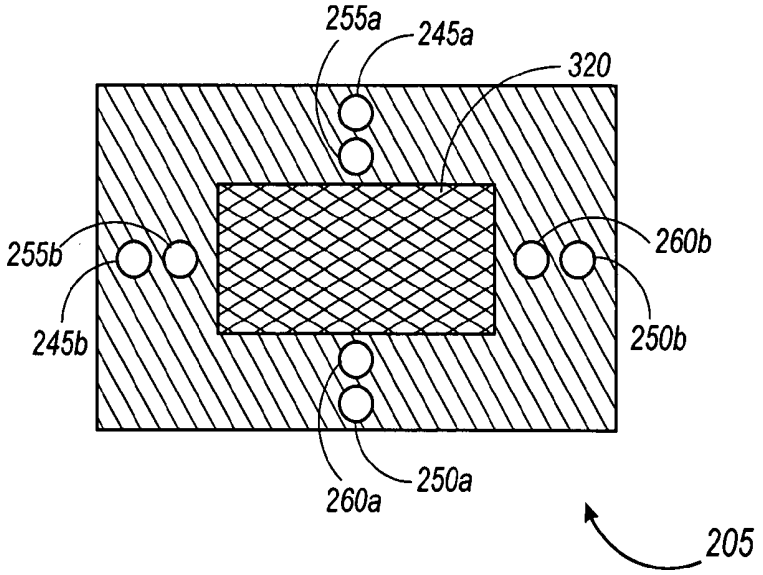

255a
245a
320
255b
260b
245b
250b
260a
250a
205

FIG. 3B

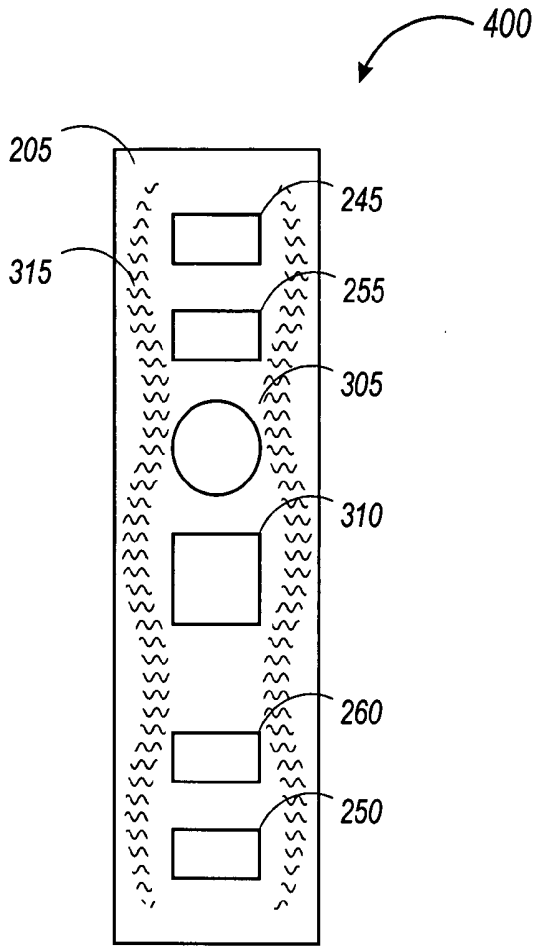

400
205
315
245
255
305
310
260
250

FIG. 4

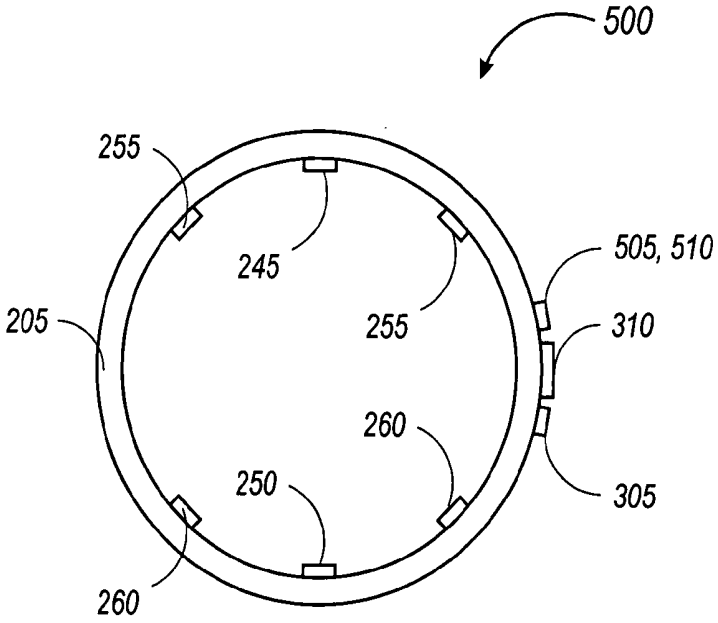

500
255
245
255
505, 510
205
310
260
250
305
260

FIG. 5

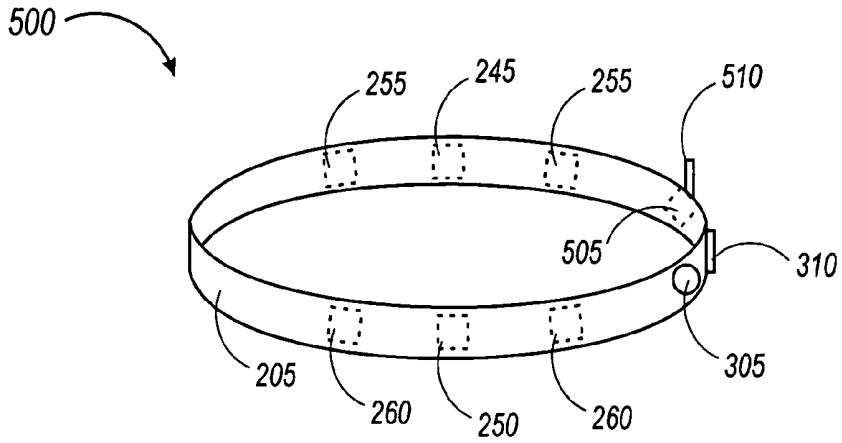

500
255
245
255
510
505
310
205
260
250
260
305

FIG. 6

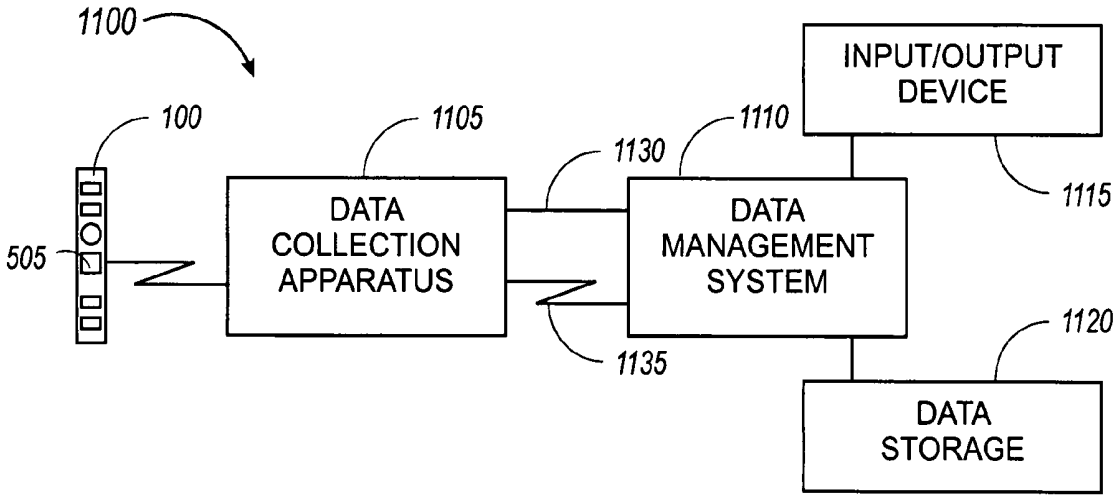

1100
100
1105
1130
1110
INPUT/OUTPUT DEVICE
1115
505
DATA COLLECTION APPARATUS
DATA MANAGEMENT SYSTEM
1135
1120
DATA STORAGE

FIG. 7

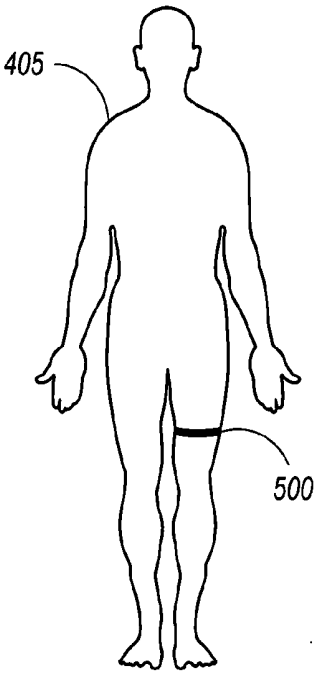


FIG. 8A

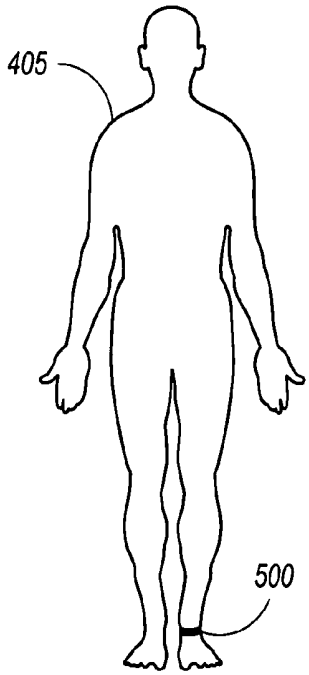


FIG. 8B

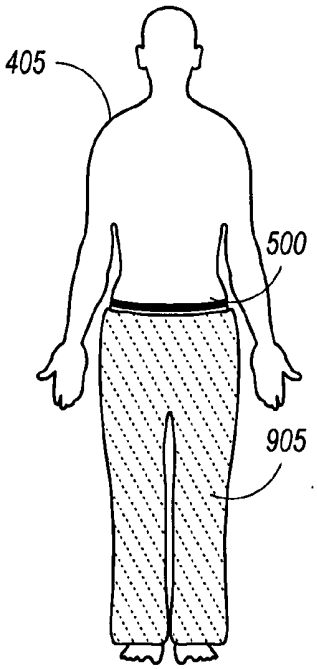


FIG. 8C

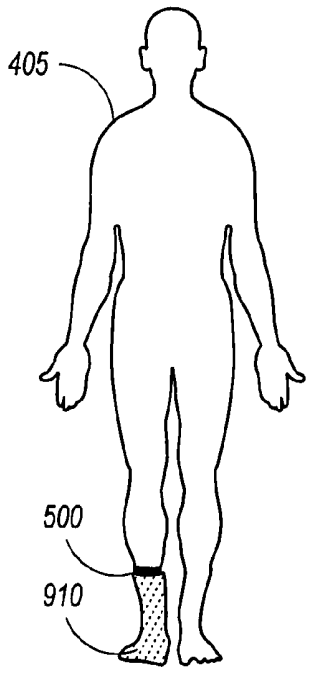


FIG. 8D

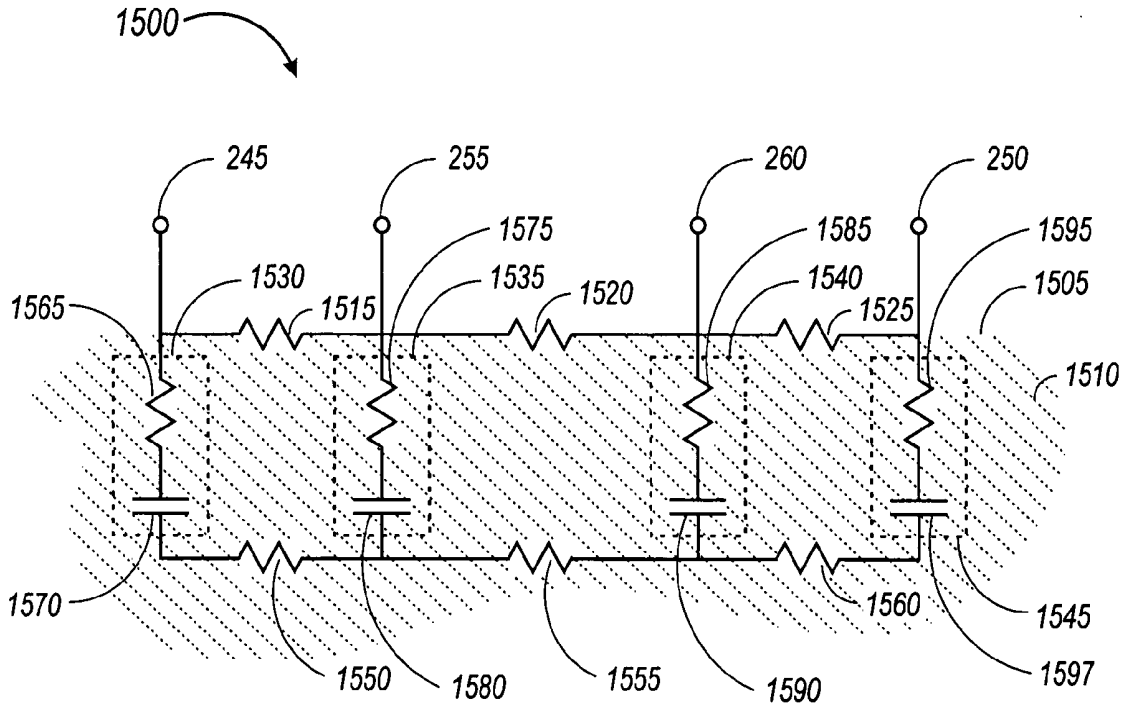

1500
245
255
260
250
1575
1585
1595
1530
1535
1540
1505
1565
1515
1520
1525
1510
1570
1560
1545
1550
1580
1555
1590
1597

FIG. 9

MONITORING PLATFORM FOR WOUND AND ULCER MONITORING AND DETECTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application Ser. No. 60/606,778 filed Sep. 2, 2004 and entitled "NON-INVASIVE MONITORING PLATFORM FOR DEHYDRATION, BLOOD LOSS, WOUND MONITORING, AND ULCER DETECTION," the entire content of which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] Many species of organisms are largely water. The amount and/or disposition of water in an individual organism (i.e., the hydration of the organism) has been correlated with the health of the individual organism. For example, an excess or a scarcity of water can be indicative of acute and/or chronic disease states. Changes in body composition such as percent fat content and the like can also result in changes in body water content.

[0003] Because the electrical impedance of an organism will vary with changes in water content, impedance measuring devices have been devised that are intended to provide indications of total body water based on measured body impedance. Although such devices have been found useful in some applications, the potential of bioimpedance data to supplement medical diagnosis and treatment has not been fully realized.

SUMMARY

[0004] In one embodiment, the invention comprises a method of monitoring a wound comprising measuring electrical impedance of tissue proximate to the wound at two or more times during wound healing.

[0005] In another embodiment, the invention comprises a wound dressing. The wound dressing comprises an absorbent material adapted to absorb wound exudate, and a plurality of electrodes situated to apply an electric current and/or voltage to tissue proximate to the wound.

[0006] In another embodiment, methods of reducing incidence of pressure wounds and/or cutaneous ulcers in a patient comprises detecting susceptibility to pressure wounds or cutaneous ulcers by measuring electrical impedance of a region of the body of the patient.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] **FIG. 1** shows a probe for monitoring the hydration of an organism.

[0008] **FIG. 2** shows another impedance measurement probe for monitoring the hydration of an organism.

[0009] **FIG. 3A and 3B** illustrate bandage impedance measurement probes.

[0010] **FIG. 4** illustrates a patch impedance measurement probe.

[0011] **FIGS. 5 and 6** illustrate a strap impedance measurement probe.

[0012] **FIG. 7** shows a system for monitoring the hydration of an organism or portion thereof.

[0013] **FIGS. 8A-8D** show various applications of strap impedance measurement probes on a human body.

[0014] **FIG. 9** shows an example of a model equivalent circuit of tissue proximate to a wound.

DETAILED DESCRIPTION

[0015] As described above, most applications of bioimpedance have been directed to monitoring the impedance of the entire body or at least large portions of it. In accordance with some aspects of the present invention, however, more localized measurements are used to beneficial effect. In some embodiments, as explained in detail below, actual or potential wound or injury sites are locally monitored to improve treatment for people that have or are susceptible to wounds of various types.

[0016] In a variety of contexts, wounds form on individuals due to disease or condition, or are created from accident and other forms of injury. These may be cuts, burns, surgical sites, bed sores and the like. Various skin ulcers such as venous stasis, ulcers, diabetic foot ulcers, pressure ulcers, burn site wounds, and donor site wounds can emerge from chronic diseases or various injuries. These cutaneous ulcers are accompanied by a degradation of the dermal layers, and often are subject to infection and resistant to healing. These wounds may be treated by cleaning, bandages, topical antibiotics, etc. Infection is a common problem, and such infections may further imperil an individual, cause more pain, delay the healing process and result in amputation or death. In many situations, monitoring the progress of wound healing is a necessary part of a successful treatment protocol.

[0017] To make such monitoring more effective and pain free, the wound or ulcer site is covered with a dressing that integrates one or more physical or biological parameter sensors. Advantageously, sensors for monitoring impedance of tissue proximate to the wound are provided to detect changes in local tissue edema. Skin temperature and/or heat flux from the skin may also be monitored by sensors on the dressing. Atypical changes in impedance, skin temperature, and or dermal heat flux may be detected and may be used to alert the patient and/or attending clinicians to possible healing interruption, infection or hemorrhaging at the wound site and facilitate early detection and treatment.

[0018] Similar apparatus used to monitor wound infections can also be used to monitor individuals at risk for wounds such as pressure sores and cutaneous ulcers. The apparatus may measure the typical changes in hydration and temperature of the tissue that is known to occur prior to the emergence of an ulcer or conditions that promote an ulcer. Early detection of the emergence of an ulcer would ensure that proper care is initiated quickly, thereby reducing the incidence of ulceration, infection and other complications.

[0019] **FIG. 1** shows a probe **100** for monitoring the hydration of an organism. Probe **100** includes a body **105**, an energy source **110**, and a sensing circuit **115**. Body **105** can be a flexible member in that it can be contoured to follow the skin surface or other portion of an organism, such as, for example, a patch or strap. Body **105** supports probe/organism interfaces **120**, **125**, **130**, **135** which apply or exchange energy with the subject and which sense energy exchange parameters in a way to measure the impedance of a region

of the subject. In most embodiments, interfaces **120**, **125130**, **135** will be electrodes adapted to exchange electrical energy with a human, although some optical element adapted to illuminate a human may also be possible. Typically, two of the interfaces **120**, **125** are used to force current flow from one point on the subject to a second point on the subject. The other two interfaces **130**, **135** are used to measure the voltage across two points on the subject. In most instances, voltage measurements will employ structures in direct contact with the skin surface. In certain applications, such voltage measurements may employ one or more contactless, voltage sensitive electrodes, e.g. capacitively coupled electrodes. It may be noted that the current application points and the voltage measurement points in these embodiments can be the same, adjacent to one another, or at significantly different locations.

[**0020**] Energy source **110** can be, e.g., an optical energy source or an electric energy source. For example, energy source can be one or more alternating and/or direct current and/or voltage source. Energy source **110** is connected to inputs **120**, **125** by leads **140**, **145**. Leads **140**, **145** can conduct energy generated by source **110** for exchange with the portion of the organism coupled to main body **105**. For example, leads **140**, **145** can be electrical wires capable of carrying an electric current for exchange with the portion of the organism, or leads **140**, **145** can be optical waveguides capable of carrying light for exchange with the portion of the organism followed by main body **105**.

[**0021**] In one electrical embodiment, a sensing circuit **115** comprises a differential amplifier connected to electrodes **120**, **125** by leads **140**, **145** and to electrodes **130**, **135** by leads **150**, **155**. Leads **140**, **145** can conduct voltage across source **110** to amplifier **115**. Leads **150**, **155** can conduct voltage across electrodes **130**, **135** as another input to the amplifier **115**. Amplifier **115** can sense voltages across electrodes **130**, **135** and electrodes **120**, **125** to generate one or more results **160**. It will be appreciated that amplifier **115** could be implemented as two or more amplifiers that separately sense relative voltages across any desired electrode pairs. Current sensing could also be implemented to directly measure the current output from source **110**.

[**0022**] In operation, main body **105** flexes to follow a portion of an organism and maintain inputs **120**, **125** and outputs **130**, **135** so that they can exchange energy with the followed portion. Source **110** generates one or more types of energy that is conducted over leads **140**, **145** through interfaces **120**, **125** and exchanged with the followed portion of the organism. In turn, interfaces **130**, **135** sense one or more energy exchange parameters from the followed portion. Sensing circuit **115** generates a result **160** based on the sensed signals. Result **160** reflects, at least in part, the hydration of the monitored organism.

[**0023**] Probe **100** can generate result(s) **160** continuously or intermittently over extended periods of time. For example, result **160** can be a subset of the comparisons of the sensed parameters at interfaces **130**, **135** with the amount of energy input at inputs **120**, **125**, or result **160** can be all such comparisons. For example, result **160** can be intermittent samples of voltages from the results of continuous application of a substantially constant current. As another example, result **160** can be periodic (e.g., every 5 to 30 minutes, such as every 10 minutes) results of successive, shorter duration current applications.

[**0024**] **FIG. 2** shows one circuit implementation of a bioelectric impedance probe **200** for monitoring the hydration of a portion of an organism. Bioelectric impedance spectroscopy is a measurement technique in which the electrical impedance of all or a portion of an organism is measured. When the conductivity of the entirety of an organism is measured such as by passing current from one ankle to an opposite wrist or between both hands, this can be referred to as whole body bioelectric impedance spectroscopy. When the electrical impedance of a portion of an organism is measured such as by a cluster of more locally placed electrodes, this can be referred to as segmental (or regional) bioelectric impedance spectroscopy. In either case, the measured electrical conductivity can reflect the hydration of the measured organism or the measured portion of the organism.

[**0025**] Bioelectric impedance spectroscopy generally involves the exchange of electrical energy with the organism. The exchanged electrical energy can include both alternating current and/or voltage and direct current and/or voltage. The exchanged electrical energy can include alternating currents and/or voltages at one or more frequencies. For example, the alternating currents and/or voltages can be provided at one or more frequencies between 100 Hz and 1 MHz, preferably at one or more frequencies between 5 KHz and 250 KHz.

[**0026**] Different frequencies of electrical energy can be used to measure conductivity in different portions of the organism. For example, in some organisms, lower frequency electrical energy may be conducted preferentially through tissues having fewer membranous components whereas higher frequencies may be conducted through a larger variety of tissues. In many cases, it is advantageous to make impedance measurements at two or more different frequencies in the same region. As explained further below, DC measurements can help characterize impedance over the skin surface. Thus, measurements at different frequencies made by a single probe can provide information regarding both the amount and disposition of water within a probed organism or within a probed portion of the organism.

[**0027**] Referring again to **FIG. 2**, bioelectric impedance spectroscopy probe **200** includes a body **205**, a current source **210**, a digital-to-analog converter **215**, an amplifier **220**, an analog-to-digital converter **225**, a memory **230**, and a controller **235**. Body **205** is a flexible member that supports two working electrodes **245**, **250** and two sensing electrodes **255**, **260**. Body **205** can be flexible enough to follow a portion of the human body to maintain electrodes **245**, **250**, **255**, **260** in contact with that portion. The followed portion can include skin surfaces, mucosal surfaces in the mouth and/or nasal passages, and other body passages or orifices. Body **205** can be sized to probe the conductivity of the entirety of an organism and thus perform whole body bioelectric impedance spectroscopy. In some advantageous embodiments described in detail herein, body **205** is sized to probe the conductivity of a portion of an organism and thus perform segmental bioelectric impedance spectroscopy.

[**0028**] Working electrodes **245**, **250** can be adapted to conduct current through or along the probed portion of the monitored organism. Sensing electrodes **255**, **260** can be adapted to measure the potential of locations in the probed portion of the monitored organism. Electrodes **245**, **250**,

255, **260** are generally electrically conductive in that their electrical impedance is relatively small when compared to the electrical impedance of the monitored portion of an organism at the probed frequency. For example, electrodes **245**, **250**, **255**, **260** can include metals, sintered metallic composites, conductive polymers, gels, carbon-based materials, silicon materials, electrically conductive microneedles, conductive solutions, or combinations thereof. In one implementation, electrodes **245**, **250**, **255**, **260** are electrically conductive adhesive gel electrodes such as the RED DOT electrodes available from 3M Corp. (St. Paul, Minn.).

[**0029**] Electrodes **245**, **250**, **255**, **260** can be supported by body **205** on the outer surface of the skin of a monitored organism. Alternatively, electrodes **245**, **250**, **255**, **260** can be supported by body **205** beneath the skin of a monitored organism. For example, electrodes **245**, **250**, **255**, **260** can be supported subdermally or electrodes **245**, **250**, **255**, **260** can be supported on transdermal elements such as microneedles that penetrate the skin. When placed on the skin surface, electrodes **245**, **250**, **255**, **260** can advantageously be each supported by body **205** at positions that are separated from one another by more than approximately ten times the thickness of the skin. When hydration is monitored in humans, electrodes **245**, **250**, **255**, **260** that are above the skin can each generally be supported at positions that are separated from one another by more than **2.5** millimeters. In one implementation, the distance between working electrodes **245**, **250** is greater than **1** cm. For embodiments that include a localized cluster of electrodes on one or more patches secured to the skin, the distance between electrodes is advantageously less than about **25** cm so that the impedance measurement is focused regionally on the subject. Such regional measurements have been found to produce useful data that can be generated and distributed with convenient apparatus.

[**0030**] In one implementation, working electrodes **245**, **250** are different than sensing electrodes **255**, **260**. For example, working electrodes **245**, **250** can be larger than sensing electrodes **255**, **260** and/or made from different materials. In other implementations, sensing electrodes **255**, **260** may be contactless electrodes, e.g. capacitively coupled electrodes (Quasar, San Diego, Calif.) while working electrodes **245**, **250** are contact-based electrodes, e.g. RED DOT electrodes.

[**0031**] Current source **210** is a source of alternating and/or direct electrical current. As deployed in probe **200**, current source **210** can drive electrical current from working electrode **245** to working electrode **250** through and/or along a monitored organism. In one implementation, current source **210** is capable of driving between 10 microamperes and 10 milliamperes, preferably between 100 microamperes and 1 milliamperes, of one or more frequencies of alternating and/or direct current through or along electrical impedances characteristic of humans. Typically, current is held at a known or measured substantially constant value, and voltage is measured to provide an impedance value. It is also possible to apply a constant voltage and measure the amount of current. Digital-to-analog converter **215** can be an integrated circuit or other electronic device that converts a digital signal into a corresponding analog signal. As deployed in probe **200**, digital-to-analog converter **215** can convert digital control signals from controller **235** into analog control signals to control the output of electrical current from current source **210**.

[**0032**] Amplifier **220** can be a differential voltage amplifier in that it amplifies a voltage difference on sensing electrodes **255**, **260**. This voltage difference results from current source **210** driving electrical current from working electrode **245** to working electrode **250** through and/or along the monitored organism. Analog-to-digital converter **225** can be an integrated circuit or other electronic device that converts this sensed voltage difference into a corresponding digital signal for reading by controller **235** and/or storage in memory **230**.

[**0033**] Memory **230** can be a data storage device that can retain information in machine-readable format. Memory **230** can be volatile and/or nonvolatile memory. For example, memory **230** can be a RAM device, a ROM device, and/or a memory disk.

[**0034**] Controller **235** is a device that manages the generation and flow of data in probe **200**. Controller **235** can be hardware configured to perform select operations or a data processing device that performs operations in accordance with the logic of a set of machine-readable instructions. In some implementations, controller can receive information related to the management of the generation and flow of data in probe **200** via one or more input devices. In some implementations, controller **235** can output information from probe **200** via one or more output devices. Custom ASICs or gate arrays can be used, as well as commercially available microcontrollers from, for example, Texas Instruments and Motorola.

[**0035**] The operations performed by controller **235** can include regulating the timing of hydration measurements and the timing of the transmission of hydration measurement results, logic operations, signal processing, and data analysis. For example, data analysis can be used to determine the bioelectric impedance of portions of a monitored organism. For example, equivalent circuit impedance analysis in the time or frequency domain can be performed. Instructions for performing such operations can be stored in a read only memory portion of memory **230**, temporary values generated during such operations can be stored in a random access portion of memory **230**, and the results of operations can be stored in a non-volatile portion of memory **230**.

[**0036**] In operation, current source **210** drives one or more frequencies of alternating and/or direct current between working electrodes **245**, **250** and through the subject organism. Amplifier **220** buffers and amplifies the potential difference between sensing electrodes **255**, **260**. Analog-to-digital converter **225** converts this signal into a digital form that can be received by controller **235** for storage at memory **230**, as appropriate. In some implementations, controller **235** may control source **210** to change the frequency and/or magnitude of current generated. The control of source **210** can be performed in light of the magnitude of the signal(s) output by amplifier **220** and/or in light of instructions received by controller **235** over one or more input devices.

[**0037**] In accordance with some aspects of the present invention, the conductivity of a region of the organism that has a wound or is susceptible to wound formation (e.g. a diabetic cutaneous ulcer) is monitored by the probe. Generally speaking, wounds that are healing normally become

drier, and the impedance and reactance of the region increases. Infected, open, interrupted healing, or draining wounds tend to have lower regional electric impedances. This can be monitored without bandage removal and visual inspection using a bandage incorporating impedance measurement sensing electrodes and/or circuits.

[0038] **FIG. 3** shows one implementation of an impedance measuring probe suitable for use in wound monitoring. On the left is a view of the bottom side of the bandage probe, and on the right is a top view. Electrodes **245**, **250**, **255**, **260** are provided around the periphery of the bandage. In one embodiment, when current is provided with electrode pairs **245***a* and **250***a*, voltage is measured across pair **255***a* and **260***a* and across pair **255***b* and **260***b*. If current is provided with electrode pairs **245***b* and **250***b*, voltage is measured across pair **255***a* and **255***b* and across pair **260***a* and **260***b*. It will be appreciated that various pairs of electrodes can be used for current supply and voltage measurements. During operation, the impedance of the tissue proximate to the wound is measured. In this context, "tissue proximate to the wound" includes actual wounded tissue, as well as tissue below and around the wound. Depending on the placement of the electrodes and the applied signal, the impedance of various current paths of different directions, depths, etc. can be explored and possibly mapped or characterized.

[0039] Additional sensors such as thermocouples or thermisters and/or heat flux sensors can also be provided, but are not shown in **FIGS. 3A and 3B**, to provide measured values useful in analysis. In general, skin surface temperature will change with changes in blood flow in the vicinity of the skin surface of an organism. Such changes in blood flow can occur for a number of reasons, including thermal regulation, conservation of blood volume, and hormonal changes. In one implementation, skin surface measurements of temperature or heat flux are made in conjunction with hydration monitoring so that such changes in blood flow can be detected and appropriately compensated for.

[0040] Probe **300** can be self-powered in that main body **205** can include (in addition to electrodes **245**, **250**, **255**, **260**) a portable power source, such as a battery **305**. Advantageously, although not necessarily, circuitry on the probe **300** is adapted to perform at least some of the signal generation and processing, control, and data storage functions of current source **210**, a digital-to-analog converter **215**, an amplifier **220**, an analog-to-digital converter **225**, a memory **230**, and a controller **235** without input from a fixed device. For example, the bandage probe **300** can be borne by the monitored organism over the wound being monitored. Circuitry **310** can be, e.g., an application specific integrated circuit (ASIC) adapted to perform these functions. Circuitry **310** can also be a data processing device and/or one or more input/output devices, such as a data communication device.

[0041] Main body **205** also advantageously includes an adhesive **315**. Adhesive **315** can be adapted to adhere to the skin surface of the monitored organism and thereby maintain electrodes **245**, **250**, **255**, **260** in contact with the portion of an organism followed by main body **205**.

[0042] The bandage **300** allows a monitored organism to be ambulatory while hydration monitoring occurs. This allows for data collection to be extended beyond periods of confinement. Thus, hydration monitoring can be continued while an organism participates in various activities at different locations.

[0043] Placement of the bandage probe **300** at appropriate locations on the body would facilitate monitoring of disease states such as cutaneous ulcers in the locations where the bandage probe has been placed. Bandage probe **300** can be incorporated into a wound dressing anywhere on the body. In these cases, the probe is advantageously combined with an absorbent material **320** such as gauze or the like to absorb wound exudates. The gauze may be incorporate one or more pharmaceutical compounds or agents in the gauze, in a delivery device, or in a resorbable delivery matrix for example. An oxygen supply device may also be provided to supply oxygen to the wound. Any of these may be provided to enhance healing and/or inhibit infection. In addition, by monitoring of the wound without removal of the bandage, incidental exposure to bacteria, etc. in the wound vicinity may be minimized. In some embodiments, compound delivery from a device on the bandage **300** or located elsewhere on the organism may be initiated by circuitry **310** in response to measured values.

[0044] **FIG. 3B** shows a rectangular embodiment with different electrode placement. In this embodiment, electrodes **245** and **250** can be used to supply currents, and electrodes **250** and **260** can be used to measure voltages.

[0045] Multiple sets of sensing electrodes can be used to measure hydration of the region. Potential differences generated between different electrode pairs during current flow in different directions can be used to gain information about the conduction of current in the entire region. A measurement of multiple potential differences between more than two sensing electrodes can also be used, e.g., to make cross measurements and ratiometric comparisons that can be used to monitor hydration while aiding in calibration and helping to account for measurement variability such as temperature changes, changes in the position of the monitored individual, and movement of the device over time.

[0046] **FIGS. 4, 5**, and **6** illustrate impedance measurement probes that can be useful to detect a subject's susceptibility to wounds such as pressure sores and diabetic foot ulcers. Susceptibility to and onset of such wounds can be detected by detecting changes in hydration state of the region prior to the onset of the sore or ulcer or that otherwise compromise the tissue structure leading to increased susceptibility to injury thereby resulting in ulcer or other wound formation. **FIG. 4** illustrates an impedance measurement probe in the form of a patch **400**. **FIGS. 5 and 6** show another implementation of an impedance measurement strap probe **500**. Main body **205** of strap probe **500** is a strap or a belt that can form a loop to encircle the body, or a portion of the body, of a monitored individual. Such an encirclement can maintain electrodes **245**, **250**, **255**, **260** in contact with the encircled portion. In addition to working electrodes **245**, **250**, two sets of sensing electrodes **255**, **260**, battery **305**, and circuitry **310**, main body **205** also includes a data communication device **505** having a transceiver **510**. Data communication device **505** can be a wireless communication device that can exchange information between circuitry **310** and an external entity.

[0047] A wireless data link can carry information using any of a number of different signal types including electromagnetic radiation, electrical signals, or acoustic signals. For example, data communication device **505** can be a radio frequency communication device. Transceiver **510** can be an

assembly of components for the wireless transmission and reception of information. The components can include, e.g., an RF antenna. The wireless receiver/transmitter circuitry can be made part of any embodiment described herein.

[0048] **FIG. 7** shows a system **1100** for monitoring the hydration of an organism. System **1100** includes one or more probes **100** along with one or more data collection apparatus **1105**, a data management system **1110**, an input/output device **1115**, and a data storage device **1120**. Probe **100** includes a wireless data communication device **505** that is capable of establishing a wireless data link **1125** with data collection apparatus **1105**. Wireless data link **1125** can transmit data using any of a number of different signals including electromagnetic radiation, electrical signals, and/or acoustic signals. When probe **100** is subdermal, data link **1125** can be a transdermal link in that data link **1125** conducts data along a path through the skin.

[0049] The data communicated along wireless data link **1125** can include a probe identifier. A probe identifier is information that identifies probe **100**. Probe **100** can be identified, e.g., by make or model. Probe **100** can also be identified by a unique identifier that is associated with a single individual probe **100**. The probe identifier can include a serial number or code that is subsequently associated with data collected by probe **100** to identify that this data was collected by probe **100**. In some embodiments, each individual electrode, or a patch or strap containing a set of electrodes incorporates an integrated circuit memory having a stored unique or quasi-unique electrode/patch identifier. An interface between the patch or electrodes and the communication device **505** can be implemented so that the communication device **505** can send electrode or patch identifiers as well as a separate identifier for the other electronics coupled to the patch. In this way, different parts of the probe can be separately replaced, while still allowing complete tracking of the physical data generation, analysis, and communication apparatus used to gather all impedance data.

[0050] The data communicated along wireless data link **1125** can also include messages to probe **100**. Example messages include commands to change measurement and/or data analysis parameters and queries regarding the status and/or operational capabilities of the probe. Data communication along wireless data link **1125** can also include information related to the initialization and activation of probe **100**. Initialization can include the communication of a probe identifier to data collection apparatus **1105**. Initialization can also include the commencement of measurement activities including, e.g. the start of an internal clock that regulates the timing of hydration measurements and the transmission of hydration measurement results. Such data communication can be conducted as an ongoing dialogue with data collection apparatus **1105**.

[0051] Data collection apparatus **1105** is a device that generally supplements probe **100** by including components and/or features that complement the components and/or features of probe **100**. For example, such components or features may be too large, too memory intensive, require too sophisticated data processing, and/or only be used too intermittently to be included on probe **100**. Data collection apparatus **1105** can be a portable device in that data collection apparatus **1105** can be moved from a fixed location and perform at least some functions without input from a fixed device. For example, data collection apparatus **1105** can be a handheld device that can be borne by a monitored individual.

[0052] Returning to **FIG. 7**, system **1100** can include a wired data link **1130** and/or a wireless data link **1135** for the exchange of data between data collection apparatus **1105** and data management system **1110**. Wired data link **1130** can terminate at a connector port **1274** on data collection apparatus **1105**, and wireless data link **1135** can terminate at transceiver **1270** on data collection apparatus **1105**.

[0053] Wireless data link **1125**, wired data link **1130** and wireless data link **1135** can exchange data in accordance with one or more communication protocols. The communication protocols can determine the format of the transmitted information and the physical characteristics of the transmission. Communication protocols can also determine data transfer mechanisms such as synchronization mechanisms, handshake mechanisms, and repetition rates. The data structures of the protocol may impact the rate of data transfer using the protocol. Data can be organized in blocks or packets and transmissions can be made at specified intervals. For example, a transmission block can include synchronization bits, an address field that includes information identifying the data source, a data field containing the hydration monitoring data, and a checksum field for testing data integrity at the receiver. The length of a data block can vary, e.g., to reduce power consumption and increase device lifetime. The same data can be transmitted multiple times to ensure reception.

[0054] In one implementation, exchanged data is organized in packets that include four sections, namely, a header section, a 64 bit address section that includes a probe identifier identifying a probe **100** (and/or an electrode or electrode set identifier), an encrypted data section, and a check-sum or error correction section. The data section can be encrypted using an algorithm that relies upon the address section.

[0055] Probe **100**, data collection apparatus **1105**, and data management system **1110** can all confirm a successful exchange of data using a confirmation such as an electronic handshake. An unsuccessful exchange of data can be denoted by transmission of an error message, which can be responded to by a retransmission of the unsuccessfully exchanged data.

[0056] In some implementations, probe **100**, data collection apparatus **1105**, and data management system **1110** can exchange data at a number of different frequencies. For example, when system **1100** includes multiple data collection apparatus **1105**, each data collection apparatus **1105** can transmit data over wireless data link **1135** using a different frequency carrier. As another example, when system **1100** includes multiple probes **100**, each probe **100** can transmit data over wireless data link **1125** using a different frequency carrier. It will be appreciated that a variety of multiple access techniques such as time or code division, could be alternatively used.

[0057] The data communicated along wireless data link **1125**, wired data link **1130**, and wireless data link **1135** can be encrypted in whole or in part. The encryption can be symmetric or asymmetric. The encryption can rely upon

encryption keys based on the probe identifier or on alphanumeric codes transmitted with the encrypted data. The encryption may be intended to be decrypted by a specific probe **100**, a specific data collection apparatus **1105**, or a specific data management system **1110**. In one implementation, data communicated along wired data link **1130** is encrypted using **128** bit encryption at the SSL layer of the TCP/IP protocol.

[**0058**] Both proprietary and public protocols can be used to exchange data between probe **100**, data collection apparatus **1105**, and data management system **1110**. For example, the global system for mobile communications (GSM), Bluetooth, and/or the internet protocol (IP) can be used.

[**0059**] In one implementation, wireless link **1125** is a spread-spectrum RF signal at wireless medical band frequencies such as the Medical Implant Communications Service (MICS) (400-406 MHz) or the Wireless Medical Telemetry Service (WMTS) (609-613 MHz and 1390-1395 MHz).

[**0060**] Data management system **1110** is a data processing device that conducts operations with the data collected by probe **100** that relates to hydration of the organism. The operations can be conducted in accordance with the logic of instructions stored in machine-readable format. The conducted operations can include the processing of such data, the display of such data, and the storage of such data.

[**0061**] Data management system **1110** can be remote from data collection apparatus **1105** in that data management system **1110** need not be part of a local data communication network that includes data collection apparatus **1105**. For example, data management system **1110** can be a data processing apparatus that is accessible by one or more medical personnel.

[**0062**] The processing of data by data management system **1110** can include data analysis to identify disease states in monitored organisms or problems with the monitoring. For example, data management system **1110** can perform impedance analysis using model equivalent circuits to determine hydration levels at different locations in a monitored organism.

[**0063**] The display of data by data management system **1110** can include the rendition of the results of hydration monitoring on one or more input/output devices **1115**. Input/output device **1115** can include visual, auditory, and/or tactile display elements that can communicate information to a human user (such as medical personnel). For example, input/output device **1115** can include a monitor, a speaker, and/or a Braille output device. Input/output device **1115** can also include visual, auditory, and/or tactile input elements such as a keyboard, a mouse, a microphone, and/or a camera. Input/output device **1115** can thus render visual, auditory, and/or tactile results to a human user and then receive visual, auditory, and/or tactile input from the user.

[**0064**] The storage of data by data management system **1110** can include the storage of the results of hydration monitoring on one or more data storage devices **1120** that retain information in machine-readable format. Data storage devices **1120** can include volatile and/or nonvolatile memory. For example, data storage devices **1120** can be a RAM device, a ROM device, and/or a memory disk.

[**0065**] In operation, all or some of the constituent components of system **1100** can operate in one or more operational stages. For example, during a test stage, the constituent components of system **1100** can test themselves to determine that they are functional. For example, probe **100** and data collection apparatus **1105** can confirm that they are capable of exchanging data along link **1125**, and data collection apparatus **1105** and data management system **1110** can confirm that they are capable of exchanging data along one or more of links **1130**, **1135**. As another example, probe **100** can confirm that inputs **120**, **125** and outputs **130**, **135** are properly positioned relative to a monitored organism. For example, when inputs **120**, **125** and outputs **130**, **135** are electrodes **245**, **250**, **255**, **260**, probe **100** can confirm that electrodes **245**, **250**, **255**, **260** are in electrical contact with the followed portion of the monitored organism.

[**0066**] During a setup stage, parameters relating to the monitoring of the hydration of an individual can be arranged. For example, a probe **100** can determine the baseline measurement result for a given hydration level in a portion of a monitored organism and adjust monitoring parameters accordingly. The standard response can be indicative of the absence of a disease state or of the absence of progression in a disease state. Changes in the baseline impedance measurements can result from changes in factors unrelated to a disease state. For example, changes in the baseline impedance measurements can result from different skin thicknesses, body compositions, or other differences between two locations. Measurements made at the different locations can be normalized to account for such differences in baseline measurements. Such a normalization can include adjustments in gain and/or adjustments in offset. Gain adjustments may be based on the absolute value of the impedance measurement(s), the impedance difference(s) observed at the old and the new locations, or combinations thereof. Offset adjustments can generally be made after gain adjustments and can be based on absolute impedance values and/or other factors. Alternatively, analysis thresholds used to identify disease states can be adjusted. For example, the input signal level can be increased to accommodate dry skin and high transdermal impedances. Data collection apparatus **1105** can receive user input over one or more of local user input portion **1205**, wireless data communication portion **1215**, and wired data communication portion **1217**. The received input can identify monitoring parameters that are to be adjusted, such as the level at which an alert is to be sounded at probe **100** and/or data collection apparatus **1105**. Data management system **1110** can also receive user input relating to the arrangement of monitoring parameters. For example, data management system **1110** can receive input from medical personnel over input/output device **1115** indicating that hydration measurement results are to be transmitted by probe **100** to data collection apparatus over link **1125** once every four hours. This timing parameter can be relayed from data management system **1110** over link **1130** to data collection apparatus **1105** which relays the timing parameter over wireless link **1125** to probe **100**.

[**0067**] Parameters relating to the communication of information over one or more of links **1125**, **1130**, **1135** can also be arranged during a setup stage. For example, the constituent components of system **1100** can select communication protocols or parameters for communication protocols.

[0068] During a synchronization stage, clocks in two or more of probe **100**, data collection apparatus **1105**, and data management system **1110** are synchronized to enable synchronous data transmission along one or more of links **1125**, **1130**, **1135**. For example, in one implementation, data collection apparatus **1105** transmits synchronization characters to data management system **1110** over wired data link **1130**. Data management system **1110** can receive the synchronization characters and compares the received characters with a synchronization pattern. When the received characters correspond sufficiently with the synchronization pattern, data management system **1110** can exit the synchronization stage and exchange other data synchronously with data collection apparatus **1105** over link **1130**. Such a synchronization process can be repeated periodically.

[0069] In one implementation, data collection apparatus **1105** can receive and/or display a serial number or other identifier of a synchronized probe **100**.

[0070] During a measurement stage, one or more probes **100** can collect data relating to the hydration of one or more monitored individuals. The probes **100** can perform data processing on the collected data, including bioelectric impedance data analysis, filtering, and, event identification.

[0071] The probes **100** can transmit data relating to the hydration monitoring (including results of processing and analyzing collected data) to one or more data collection apparatus **1105**. The transmitted data can include a probe identifier that identifies the transmitting probe **100**. The transmitted data can be encrypted.

[0072] Data collection apparatus **1105** can also command one or more probes **100** to transmit data relating to the hydration monitoring over link **1125**. For example, data collection apparatus **1105** can transmit a query to probe **100**. The query can request that probe **100** provide information regarding some aspect of the hydration monitoring. For example, a query can request that probe **100** transmit a confirmation that hydration monitoring is occurring over link **1125**, a query can request that probe **100** transmit a recent measurement result over link **1125**, or a query can request that probe **100** transmit one or more events of a particular character over link **1125**. Data collection apparatus **1105** can transmit queries to probe **100** periodically, e.g., every hour or two.

[0073] Data collection apparatus **1105** can also relay some or all of the data transmitted from probe **100** to data management system **1110**. The data can be relayed over one or more data links **1130**, **1135**. Data collection apparatus **1105** can relay such data directly, i.e., without performing additional analysis on the information, or data collection apparatus **1105** can perform additional processing on such before relaying a subset of the data to data management system **1110**. Data collection apparatus **1105** can notify a local user that data has been relayed by displaying a data relay notice on local user output portion **1210**. Alternatively, data can be relayed by data collection apparatus **1105** without notification to a local user.

[0074] Data collection apparatus **1105** can also receive user input over one or more of local user input portion **1205**, wireless data communication portion **1215**, and wired data communication portion **1217**. The received input can identify that data collection apparatus **1105** is to transmit data to one or more probes **100** over link **1125**. For example, the received input can identify that data collection apparatus **1105** is to instruct probe **100** to generate an alarm signal indicating that a monitored person suffers under a disease state. As another example, the received input can identify that data collection apparatus **1105** is to transmit a query to a probe **100** over wireless link **1125**. As another example, the received input can identify that data collection apparatus **1105** is to transmit an instruction instructing probe **100** to change a parameter of the hydration monitoring, including one or more threshold values for identifying a disease state.

[0075] Data collection apparatus **1105** can also perform data processing and storage activities that supplement the data processing and storage activities of probe **100**. For example, data collection apparatus **1105** can perform more extended data analysis and storage, including signal processing and analysis. For example, data collection apparatus **1105** can perform impedance analysis using model equivalent circuits to determine hydration levels at different locations in a monitored organism. As another example, data collection apparatus **1105** can perform trending analyses that identify a general tendency of hydration levels to change over extended periods of time, or data collection apparatus **1105** can perform comparisons between hydration levels obtained using multiple probes **100**. The multiple probes **100** can monitor the hydration of a single organism, or the multiple probes can monitor the hydration of multiple organisms. Data collection apparatus **1105** can compare and correlate monitoring results from multiple probes to calibrate one or more probe **100** and minimize errors during monitoring.

[0076] Data collection apparatus **1105** can also compare and/or correlate the results of hydration monitoring with the results of monitoring other biological parameters. For example, data collection apparatus **1105** can compare and correlate the results of hydration monitoring with the results of heart monitoring, drug delivery schedules, and temperature monitoring. Data collection apparatus **1105** can receive the other monitoring results over one or more of local user input portion **1205**, wireless data communication portion **1215**, and wired data communication portion **1217**. For example, data collection apparatus **1105** can receive the other monitoring results over one or more of links **1125**, **1130**, **1135**.

[0077] Data collection apparatus **1105** can also exchange data with other devices and systems (not shown in **FIG. 6**). For example, data collection apparatus **1105** can receive other monitoring results directly from other monitoring instruments. As another example, data collection apparatus **1105** can transmit data relating to the results of hydration monitoring to other local or remote parties. The other parties can be external entities in that they do not share a legal interest in any of the constituent components of system **1100**. For example, the other parties can be a medical group that has contracted with an owner of system **1100** to monitor hydration of an individual.

[0078] Data management system **1110** can receive the results of hydration monitoring from data collection apparatus **1105** over one or both of data link **1130**, **1135**. The received results can include analyses of the hydration of an organism, as well as comparisons and correlations of monitoring results from multiple organisms or other biological parameters.

[0079] Data management system **1110** can conduct operations with the received data, including processing the data to identify disease states and problems with the monitoring. For example, data management system **1110** can perform impedance analysis using model equivalent circuits to determine hydration levels at different locations in a monitored organism. As another example, data management system **1110** can perform trending analyses that identifies a general tendency of hydration levels to change over extended periods of time, or data management system **1110** can perform comparisons between hydration levels obtained using multiple probes **100**. The multiple probes **100** can monitor the hydration of a single organism, or the multiple probes can monitor the hydration of multiple organisms. Data management system **1110** can compare and correlate monitoring results from multiple probes to calibrate one or more probe **100** and minimize errors during monitoring. Data management system **1110** can also perform analyses that require hydration monitoring results from statistically significant numbers of organisms. Such analyses can include billing assessments, geographic assessments, epidemiological assessments, etiological assessments, and demographic assessments.

[0080] Data management system **1110** can render the results of hydration monitoring on one or more input/output devices **1115** and store the results of hydration monitoring on one or more data storage devices **1120**. Data management system **1110** can also provide the results of the data processing to data collection apparatus **1105** and/or probe **100** over data links **1125**, **1130**, **1135**. The provided results can include an indication that a disease state is present and/or an indication that probe **100** should generate an alarm signal indicating that a monitored organism suffers under a disease state. Data management system **1110** can also provide such indications to external entities, including medical personnel interacting with input/output device **1115** and medical personnel in the vicinity of the monitored organism. As another example, data management system **1110** can also post an indication in an external system such as the clinical information system of a healthcare organization or an Internet portal.

[0081] **FIGS. 8A-8D** illustrate example deployments of implementations of strap probe **500** to monitor hydration in a region of a diabetic person to detect susceptibility to leg and foot ulcers. In **FIG. 8A**, strap probe **500** is sized to encircle the thigh of person **405** and is deployed to probe the conductivity of the thigh of person **405**. In **FIG. 8B**, strap probe **500** is sized to encircle the lower leg of person **405** and is deployed to probe the conductivity of the lower leg of person **405**. As shown, strap probe **500** encircles the ankle, but strap probe **500** can also encircle the foot, the calf, or a toe to probe the conductivity of the lower leg. In **FIG. 9A**, strap probe **500** is incorporated into a pair of pants **905** and sized to encircle the torso of person **405** to probe the conductivity of the torso of person **405**. Incorporating a probe **500** into pants **905** may reduce the intrusiveness of probe **500** and help ensure that a monitored individual deploys probe **500**. In **FIG. 9B**, strap probe **500** is incorporated into a sock **910** and sized to encircle the lower leg of person **405** to probe the conductivity of the lower leg of person **405**. Incorporating a probe **500** into sock **910** may reduce the intrusiveness of probe **500** and help ensure that a monitored individual deploys probe **500**. It will be appreciated that for monitoring susceptibility and potential onset of ulcers, sores, and the like, a continuously borne probe is not necessary. Periodic impedance measurements with a hand-held probe could be performed as an alternative.

[0082] The use of hand held or otherwise not attached probe may be aided by the use of external guides, e.g. templates having fixed geometries or distances, for increasing the reproducibility of measurement location on the body. Alternatively, either naturally occurring landmarks, e.g. venous patterns, or landmarks applied to the body, e.g. temporary tattoos, may be used to help reproducibility of measurement site or probe orientation.

[0083] **FIG. 10** shows an example of a model equivalent circuit **1500** that can be used to understand the effects of various tissue impedances on an overall impedance measurement. In particular, model equivalent circuit **1500** that can be used to model the electrical conductivity of an organism or local region of an organism. Circuit **1500** models the impedances using a probe **200** that supports electrodes **245**, **250**, **255**, **260** above a skin surface **1505** of an organism **1510**.

[0084] Model circuit **1500** includes a series of surface impedances **1515**, **1520**, **1525**, a series of transdermal impedances **1530**, **1535**, **1540**, **1545**, and a series of subdermal impedances **1550**, **1555**, **1560**. Surface impedances **1515**, **1520**, **1525** can model the surface electrical impedances between the relevant of electrodes **245**, **250**, **255**, **260**. Surface impedances **1515**, **1520**, **1525** can model both the conductivity through the surface of the skin and the conductivity through sweat and other conducting fluids on the surface of the skin. In one implementation, surface impedances **1515**, **1520**, **1525** are modeled as non-reactive (i.e., resistive) elements.

[0085] Transdermal impedances **1530**, **1535**, **1540**, **1545** can model the electrical impedances through the skin of a monitored organism. Transdermal impedance **1530** includes a resistive component **1565** and a reactive component **1570**. Transdermal impedance **1535** includes a resistive component **1575** and a reactive component **1580**. Transdermal impedance **1540** includes a resistive component **1585** and a reactive component **1590**. Transdermal impedance **1545** includes a resistive component **1595** and a reactive component **1597**. Reactive components **1570**, **1580**, **1590**, **1597** can model the electrical impedance through dense cellular layers as a capacitive element, whereas resistive components **1565**, **1575**, **1585**, **1595** can model the electrical impedance through hydrated and other portions of the skin as a resistive element.

[0086] Subdermal impedances **1550**, **1555**, **1560** can model electrical impedances through a monitored organism. For example, subdermal impedances **1550**, **1555**, **1560** can model the electrical impedances of a portion of the monitored organism as a resistive volume conductor bounded by the skin.

[0087] In one implementation, in bioelectric impedance spectroscopy, probe **200** supports electrodes **245**, **250**, **255**, **260** above skin surface **1505**. Current source **210** can drive electrical current between electrodes **245**, **250**. The driven current can include both direct current and alternating current components. The potential at electrodes **245**, **250**, **255**, **260** provides information about the net impedance across equivalent circuit **1500** as well as the impedance of different paths across equivalent circuit **1500**.

[0088] For example, when direct current is driven across circuit **1500**, a large portion of the direct current will pass through surface impedances **1515**, **1520**, **1525**. Potential measurements at electrodes **245**, **250**, **255**, **260** under direct current application can be used to estimate the impedance of surface impedances **1515**, **1520**, **1525**. When certain frequencies of alternating current are driven through circuit **1500**, some portion of the alternating current can pass through surface impedances **1515**, **1520**, **1525**, transdermal impedances **1530**, **1535**, **1540**, **1545**, and subdermal impedances **1550**, **1555**, **1560**. Potential measurements at electrodes **245**, **250**, **255**, **260** can be used to estimate impedances **1515**, **1520**, **1525**, **1530**, **1535**, **1540**, **1545**, **1550**, **1555**, **1560**. Such estimations can be made in light of the estimations of surface impedances **1515**, **1520**, **1525** made using direct current.

[0089] The impact of various factors on the electrical conductivity of an organism can be accommodated by changing the mathematical analysis of model circuit **1500** or by changing aspects of data collection. For example, when surface impedances **1515**, **1520**, **1525** are particularly low, e.g., due to heightened conductivity through sweat or other conducting fluids on the surface of the skin, the measured potentials at electrodes **245**, **250**, **255**, **260** can be mathematically corrected to accommodate the lowered conductivity. For example, previously obtained surface impedance estimates can be used to estimate the effect that changes in surface impedances **1515**, **1520**, and **1525** have on the total impedance measurement, and thus isolate the change in sub-dermal impedance so as to more accurately monitor changes in subdermal tissue hydration. Alternatively, bioelectric spectroscopy measurements can be delayed altogether or probe **200** can output an indication to a monitored individual that the individual should dry the measurement region.

[0090] Model equivalent circuit **1500** can be used in conjunction with custom approaches to data analysis for monitoring the hydration of an organism. Such data analysis approaches can be used to interpret monitoring data and to identify changes in the amount and distribution of water in a monitored organism. Data analysis approaches can also be used to incorporate results of other bioparameter measurements and responses to survey questions into the hydration monitoring. In certain implementations, such questions may be transmitted automatically to the organism from the data collection unit or the data management system. An implementation of such an automated process may include the use interactive voice response systems (IVRS) or displayed questions displayed on the data collection unit.

[0091] Data analysis approaches can be performed in accordance with the logic of a set of machine-readable instructions. The instructions can be tangibly embodied in machine-readable format on an information carrier, such as a data storage disk or other memory device. The instructions can also be embodied in whole or in part in hardware such as microelectronic circuitry.

[0092] Data analysis approaches can yield analysis results that can be displayed to a human user. The human user can be the monitored individual or another individual, such as a medical professional. The analysis results can be displayed in response to a prompt from the user or automatically, i.e., without user input. For example, the analysis results can be displayed automatically when hydration indicative of a disease state is identified. When hydration monitoring is performed using a system **1100**, analysis results can be displayed at a probe **100**, at a data collection apparatus **1105**, and/or at a data management system **1110** (**FIGS. 11, 13, 14**). Analysis results can be displayed using other output devices such as the postal service, facsimile transmission, voice messages over a wired or wireless telephone network, and/or the Internet or other network-based communication modalities.

[0093] Data analysis can be performed continuously or intermittently over extended periods of time. The analyzed data can be measurement results collected continuously or intermittently. The analyzed data can be a subset of the data collected or the analyzed data can be all of the data collected. For example, the analyzed data can be intermittent samples redacted from the results of continuous hydration monitoring.

[0094] Data analysis operations can be performed at one or more of probe **100**, data collection apparatus **1105**, and/or data management system **1110**. In one implementation, data analysis is distributed between probe **100** and data collection apparatus **1105**. In particular, probe **100** can perform initial analyses, including signal processing, noise filtering, and data averaging operations. The operations can be performed on data from one or more measurements taken at one or more frequencies. The operations can be performed on raw data or on data where variations have been accommodated. For example, the operations can be performed on data collected at certain points during breathing. These initial analysis results can be transmitted, along with other information such as a probe identifier and a time/date stamp, to data collection apparatus **1105**. At data collection apparatus **1105**, data analysis operations can include the identification of trends or shifts in hydration associated with disease states such as pulmonary edema, as well as comparisons between received data and threshold values. In addition such analysis may include a mapping of the pre-emergent wound or wound region. Such mapping and characterization may include a graphical representation of healing pattern of the region in question and/or comparison of observed values to healthy or normally healing tissue. Such comparison may present measured data directly or representations of measured data, e.g. a healing stage index, displayed numerically or as colored domains of a graphic representation of the region in question, e.g. red=poorly healing or at risk for ulceration, green=normally healing or health tissue. Wound and/or regional status may be displayed on the probe, data collection unit and/or at the data management system.

[0095] In another implementation, data analysis operations are performed primarily at data collection apparatus **1105** and data analysis at probe **100** is minimal. When data analysis at probe **100** is minimal, data analysis and data storage can be consolidated at data collection apparatus **1105** and probe **100** can include simplified circuitry with reduced power requirements and cost.

[0096] Data analysis can also be performed at data management system **1110**. Such data analysis can include multivariable analysis where hydration monitoring results are analyzed in light of other statistical variables such as weight, heart rate, respiration, time of day, month, eating patterns, physical activity levels, and other variables. The other

statistical variables need not be entirely independent of the hydration monitoring results. The hydration monitoring results used in multivariable analysis can be obtained over extended periods (e.g., days, weeks, or months) from one or more organisms. The results of such multivariable analysis can be used to develop new and improved analyses of hydration monitoring results, including improved algorithms. Such analysis may also include improved pattern definition techniques, neural net analysis and/or artificial intelligence based systems.

[0097] A variety of other analysis techniques can be applied to hydration monitoring results. These include the use of established guideline values for data that is used to determine fluid changes associated with the onset or progression of pulmonary edema. Also, clinician-modified variables such as tailored threshold values can be applied to permit increased accuracy and specificity.

[0098] Data analysis can include comparisons involving recent hydration monitoring results. For example, recent hydration monitoring results can be compared with previous hydration monitoring results, predicted results, or population results. Future hydration monitoring results can be predicted based on the current state of the monitored individual and on past hydration monitoring results obtained with the same or with other individuals or a population or demographic group. Such comparisons may include, for example, the use of population data tables, multiple reference measurements taken over time, or the results of trend analyses based upon extended hydration monitoring.

[0099] Accordingly, other implementations are within the scope of the following claims.

What is claimed is:

1. A method of monitoring a wound, said method comprising measuring electrical impedance of tissue proximate to the wound at two or more times during wound healing.

2. The method of claim 1, comprising connecting two or more electrodes to skin surfaces proximate to said wound.

3. The method of claim 2, wherein the electrodes are an integral part of a wound dressing.

4. The method of claim 1, comprising comparing electrical impedance measurements obtained at different times.

5. The method of claim 1, comprising performing a therapeutic treatment or action on said wound in response to one or more impedance measurements.

6. The method of claim 1, further comprising communicating information related to measured wound status to one or both a patient with said wound and medical personnel.

7. The method of claim 1, further comprising sensing skin temperature proximate to said wound.

8. The method of claim 1, further comprising sensing heat flux from skin proximate to said wound.

9. A wound dressing comprising:

an absorbent material adapted to absorb wound exudate, and

a plurality of electrodes situated to apply an electric current and/or voltage to tissue proximate to said wound.

10. The wound dressing of claim 9, wherein said dressing additionally comprises circuitry configured to supply current through said tissue via at least two of said electrodes.

11. The wound dressing of claim 10, wherein said dressing additionally comprises circuitry configured to measure voltage across at least two of said electrodes.

12. The wound dressing of claim 9, wherein said dressing additionally comprises a wireless transmitter.

13. The wound dressing of claim 9, wherein said dressing additionally comprises a device and/or a pharmaceutical compound or agent to enhance healing or inhibit infection.

14. The wound dressing of claim 8, wherein said dressing additionally comprises one or more temperature sensors.

15. A method of reducing incidence of pressure wounds in a patient comprising detecting susceptibility to pressure wounds by measuring electrical impedance of a region of the body of said patient.

16. The method of claim 15, comprising initiating treatment in response to said measuring.

17. A method of reducing incidence of cutaneous ulcers in a patient comprising detecting susceptibility to cutaneous ulcers by measuring electrical impedance of a region of the body of said patient.

18. The method of claim 17, additionally comprising initiating treatment in response to said measuring.

19. The method of claim 17, wherein said patient is diabetic.

20. The method of claim 17, wherein said region comprises one or both lower legs of said patient.

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专利名称(译)	监测平台用于伤口和溃疡的监测和检测		
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摘要(译)

用于监测水合作用的系统和技术。在一个实施方式中，一种方法包括测量对象的区域的电阻抗以生成阻抗测量结果，以及将数据无线地发送到远程装置。测量阻抗的探针可以贴片的形式粘附固定到受试者。