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(54) BODY SURFACE PROBE, APPARATUS AND METHOD FOR NON-INVASIVELY DETECTING MEDICAL CONDITIONS

KÖRPEROBERFLÄCHENSONDE, GERÄT UND VERFAHREN FÜR DEN NICHTINVASIVEN NACHWEIS MEDIZINISCHER ERKRANKUNGEN

SONDE DE SURFACE CORPORELLE, DISPOSITIF ET PROCEDE DE DETECTION NON INVASIVE D'ETATS MEDICAUX

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Description

FIELD AND BACKGROUND OF THE INVENTION

[0001] The present invention relates to probes for application to selected areas of a subject's body for monitoring the physiological condition or changes thereof of a mammalian subject or detecting various medical conditions of the subject. The invention also relates to apparatus utilizing such probes, and also to methods utilizing such probes for detecting various medical conditions or physiological states.

[0002] The invention is particularly useful for the non-invasive detection of a medical condition or physiological state of a subject by monitoring changes in the peripheral arterial tone as described in U.S. Patents 6,319,205, 6,322,515, 6,461,305 and 6,488,633,, and in corresponding patents and applications filed in other countries, hereinafter referred to as the above-identified patents and applications. The invention is therefore described below with respect to the above-identified patents and applications, but it will be appreciated that various features of the invention could also be advantageously used in other probes and in the detection of other types of medical conditions or physiological conditions.

[0003] The above-identified patents and applications disclose various probe constructions, methods and apparatus for the non-invasive detection of a medical condition or physiological state of a subject, particularly by monitoring changes in the peripheral arterial tone as manifested by changes in the pulsatile arterial blood volume in a terminal extremity of a body part, e.g., a digit (finger or toe) of the subject. The various medical conditions detected by such probes, as described therein, include myocardial ischemia, sleep apnea and other sleep disordered breathing conditions, endothelial dysfunction (ED), and sleep disorders, as well as certain physiological states, such as mental stress, sympathetic nervous system reactivity, blood pressure, REM stage sleep, responses to physical, pharmacological or mental agents or stressors, etc.

[0004] In general, the probes described in the above-identified patents and applications include a housing defining at least one compartment for receiving the distal end of the subject's body part (e.g., a finger or toe), including its terminal-most extremity, such that the compartment is closed at one end and open at the opposite end, and a sensor for sensing a predetermined condition of the body part after received within the compartment. The preferred embodiments described therein are particularly useful for monitoring peripheral arterial tone in a subject's finger or toes, and for that purpose, they included pressurizing means for applying a static pressure field substantially uniformly around the distal end of the subject's finger, including its terminal-most extremity. The pressure field is of a predetermined magnitude sufficient to substantially prevent distention of the venous vasculature, to substantially prevent venous blood pooling within the applied pressure field, to substantially prevent uncontrolled venous backflow and retrogade shockwave propagation into the distal end of the finger, and to partially unload the wall tension of, but not to occlude, the arteries in the distal end of the finger when at heart level or below.

[0005] The prevention of venous pooling and venous distention is intended to prevent the occurrence of induced veno-arteriolar reflex vasoconstriction. The prevention of uncontrolled venous backflow and retrogade shockwave propagation into the distal end of the finger, and the partial unloading of arterial wall tension, contribute to the optimal measurement of arterial pulse signals divorced from venous volume changes and divorced from confounding induced reflex changes due to artifacts of the measurement method. The probe sensors described in the above-identified patents and applications were thus optimally configured to sense changes in the distal end of the subject's finger (or other body part) related to changes in volume therein due to pulsatile changes in instantaneous blood volume related to arterial tone.

[0006] It would be highly desirable to provide a probe allowing measurements to be made at a broader range of body sites. Such a probe could be used to facilitate the non-invasive determination of a wide range of physiological conditions, e.g., by comparing physiological changes at sites at which peripheral arterial tone are known to be governed by differing physiological control mechanisms. Such knowledge can, for example, allow for the discrimination between reflex mediated arterial tone changes and changes in arterial pulsatile amplitude due to mechanical hemodynamic consequences of reduced or otherwise changed cardiac stroke volume.

[0007] In addition to the advantages conferred by facilitating the measuring of peripheral arterial tone at a broader range of body sites, the ability to record a pulsatile arterial signal that is effectively divorced from venous blood changes, provides important advantages for the non-invasive measurement of blood oxygen saturation by the method of pulse oximetry. An important case in point is the application of such a probe to a measurement site overlying a superficial artery, wherein the level of blood oxygen may more accurately represent the actual systemic arterial oxygenation level than would measurements derived from sites overlying a vascular bed comprised largely of microvascular arterial and venous blood vessels. The combined, simultaneous, measurement of arterial blood saturation level and peripheral arterial pulsatile volume changes from the same probe would provide even greater diagnostic advantages.

[0008] Moreover, such a probe could be used at body locations better tolerated by the subject, or less likely to result in the subject removing the device, as is the case for a finger mounted probe, for example. Such a probe would also be useful for measurements on babies, young children, mentally compromised subjects, or subjects with structural or functional disorders of the fingers or toes.

[0009] European Patent Publication No. 0326384 A1 relates to a pulse wave detecting apparatus having a housing which is fixed to a body surface of a subject, a pressing device accommodated in the housing for pressing an artery of the subject via the body surface, and a pulse wave detecting device for detecting a pulse wave of the artery which is produced in relation with the pressing of the pressing means.

[0010] Japanese Patent Publication No. JP S54 59786 U relates to a spring-loaded device configured to urge an illumination means and a measurement sensor toward a body member such as a finger.

[0011] U.S. Patent No. 4,915,116 relates to a fingertip pulse wave sensor for detecting changes in the volume of a blood vessel in a fingertip held between a light-emitting element and a light-receiving element. A fingertip supporting base has a horizontal fingertip cushion supporting surface with a light-receiving element buried therein. An elastic body is capable of maintaining the pressure applied to the fingertip at a constant value with respect to variations in the stroke of a slider provided with a pad with a light-emitting element buried therein.

OBJECTS AND BRIEF SUMMARY OF THE INVENTION

[0012] An object of the present invention is to provide a probe as defined in claim 1 which allows measurements to be made at virtually any body site and thereby provides many of the advantages discussed above. Another object of the invention is to provide apparatus as defined in claim 14 for use with such probes; and a further object is to provide a method of using such probes, defined in claim 27, for detecting various medical conditions or physiological states.

[0013] According to one aspect of the present invention, there is provided a probe as defined in claim 1.

[0014] According to the invention the pressure applicator is configured to apply the static pressure to a relatively restricted area of the subject's skin, which area occupies a relatively small fraction of the surface perimeter of the respective body part at the measurement site, to thereby permit free venous drainage from the measurement site via a wide region of unrestricted passageways surrounding the measurement site.

[0015] Preferably, the pressure applicator applies to the measurement site a static pressure which is above the subject's local venous pressure and slightly below the subject's diastolic blood pressure.

[0016] Several embodiments of the present disclosure are described below for purposes of example. In one embodiment, the pressure applicator comprises a fluid chamber and an external source of fluid for applying the pressure to the measurement site and subsequently measuring the pressure. In another embodiment, the pressure applicator comprises a fluid chamber with at least one elastic wall constructed to utilize Laplace's law and including a self-contained fluid for applying the static pressure to the measurement site such that the level of pressure applied by the probe is substantially unaffected by the mechanical characteristics of the underlying tissues. In a further embodiment, the pressure applicator comprises a chamber including a spring therein for applying the static pressure to the measurement site; and in a still further embodiment, the pressure applicator comprises a resilient elastomeric material, such as sponge rubber or the like, for applying the static pressure to the measurement site.

[0017] According to another aspect of the present invention, there is provided apparatus for detecting and indicating a medical condition of a subject, comprising: a probe as set forth above for application to a measurement site on the subject's skin and for producing an output corresponding to measured changes in the pulsatile arterial blood volume thereat; and a data processor system for utilizing the measured changes to detect and indicate a medical condition or a physiological state of the subject.

[0018] According to further features in some described embodiments, the apparatus further comprises at least one additional probe as set forth above for application to at least one additional measurement site on the subject's skin and for measuring changes in the pulsatile arterial blood volume thereat; the data processor system utilizing the measured changes of both of the probes for detecting and indicating the medical condition or physiological state of the subject.

[0019] As will be described more particularly below, such probes may be constructed for application to measurement sites in which the vascular beds thereat have different levels of autonomic nervous system activity; or in which the vascular beds are mainly comprised of conduit or conducting arteries; or in which the pulsatile volume of the vascular beds are respectively predominantly affected by autonomic nervous system activity and by the level of systemic blood pressure, etc.

[0020] According to a further described preferred embodiment, the probe could include an electrode for sensing a bio-potential such as the electrocardiograph (ECG) signal of a subject, the data processor utilizing the measured changes in the pulsatile arterial blood volume, and the ECG signal, to determine the pulse transit time (PTT) or the pulse propagation velocity. Sensors of other physiological parameters could also be substituted for the bio-potential sensor. As will be described more particularly below, such information can also be extremely useful in detecting and indicating the medical condition of the subject.

[0021] According to still further aspects of the present invention, there is provided a method and apparatus using probes as set forth above for detecting and indicating various medical conditions of a subject.

Comparison with Finger (and Toe) Probes

[0022] Heretofore, the practical application of the arte-

rial pulse signal measurement methodology for isolating an essentially pure arterial pulsatile volume measurement has been restricted to sites which incorporated the body's terminal extremities, i.e., a finger or toe. This is due to the fact that such probes are applied circumferentially over the entire perimeter of the body region being measured in order to apply to the measurement site the required static pressure which partially unloads the wall tension of, but does not occlude, the arteries in the measurement site. Thus, a full perimeter pressure band inherently induces venous distention and venous pooling distal to the site of pressure application.

[0023] Such venous distention and venous pooling can only be prevented if the entire distal surface of the measurement site, up to and including the very tip, is enclosed within the uniform pressure field such that no part of the vascular bed is in fact distal to the pressure field. The probes described in the above cited patents and applications were generally constructed to ensure that the applied pressure field reaches up to, and in fact beyond, the terminal end of the extremity so as to avoid the occurrence of venous pooling and venous distention, and thus avoid the disadvantageous consequences of unchecked distal venous pooling and distention.

[0024] In contrast, the probes constructed in accordance with the present invention are able to measure arterial pulse signals and their changes from virtually any point on the body surface without causing deleterious venous pooling effects. This is achieved by constructing the probes to apply the appropriate pressure field to a given body surface without completely encircling the measurement site. Under such circumstances distal venous pooling is avoided since venous drainage can occur freely via alternate, fully unrestricted pathways surrounding the point or region of measurement and thus the need to apply a pressure field extending distally to the terminal end of the extremity is avoided.. At the actual site of the measurement, the applied pressure would be such that the veins would be maintained in a collapsed state save for the transmitted pulsatile arterial throughput.

[0025] Furthermore, an expanded region of uniform pressure application, extending in area beyond the central measurement region, confers the additional benefits of extending the effective boundary of the pressure field overlying the sensing region, and in addition, of buffering the measurement site from retrograde venous shockwave signals and the like.

[0026] In addition, since such probes can be constructed for application to virtually any body site, such probes allow measurements to be concurrently made, as indicated above and as will be described more particularly below, at a plurality of different body sites to provide considerable additional information useful for indicating or detecting various medical conditions or physiological states of the subject.

[0027] Further features and advantages of the invention will be apparent from the description below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] Embodiments of the present disclosure are herein described, by way of example only, with reference to the accompanying drawings, wherein:

Figs. 1a and 1b are diagrammatic top and side views, respectively, illustrating one form of probe constructed in accordance with the present disclosure in which the pressure applicator includes a fluid chamber having an external source of fluid for facilitating pressure application and for measuring changes in the pulsatile arterial blood volume; and Fig. 1c is a view corresponding to that of Fig. 1b showing the probe applied to a subject's skin for measuring changes in the pulsatile arterial blood volume thereat;

Figs. 2a, 2b and 2c are diagrammatic views corresponding to Figs. 1a, 1b and 1c, respectively, illustrating another probe constructed in accordance with the present invention in which the pressure is applied by a fluid chamber having at least one elastic wall constructed to utilize Laplace's law, as more particularly described for example in published Application U.S. 2002/0072681 A1;

Figs. 3a, 3b and 3c are diagrammatic views corresponding to those of Figs. 1a, 1b and 1c, respectively, illustrating a third probe constructed in accordance with the present invention in which the pressure applicator includes a spring for applying the static pressure;

Figs. 4a, 4b and 4c are diagrammatic views, corresponding to Figs. 1a, 1b and 1c, respectively, illustrating a fourth probe constructed in accordance with the present invention in which the pressure applicator includes a resilient sponge material for applying the static pressure;

Figs. 5a, 5b and 5c are diagrammatic views, corresponding to those of Figs. 4a, 4b and 4c, more particularly illustrating the structure of the probe of those figures and the inclusion of an ECG electrode in the probe;

Fig. 6 diagrammatically illustrates one manner of clamping the probe to a restricted area on the surface of a subject's skin;

Fig. 7 diagrammatically illustrates another manner of clamping the probe to a restricted area of the subject's skin;

Fig. 8 is a block diagram illustrating one form of apparatus constructed in accordance with the present invention to utilize the measurements of a plurality of probes for detecting or indicating the medical condition or physiological state of the subject;

Fig. 9 includes two traces which demonstrate, as will be described more particularly below, that measurements of arterial blood volume changes substantially free of venous pooling can be made at virtually any location of a subject's body;

Fig. 10 illustrates, in the upper trace the output signal

from a probe applied to the finger pressurized to a minimum pressure field, and in the lower trace the output signal from a probe mounted on the palm and pressurized to a near diastolic pressure field;

Figs. 11a, 11b and 11c are diagrammatic views, corresponding to Figs. 1a, 1b and 1c, respectively, illustrating a further probe constructed in accordance with the present invention including an optical sensor; while Figs. 11d and 11e are plan and side views, respectively, more particularly illustrating the construction of the optical sensor;

Fig. 12 is a block diagram illustrating apparatus constructed in accordance with the present invention to utilize the measurements of the probe of Figs. 11a - 11e;

Figs. 13a and 13b are plan and side views, respectively, corresponding to Figs. 11d and 11e, respectively, but illustrating the probe as also including an ECG electrode;

Fig. 14 is a block diagram illustrating apparatus constructed in accordance with the present invention to utilize the measurements of the probe of Figs. 13a and 13b;

Fig. 15 illustrates the manner of using two probes constructed in accordance with the present invention, one applied to the palm and the other applied to the finger, to detect changes in the pulsatile arterial blood volume at two different locations on the subject's body having different short term responses to reflex events;

Fig. 16 illustrates the outputs of two probes constructed in accordance with the present invention applied to different parts of the subject's body (finger and palm) during a 30-minute period of sleep;

Figs. 17 and 18 illustrate the outputs of two probes constructed in accordance with the present invention applied to different parts of the subject's body (forehead and hand) in which the vascular beds have different reactivity to autonomic stimulation;

Fig. 19 illustrates the output of a probe constructed in accordance with the present invention applied to a radial artery or other major superficial artery overlying a bony region; and

Fig. 20 illustrates the outputs of two probes constructed in accordance with the present invention applied to a hand and radial artery, respectively.

[0029] It is to be understood that the foregoing drawings, and the description below, are provided primarily for purposes of facilitating understanding the conceptual aspects of the invention and various possible embodiments thereof, including what is presently considered to be a preferred embodiment. In the interest of clarity and brevity, no attempt is made to provide more details than necessary to enable one skilled in the art, using routine skill and design, to understand and practice the described invention. It is to be further understood that the embodiments described are for purposes of example only, and that the invention is capable of being embodied in other forms and applications than described herein.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0030] As indicated earlier, the body probes constructed in accordance with the present invention are capable of being applied to almost any selected area of a subject's skin for measuring changes in the pulsatile arterial blood volume thereat, without restricting the probe to a terminal extremity, such as the finger or toe of the subject's body. The probe includes a base for application to the selected area of the subject's skin at the measurement site, a pressure applicator carried by the base for applying a static pressure to the subject's skin at the measurement site, and a sensor carried by the pressure applicator for sensing changes in the pulsatile arterial blood volume at the measurement site. According to the present invention, the pressure applicator applies to the measurement site a static pressure of a magnitude to partially unload the wall tension of, but not to occlude, the arteries at the measurement site. The pressure applicator is configured to substantially prevent venous distention and blood pooling at the measurement site by applying sufficient external counter pressure to effectively collapse the underlying veins and limit the local venous blood flow to the arterial throughput while permitting free venous drainage with respect to the measurement site through tissues surrounding the measurement site. The latter is effected, in the described preferred embodiments, by applying the static pressure to a relatively restricted area of the subject's skin, which area occupies a relatively small fraction of the surface perimeter of the respective body part at the measurement site, to thereby permit free venous drainage from the measurement site via a wide region of unrestricted passageways surrounding the measurement site.

[0031] The drawings illustrate a number of probes constructed in accordance with the foregoing features of the present disclosure.

[0032] The probe illustrated in Figs. 1a - 1c, and therein generally designated 10, includes a base 11 of a non-stretchable material; a pressure applicator 12 centrally of the base; and a sensor 13 centrally of the pressure applicator for sensing changes in the pulsatile arterial blood volume at the respective measurement site. The surface of base 11 facing the pressure applicator 12 and sensor 13, brought into contact with the subject's skin, includes an adhesive layer 14 for adhering the base to the subject's skin at the measurement site.

[0033] As described earlier, pressure applicator 12 applies a static pressure of an appropriate level to enhance arterial pulsatile pressure measurements, by unloading vascular wall tension, while at the same time preventing venous distention and pooling. Thus, since the pressure applicator is applied to a relatively restricted area of the subject's skin which area occupies a relatively small fraction of the surface perimeter of the respective body part

at the measurement site, the static pressure applied at the measurement site permits free venous drainage from the measurement site via a wide region of unrestricted passageways surrounding the measurement site.

[0034] In probe 10 illustrated in Figs. 1a - 1c, the pressure applicator 12 includes a fluid chamber 15 connected via a tube 16 to a source of pressurized fluid (e.g., air), and a rigid cap 17 on the side of the applicator opposite to that carrying the sensor 13. Thus, when the base 11 has been firmly adhered to the subject's skin at the measurement site by the adhesive surface 14, pressure applicator 12 may be pressurized, via tube 16, to apply to the measurement site the appropriate pressure, as set forth above, to enable sensor 13 to sense changes in the pulsatile arterial blood volume without the effects of venous distention and pooling. The actual volume changes occurring within the above described pressurized pneumatic system may be measured and thus serve as an independent signal for measuring the changes in the pulsatile arterial blood volume without the effects of venous distention and pooling as described in a previous application (Foreign Application [IL] 118976 Jul 30, 1996, see Fig. 5 thereof). The latter sensing modality may be used independently or in combination with other sensing modalities

[0035] Sensor 13 could be any type of sensor, such as any of those described or mentioned in the above-cited patents and applications, for detecting mechanical perturbations, volumetric changes, pressure changes, optical density changes or surface-reflectivity changes, laser Doppler device, or other flow meter devices, electromagnetic changes, Hall effect changes, strain gauge devices piezo-electric elements etc.

[0036] The various medical conditions or physiological states detectable by probe 10, as well as the other probes constructed in accordance with the present present disclosure as described below, include myocardial ischemia, sleep apnea, hypopnea, upper airway resistance syndrome, endothelial dysfunction (ED), and sleep disorders, as well as certain physiological states, such as mental stress, sympathetic nervous system reactivity, responses to physical, pharmacological agent, or mental stressors, blood pressure, REM stage sleep, etc. or any of the medical conditions or physiological states described or mentioned in the above-cited patents and applications. As will be described below with respect to Figs. 11a - 14, particularly important advantages are obtainable when the invention is implemented in pulse oximetry probes.

[0037] Figs. 2a - 2c illustrate another probe constructed in accordance with the present invention, and therein generally designated 20, also including a base 21 for application to a selected area of the subject's skin at the measurement site; a pressure applicator 22 carried by the base for applying a static pressure to the subject's skin at the measurement site; a sensor 23 carried centrally of the pressure applicator for sensing changes in the pulsatile arterial blood volume at the measurement site; and an adhesive layer 24 for adhering the base 21 to the subject's skin at the measurement site. In this case, however, the pressure applicator 22 comprises a fluid chamber with at least one elastic wall constructed to utilize Laplace's law. Thus, as described, e.g., in the above-cited U.S. Patent 6,461,305, an appropriate implementation of Laplace's law is capable of producing a fixed predetermined pressure on an external elastic membrane irrespective of the underlying tissue characteristics. Long term preservation of fluid volume prior to use in such device could be achieved by way of rupturing an internal air-sac (packaging bubbles), or by deforming a volume-occupying plastic former, or by using bistable volume-occupying elements, as described for example in our pending published application No. U.S. 2002/0072681 A1.

[0038] Figs. 3a - 3c illustrate another probe, therein generally designated 30, constructed in accordance with the present invention to also include a base 31 for application to the selected area of the subject's skin; a pressure applicator 32 for applying a static pressure to the subject's skin at the measurement site; a sensor 33 for sensing changes in the pulsatile arterial blood volume at the measurement site; and an adhesive layer 34 for adhering the base to the subject's skin at the measurement site. In this case, however, the pressure applicator 32 includes a coil spring 35 within a rigid housing 36 carrying the sensor 32 at one end of the spring projecting from the housing for applying, to the measurement site sensed by sensor 33, the appropriate pressure for unloading vascular wall tension, and thereby enhancing arterial pulsatile pressure measurements, while at the same preventing venous distension and pooling, as described above.

[0039] Spring 35 of the pressure applicator 32 is preferably of a relatively large length in its uncompressed condition such that the effective pressure generated by it, when compressed, is substantially unaffected by relatively small variations in compressed length due to the mechanical characteristics of the underlying tissues. This is particularly so when a substantial fraction of spring 35 in its compressed state is contained within housing 36.

[0040] Figs. 4a - 4c illustrate a probe, therein generally designated 40, of similar construction as in Figs. 3a - 3c, but including a cylindrical column of elastic material, such as a sponge material, instead of the spring-loaded mechanism of Figs. 3a - 3c. Thus, the probe of Figs. 4a - 4c also includes a base 41, a pressure applicator 42, a sensor 43, and an adhesive coating 44, corresponding to elements 31 - 34, respectively in Figs. 3a - 3c, except that, in the case of Figs. 4a - 4c, the pressure applicator 42 includes a cylindrical column 45 of a resilient elastomeric material, such as an elastomeric spongy material, instead of the spring 35 in Figs. 3a - 3c. within a rigid housing 46 corresponding to the rigid housing 36 of Fig. 3a - 3c. The resilient elastomeric material 45 in probe 40 should also be of a relatively large uncompressed length such that the effective pressure generated by it, when compressed, is substantially unaffected by relatively small variations in the compressed length due to the me-

chanical characteristics of the underlying tissues. As in the previous case, this is particularly so when a substantial fraction of the cylindrical elastomeric column 45 in its compressed state is contained within rigid housing 46.

[0041] Figs. 5a - 5c illustrate a probe, generally designated 50, of similar construction as shown in Figs. 4a - 4c, also including a base 51 coated on its underside with an adhesive layer 54, a pressure applicator 52 in the form of a column 55 of an elastomeric or spongy material covered at its upper face by a rigid cap 56, and a sensor projecting from the lower face of the elastomeric column 55 for contact with the subject's skin at the measurement site. In probe 50, the sensor is an optical sensor, including an optical transmitter 53a and an optical receiver 53b for optically sensing changes in the pulsatile arterial blood volume at the measurement site.

[0042] Probe 50 illustrated in Figs. 5a - 5b further includes an ECG electrode 57 for sensing electrocardiograph (ECG) signals, concurrently with the measurement of changes in the pulsatile arterial blood volume by sensors 53a, 53b. The sensed ECG signal may also be used with the arterial blood volume measurements to detect or indicate a medical condition or physiological state of the subject, e.g., by producing a measurement of the pulse propagation velocity.

[0043] Fig. 6 illustrates a clamping arrangement which may be used, instead of or together with the adhesive coating applied to the underside of the probe base, for clamping the probe to a restricted area of the subject's skin (e.g., the subject's wrist), which restricted area occupies a relatively small fraction of the surface perimeter of the respective body part (wrist) at the measurement site. Such an arrangement permits free venous drainage from the measurement site via a wide region of unrestricted passageways surrounding the measurement site.

[0044] In Fig. 6, the probe is generally designated 60. It may be of any of the above-described constructions, with or without (preferably with) the adhesive coating (e.g., 14) on the underside of the base (e.g., 11). The clamp used, generally designated 61 in Fig. 6, may be, for example, a spring-loaded caliper. It includes one leg 62 engageable with the base of probe 60 for pressing it against the subject's skin at that location of the body part (e.g., wrist); a second leg 63 engageable with a pressure pad 64 at the opposite side of the subject's body part to apply a counter-force to the respective body part; and a third leg 64 engageable with another pressure pad 65 at a third point of contact with the body part, to thereby produce a three-point clamping arrangement on the respective body part.

[0045] The pressure applied by leg 62 against the base of the probe 60, together with the pressure generated by the pressure applicator portion of the probe (e.g., pressure applicator 12, Figs. 1a - 1c), should preferably be above normal venous pressure, but below the diastolic arterial blood pressure, to thereby enhance the arterial pulsatile pressure measurements by the sensor (e.g. 12, Figs. 1a - 1c) at the measurement site. Thus, since the pressure applied to the body part (e.g., wrist) does not extend for the entire perimeter of the body part, such a clamping arrangement permits free venous drainage with respect to the measurement site (i.e., occupied by the sensor) through the tissues surrounding the measurement site, thereby preventing venous distention and blood pooling at the measurement site.

[0046] Fig. 7 illustrates a slightly different clamping arrangement for clamping the probe, therein generally designated 30, to the body part (e.g., wrist). The clamping arrangement illustrated in Fig. 7 is a spring loaded bracelet, generally designated 71, encircling the respective body part (e.g., wrist). Bracelet 71 also includes one leg 72 for applying the appropriate pressure to the sensor 70 at one side of the body part, another leg 73 for applying a counter-pressure to a pressure pad 74 at the opposite side of the body part, and a further leg 75 for applying pressure to a further pressure pad 75 at a third point of the body part, to thereby provide a three-point mounting of the bracelet. In all other respects, the spring loaded bracelet 71 illustrated in Fig. 7 operates in the same manner as described above with respect to Fig. 6 to enhance the arterial pulsatile pressure measurements by probe 70, by unloading vascular wall tension while at the same time preventing venous distension and pooling.

[0047] As indicated earlier, an important advantage of the novel probe constructed in accordance with the present invention is that a plurality of such probes may be used at different locations of the subject's body for measuring changes in the pulsatile arterial blood volume at each such location. Such measurements at the different measurement sites can provide further information useful for detecting and indicating various medical conditions of the subject.

[0048] For example, a plurality of body surface probes can be used to obtain simultaneous and comparative measurements from arterial-venous shunt rich palmar surfaces of the hand or plantar surfaces of the foot, and other parts of those limbs which have corresponding arterial-venous surfaces which are shunt poor. Such comparisons may help to accentuate the intensity of autonomic nervous system activation, since arterio-venous rich sites have greater autonomic control. Further applications of the invention utilizing two or more such probes are described below particularly with reference to Figs. 10 - 16.

[0049] Fig. 8 is a block diagram illustrating the main components of apparatus utilizing one, two, or more such probes. In the example illustrated in Fig. 8, the apparatus includes two such probes 81, 82, which may be of any of the foregoing constructions. Each probe, therefore, would include a base for application to the selected area of the subject's skin at the measurement site, a pressure applicator carried by the base for applying the required static pressure to the subject's skin at the measurement site, and a sensor for sensing changes in the pulsatile arterial blood volume at the measurement site, as more

particularly described above. If one (or both) of the sensors included an ECG electrode (corresponding to ECG electrode 57 in Figs. 5a - 5c), the apparatus could be utilized not only for measuring changes in the pulsatile arterial blood volume at the respective measurement site, but also for generating ECG signals, e.g., to determine the pulse transition time and/or pulse propagation velocity. Such information would also be useful in detecting or indicating the medical condition or physiological state of the subject. As will be described, several other biopotential based or non-biopotential based signals may usefully be recorded in combination from a common probe as illustrated for the case of an ECG electrode in Figs. 5a - 5c.

[0050] As shown in Fig. 8, the outputs of the probes 81, 82 are applied to an amplifier and filter circuit 83, converted to digital by an A/D circuit 84, and inputted into a data processor system 85 having a CPU, storage display, etc.

[0051] Probes 81, 82 illustrated in Fig. 8 may be wire-connected to the data processor 85 via circuits 83 and 84, or may communicate with data processor via a wireless communication link, e.g., RF, infra-red, acoustical, etc. In the latter case, the energy supply for sensing changes in the pulsatile arterial blood volume at the respective measurement site, and for transmitting such measurements to the data processor system, would be contained within the probe itself, thereby freeing the subject from attachment to the data processor. In the case where either or both probes 81, 82 are wire-connected to the processor 85, the latter and its supporting system may be mounted on the subject, as previously described in US Patent 6,461,305 thus providing the subject with freedom of movement.

[0052] A sleep/wake detector such as an actigraph device can also be incorporated into a probe device or into the subject mounted processor 85 and its supporting system, as described for example in our pending published Application No. U.S. 2003/0004423 and in WO 01/64101 (Method and Apparatus for the Non-Invasive Detection of Particular Sleep-State Conditions by Monitoring the Peripheral Vascular System). In addition to the pulsatile arterial volume signal, other physiological parameters can also be sensed by the body surface probes. In principal any of the known physiological parameters which can be can be sensed from the body's surface can also be sensed, together with the arterial pulsatile volume signal. Examples of such parameters include: blood oxygen saturation levels sensed by the method generally known as pulse oximetry; sounds such as those related to breathing; biological potentials, such as electro-cardiography (ECG), electro-encephelography (EEG), electromyography (EMG), electro-oculography (EOG), using at least a bipolar measurement setting; pulse transit time (PTT); local skin temperature; galvanic skin response signal (GSR); and any other known biological parameter that can be sensed from the surface of the skin.The simultaneous measurements derived from different measurement sites may provide further useful information by facilitating the measurement of bio-potentials such as ECG, EOG, EMG, EEG, etc. which require at least a single dipole for adequate measurement. As mentioned, non-biopotential signals such as skin temperature, galvanic skin response, and acoustic recordings, can further provide useful information. The above listed signals may be derived from the same probe device as that used for sensing changes in the pulsatile arterial blood volume at the measurement site in the manner illustrated for an ECG electrode in Figs. 5a - 5c.

[0053] The following experiment was conducted to demonstrate that the venous pooling artifact free measurement of arterial pulse signals and their changes can be derived from virtually any point on the body surface using the above-described probes, in a manner similar to that of the finger (or toe) probes described in the above-identified patents and applications.

[0054] Fig. 9 shows the acute affect of induced venous pooling and its resolution, using a previously described finger probe. More particularly, this figure shows the time-course of pulse wave amplitude in two adjacent fingers when a proximal cuff on the upper arm is alternately inflated to a pressure of 40 mmHg and then deflated back to 0 mmHg. The result of inflating the proximal cuff to 40 mmHg is to induce venous distention in the tissues distal to the cuff. The upper trace shows the pulse-wave amplitude recorded from the finger probe when a minimal external pressure is applied while the lower trace shows the pulse-wave amplitude recorded by the finger probe when pressure field of near diastolic pressure is applied over the entire surface of the two distal most phalanges. It is clear that in the finger with the minimal external pressure field, the periods of induced venous distention are associated with substantial attenuation of the pulse-wave amplitude, compared to when there is no applied venous distention. In sharp contrast to this, the simultaneous recording from the finger within the pressure field is essentially unaffected by the induced venous distention.

[0055] Fig. 10 shows a similar the results of a similar experiment when the time-courses of the pulse wave amplitude sensed by a body surface probe constructed in accordance with the invention (e.g., Figs. 4a - 4c) and mounted, respectively on the palm (lower trace) and a finger (upper trace) recorded from a finger probe in which a minimal external pressure is applied, when a proximal cuff on the upper arm is alternately inflated to a pressure of 40 mmHg and then deflated to 0 mmHg. Inflating the cuff to 40 mmHg induces venous distention in the tissues distal to the cuff. The upper trace is the pulse signal from a prior finger probe within minimal external counter pressure environment; and the lower trace is the pulse signal from the novel palm-mounted body surface probe within a near diastolic pressure field applied to the local measurement site only.

[0056] In both cases illustrated in Figs. 9 and 10, in the absence of the pressure field, periods of induced venous distention are associated with substantial attenuation of

the pulse signal. In sharp contrast, the simultaneous recording from the finger or the palm region within the respective pressure fields generated by the different probe devices were both essentially unaffected by the induced venous distention.

[0057] The acute effect of this locally induced signal attenuation is further complicated by a tendency for induced veno-arteriolar vasconstriction to propagate centripitally over time.

[0058] Figs. 11a - 11e illustrate a probe, therein generally designated 80, similar to probe 50 of Figs. 5a - 5b, but particularly suitable for making pulse-oximetry measurements.

[0059] Pulse oximetry is based on the characteristic that oxygenated hemoglobin absorbs more infrared light and allows more red light to be transmitted; while deoxygenated (or reduced) hemoglobin behaves in an opposite manner and absorbs more red light and allows more infrared light to be transmitted. At a wavelength of about 805 nm light absorption or transmission is unaffected by the level of oxygen saturation (i.e. the isobestic wavelength).

[0060] By alternatively exposing the measurement site to red and infrared (or to the isobestic wavelength) light from appropriate LEDs switched in rapid succession, the level of transmitted (or scattered) light can be measured using a light sensitive element. By calculating the comparative differences in absorptions at respectively high and low points of the pulse wave at both respective wavelengths, and using an empirically derived conversion equation, it is possible to then compute the proportion of hemoglobin which is oxygenated.

[0061] There are two main methods of performing pulse oximetry: (a) transmission mode, in which the light source and optical detector are placed on opposite sides of the tissue; and (b) reflection mode in which they are placed along side of each other.

[0062] The wavelengths used are within the ranges of 600-750 nm (red) and 850-1000 nm (infrared). Typical values are 660 nm for red, and 920 or 940 nm for infrared, or a combination of 650nm and 805nm.

[0063] Thus, probe 80 illustrated in Figs. 11a - 11e also includes a base 81 coated on its underside with an adhesive layer 84, a pressure applicator 82 in the form of a column 85 of an elastomeric or spongy material covered at its upper face by a rigid cap 86, and a sensor projecting from the lower face of the elastomeric column 85 for contact with the subject's skin at the measurement site. As shown particularly in Figs. 11d and 11e, the sensor includes two transmitters 83a, 83b (e.g., LEDs) of different wavelengths, and a receiver 83c (e.g., a photo detector) spaced from the two LEDs by an opaque surface 83d to be pressed against the subject's skin. It will thus be seen that, by rapidly switching the two LEDs in succession, the level of light transmitted (or scattered) by the tissue occupying surface 83d will be detected by photo detector 83c, to enable a computation to be made as to the blood oxygen saturation level of the tissue placed against the opaque surface 83d.

[0064] Fig. 12 is a block diagram illustrating the apparatus, generally designated 90, for utilizing the outputs of photo detector 83c for producing measurements of blood saturation level and arterial pulsatile volume. As shown in Fig. 12, the photo detector 83c produces, two outputs each corresponding to the level of the light received from one of the two LEDs 83a, 83b. These photo detector outputs are applied as inputs 91a, 91b, to a separate amplifier/filter channel 92a, 92b for amplification and filtration, before being converted via A/D converter 93 to digital form and inputted into a CPU 94. CPU 94 employs the appropriate conversion equations (e.g., empirically derived) to compute the blood saturation level, arterial pulsatile volume, etc., as shown by block 94. These values are then stored and/or displayed, as shown by block 96.

[0065] Figs. 13a and 13b illustrate a probe construction similar to that of Figs. 11a-11e, except one that it also includes a conductive element such as an ECG electrode. Thus, as shown in Figs. 13a and 13b, the probe, then generally designated 100, also includes the two light transmitters 103a, 103b, and the receiver 103c. Here, however, the space between the latter elements is occupied by the conductive element such as an ECG electrode 104a to enable the probe also to measure electrical potentials such as the ECG signals from the subject.

[0066] The construction of probe 100 of Figs. 13a, 13b is otherwise the same as probe 80 of Figs. 11a-11e.

[0067] Fig. 14 illustrates apparatus for processing the output of probe 100, which apparatus is similar to that of Fig. 12 for processing the output of probe 90, except that the apparatus of Fig. 14 also includes inputs from the two ECG electrodes 104a, 104b. Accordingly, the other elements illustrated in Fig. 14 are identified with the same reference numerals as in Fig. 12, with the addition of the input from the ECG electrode 104a together with that from another probe being identified as inputs 91c, 91d, respectively.

Possible Applications of the Novel Body Surface Probes

[0068] Following is a partial list of possible applications for the above described probe, apparatus and method:

1. The novel body surface probes may constitute an alternative sensing probe for all applications of the peripheral arterial pulsatile volume or peripheral arterial tone measurements referred to in all our previous above-identified patents and applications, (e.g., sleep-medicine related, exercise-stress testing related, endothelial function testing related, responses to physical, pharmacological or mental agents or stressors, etc.). An example of short term responses to reflex events in simultaneous finger and palm measurements is shown in Fig. 15. The suitability of the body surface probe as an alternative to the previously described probes is further empha-

sized in Fig. 16. This shows the time course of finger and palm arterial pulse amplitude as a function of time during a 30 minute period of sleep during which frequent apneas occurred. The frequent periodical falls in signal amplitude, occurring at the same times in both signals are the result of those apnea events during sleep.

2. The novel body surface probes may also be applicable to arterio-venous shunt rich palmar surfaces of the hand or plantar surfaces of the foot and may be less disturbing than the previously-described finger probes, easier to apply, less prone to accidental or intentional removal (particularly among young subjects such as babies or infants), and more suitable if fingers are abnormally small or large, or if misshapen or deformed, or for young children with small fingers or those tending to remove finger probes.

3. The novel body surface probes can also be used to obtain simultaneous and comparative measurements from for example, arterio-venous shunt rich palmar surfaces of the hand or plantar surfaces of the foot and corresponding arterio-venous shunt poor dorsal aspects of those limbs. Such comparisons may help to accentuate the intensity of autonomic nervous system activation, since arteriovenous rich sites have greater autonomic control.

4. Likewise, two or more such novel body surface probes may be simultaneously applied to other combinations of body sites, such as the forehead, where vascular beds are very much less reactive to autonomic stimulation, and the palmar surface of the hand where autonomic regulation is extremely high. Such comparisons can be used to differentiate between reflex mediated vasoconstriction which affects the hand's palmar surface only, as shown in relation to the inspiratory gasp events indicated in Figs. 17 and 18, and a diminution of the arterial pulse wave amplitude due to a reduction in stroke volume or a fall in pulse pressure which would affect both sites. This is illustrated in Fig. 18 in relation to the Valsalva maneuver.

5. Body surface probes may be applied to a radial artery or other major superficial artery preferably overlying a bony region, and to a peripheral arterial vascular bed such as the palmar surface of the hand, to get an index of conducting or conduit artery behavior which is relatively less affected by autonomic nervous system in comparison to the peripheral arterial site which is more strongly affected by the autonomic nervous system. A recording derived from a radial artery is shown in Fig. 19.

6. Similar to application 4 above, a pair of the novel body surface probes may be applied respectively to a radial artery or other major superficial artery preferably overlying a bony region, and to a peripheral arterial vascular bed such as the palmar surface of the hand. A comparison of the probe outputs would provide an index of conduit artery behavior which is relatively less affected by autonomic nervous system, in comparison to the peripheral arterial site which is more strongly affected by the autonomic nervous system. Such probes may be used simultaneously at a large arterial site and in multiple peripheral sites as described in applications 2, 3 and 4 above.

7. The application of a body surface probe may be useful for evaluating the level of endothelial function to facilitate Endothelial Dysfunction diagnostic assessment as described in considerable detail in WO 02/34105 (Method and Apparatus for Non-Invasively Evaluating Endothelial Activity in a Subject).

In this application, the novel body surface probe sensor may be used in place of the various sensor types described in that patent dealing with endothelial function evaluation. The novel body surface probe devices may be used to perform all of the assessments described there. Its use may also be more convenient in many cases.

The application of the novel body surface probe over a radial artery, or any other major superficial artery preferably overlying a bony region, may be especially useful for evaluating endothelial function or determining if a state of endothelial dysfunction (ED) is present or not, in regard to large conduit arteries, or in regard to microvascular arterial blood vessels.

The combined assessment of endothelial function or the determination of whether a state of endothelial dysfunction (ED) is present or not, in relation to both large conduit vessels and to microvascular arterial blood vessels, can be made simultaneously by using a plurality of the body surface probes at the appropriate sites. The combined assessment of endothelial function or the determination of whether a state of endothelial dysfunction (ED) is present or not, in relation to both large conduit vessels and to microvascular arterial blood vessels, can be of further value since this not only facilitates determining the separate responses of both types of vascular beds, it also facilitates the determination of their comparative responses.

8. The novel body surface probes may be also applied to a large superficial artery such as the radial artery as a robust means of determining BP trends. The amplitude of a pulsatile blood volume signal from a given large artery is primarily a function of arterial blood pressure. In contrast, the level of peripheral arterial tone in peripheral vascular beds comprising arterial vessels of a wide spectrum of calibers is primarily a function of the resistance of a given vascular bed and the blood pressure. By sensing changes in the pulstile arterial blood volume at a large vessel and at a peripheral site down stream from that large vessel, it is possible to determine the separate and comparative contributions of generalized system blood pressure changes and peripheral vascular re-

sistance changes.

Fig. 20 illustrates an example of the latter application. This figure shows the peripheral signal recorded from the palmar surface of the hand (upper trace) and a simultaneous recording from the radial artery (lower trace). It is notable that the recording from the large artery is far less variable than that recorded from the peripheral location. It is also of interest that the trends of the respective large and small artery signs are often reciprocal in direction. This is consistent with the reciprocal relationship existing between peripheral resistance and blood pressure when cardiac output is stable. Thus combined measurements at these sights can provide a more complete understanding of the physiological state of the subject.

9. The novel body surface probes may also be applied to mid temporal arteries to monitor cerebral blood flow.

10. The novel body surface probes may also be used to measure pulse propagation velocity when two probes are placed in series at a known distance from each other along a major arterial pathway. (Propagation velocity is a potential blood pressure measurement surrogate and compliance index).

11. The novel body surface probes may also be used to measure the time course of mechanical perturbations, volumetric changes, pressure changes, optical density changes etc. consequent to the pulsatile arterial volume changes, as well as their variations, for the various diagnostic applications previously described, as well as for the purpose of providing input information for biofeedback treatment.

Advantages of Body Surface Probes in Pulse Oximetry Measurements

[0069] The use of the novel body surface probes for measurements by pulse oximetry provides two particularly important advantages:

1) The applied pressure field physically removes local venous blood in the measurement site. This is an important factor in the accurate measurement of the oxygen content of arterial blood since variations in venous blood can occur and these can contribute to the pulsatile difference measurements As a result a more accurate measurement is possible.

The optical density of the tissues is a combination of solid tissues, pulsatile arterial blood volumes, and fixed essentially non-arterial blood volumes. The solid tissues are by definition constant, and their contribution to light absorption is likewise constant. In contrast, the non-pulsatile arterial blood volume which is in very large part venous blood is capable of considerable variation. In vascular beds where there are direct arterio-venous pathways such as in the fingers, low pressure venous pulsation can also potentially occur. By ensuring that only pulsatile arterial blood is being measured this potential source of error is removed.

2). The novel body surface probes can provide an additional advantage for pulse oximetry measurement since they can be placed at body sites which directly overly superficial arteries, thus facilitating direct measurement from an arterial source.

[0070] In general pulse oximetry is performed on the fingers, toes or ear lobes. These measurement sites are mostly composed of microcirculatory vascular beds in which there is a mixture of blood vessel types including arterial, capillary, arterio-venous and venous vessels. The admixture of arterial and venous blood at such sites is the reason why oximetry is based on the pulsatile component of the signal.

[0071] Given the increased range of body sites made available by the body surface probes, it is possible to select a measurement site which directly overly superficial arteries. Provided that such arterial vessels are sufficiently thin walled, improved accuracy can be achieved since the blood is by definition arterial.

[0072] While the invention has been described with respect to several preferred embodiments and several preferred applications, it will be appreciated that these are set forth merely for purposes of example, and that many other variations, modifications and applications of the invention can be made.

Claims

1. A probe (20, 30, 40) for application to a selected area of a subject's skin covering a body part, which selected area serves as a measurement site for measuring changes in the pulsatile arterial blood volume thereat, comprising:

a base (21, 31, 41) for application to the selected area of the subject's skin at said measurement site;

a pressure applicator (22, 32, 42) carried by said base (21, 31, 41) for applying a static pressure to the subject's skin at said measurement site when said base is applied thereto;

and a sensor (23, 33, 43) carried by said pressure applicator (22, 32, 42) for sensing changes in the pulsatile arterial blood volume at said measurement site when the base is applied thereto;

an adhesive layer (24, 34, 44) arranged to adhere a surface of the base (21, 31, 41) within which the pressure applicator (22, 32, 42) is centrally carried to the selected area of the subject's skin so that the pressure applicator (22, 32, 42) pressurizes said selected area measurement site to a predetermined said static pressure;

characterized in that said pressure applicator (22, 32, 42) comprises an elastic material configured to apply to said measurement site, by adhering of the adhesive layer of the base (21, 31, 41) thereto, a predetermined static pressure, wherein the predetermined static pressure is selected to be of a sufficient magnitude to partially unload the wall tension of, but not to occlude, the arteries at said measurement site such as to substantially prevent venous distention and blood pooling at said measurement site by applying sufficient external counter pressure to effectively collapse the underlying veins and limit the local venous blood flow to the arterial throughput while permitting free venous drainage with respect to said measurement site through tissues surrounding said measurement site;
and **in that** said pressure applicator (22, 32, 42) is configured to apply said static pressure to a relatively restricted area of the subject's skin, which area occupies a small fraction of the surface perimeter of the respective body part at said measurement site, to thereby permit free venous drainage from said measurement site via a wide region of unrestricted passageways surrounding the measurement site.

2. The probe according to Claim 1, wherein said pressure applicator (22, 32, 42) applies to said measurement site a static pressure which is above the subject's local venous pressure and slightly below the subject's diastolic blood pressure.

3. The probe according to Claim 1, wherein said pressure applicator comprises a fluid chamber having an elastic wall (25) constructed to completely contain a fluid therein such that the pressure applied by said probe is substantially unaffected by the mechanical characteristics of the underlying tissues.

4. The probe according to Claim 1, wherein said pressure applicator (32) comprises a housing (36) including a spring (35) for applying said static pressure to said measurement site.

5. The probe according to Claim 4, wherein said spring (35) for applying said static pressure to said measurement site is a coil spring of uncompressed length such that the effective pressure generated by it when it is compressed is substantially unaffected by relatively small variations in compressed length due to the mechanical characteristics of the underlying tissues.

6. The probe according to Claim 1, wherein said pressure applicator (42) comprises a resilient elastomeric material (45) for applying said static pressure to said measurement site.

7. The probe according to Claim 6, wherein said resilient elastomeric material for applying said static pressure to said measurement site is of a relatively large uncompressed length such that the effective pressure generated by it, when it is compressed, is substantially unaffected by relatively small variations in compressed length due to the mechanical characteristics of the underlying tissues.

8. The probe according to Claim 1, wherein said base (21, 31, 41) is of a non-stretchable material and carries said pressure applicator (22, 32, 42) and sensor (23, 33, 43) at the center thereof.

9. The probe according to Claim 1, wherein said base (21, 31, 41) includes the adhesive layer (24, 34, 44) on its surface facing the pressure applicator (22, 32, 42) and sensor (23, 33, 43) for adhering the base to the subject's skin at the measurement site.

10. The probe according to Claim 1, wherein said probe (50) also includes an optical sensor (53a, 53b) for sensing the blood oxygen saturation level.

11. The probe according to Claim 1, wherein said probe (50) also includes an electrode (57) for sensing an electrical potential such as the electrocardiograph (ECG) signal of the subject.

12. The probe according to Claim 1, wherein said probe also includes an acoustic sensor for sensing a sound signal of the subject.

13. The combination of a probe according to Claim 1, with a clamping device (61) for applying a clamping force (via leg 62) to said base of the probe (62) when applied to said measurement site, and a counterforce (via leg 63) to the respective body part of the subject at the opposite side of said measurement site.

14. Apparatus for detecting and indicating a medical condition or a change in physiological state of a subject, comprising:

a probe (20, 30, 40) according to Claim 1 for application to a measurement site on the subject's skin and for producing an output corresponding to measured changes in the pulsatile arterial blood volume thereat;
and a data processor system (85) for utilizing said measured changes to detect and indicate a medical condition or change in physiological state of the subject.

15. The apparatus according to Claim 14, wherein said

data processor system (85) utilizes said measured changes in pulsatile arterial volume to indicate the peripheral arterial tone of the subject.

16. The apparatus according to Claim 14, wherein said data processor system utilizes (85) said measured changes in pulsatile arterial volume to indicate changes in the systemic blood pressure of the subject.

17. The apparatus according to Claim 14, wherein said data processor system (85) utilizes said measured changes to indicate the pulse rate of the subject.

18. The apparatus according to Claim 14, wherein said data processor system (85) utilizes said measured changes in the pulsatile arterial blood volume to indicate the level of vascular tone at the measurement site.

19. The apparatus according to Claim 14, wherein said sensor is an optical sensor (53a, 53b) , and said data processor system (85) utilizes said measured changes in pulsatile arterial volume to produce a measurement of the oxygen saturation level of the blood.

20. The apparatus according to Claim 14, wherein said apparatus further comprises at least one additional probe (80, 81) according to Claim 1 for application to at one additional measurement site on the subject's skin and for measuring changes in the pulsatile arterial blood volume thereat; said data processor system (85) utilizing the measured changes of both of said probes for detecting and indicating the medical condition or the change in physiological state of the subject.

21. The apparatus according to Claim 20, wherein said probes (81, 82) are constructed for application to measurement sites in which the vascular beds thereat have different levels of autonomic nervous system activity or responsiveness.

22. The apparatus according to Claim 20, wherein said probes (81, 82) are constructed for application to measurement sites in which the vascular beds thereat are mainly comprised of conduit (conducting) arteries and microcirculatory vascular beds respectively.

23. The apparatus according to Claim 20, wherein said probes (81, 82) are constructed for application to measurement sites in which the pulsatile volume of the vascular beds are respectively predominantly affected by autonomic nervous system activity or by the level of systemic blood pressure.

24. The apparatus according to Claim 20, wherein said probes (81, 82) are constructed for application to measurement sites in which the pulsatile volume of the vascular beds are unequally affected by autonomic nervous system activity; and wherein said data processor system (85) compares the outputs of said probes to indicate the medical condition or change in physiological state of the subject.

25. The apparatus according to Claim 20, wherein said probes (81, 82) are constructed for application to two or more measurement sites at a known distance from each other; and wherein said data processor system utilizes the outputs of said probes for indicating the pulse propagation velocity.

26. The apparatus according to Claim 20, wherein at least one of said probes includes an electrode (57) for sensing the electrocardiograph (ECG) signal of a subject; and wherein said data processor system (85) utilizes said measured changes in the pulsatile arterial blood volume, and said ECG signal, to determine the pulse trasit time and/or pulse propagation velocity.

27. A method of detecting and indicating a change in physiological state of a subject, comprising:

applying a probe (20, 30, 40) according to Claim 1 to a measurement site on the subject's skin for measuring changes in the pulsatile arterial blood volume thereat;
and utilizing said measured changes to detect and indicate a change in physiological state of the subject.

28. The method according to Claim 27, wherein said probe (20, 30, 40) is applied to a relatively restricted area of the subject's skin substantially overlying a medium to large sized artery.

29. The method according to Claim 27, wherein said probe (20, 30, 40) is applied to a relatively restricted area of the subject's skin which is relatively rich in arteriovenous anastamoses vessels.

30. The method according to Claim 27), wherein said probe (20, 30, 40) is applied to a relatively restricted area of the subject's skin which is relatively poor in arteriovenous anastamoses vessels.

31. The method according to Claim 27, wherein said probe (20, 30, 40) is applied to a relatively restricted area of the subject's skin on the subject's forehead.

32. The method according to Claim 27, wherein said probe (20, 30, 40) is applied to a relatively restricted area of the subject's skin on the subject's forearm.

33. The method according to Claim 27, wherein said probe (20, 30, 40) is applied to a relatively restricted area of the subject's skin at the subject's wrist.

34. The method according to Claim 27, wherein said probe is applied to a relatively restricted area of the subject's skin on the palm of the subject's hand or on the sole of the subject's foot.

35. The method according to Claim 27, wherein said sensor is an optical sensor (53a, 53b), and said data processor system (85) utilizes said measured changes in pulsatile arterial volume to produce a measurement of the oxygen saturation level of the blood.

36. The method according to Claim 27, wherein said probe (20, 30, 40) is applied over a superficial artery for evaluating an endothelial function of the subject.

37. The method according to Claim 27, wherein said probe (20, 30, 40) is applied over a skin region predominantly containing microvascular blood vessels for evaluating an endothelial function of the subject.

38. The method according to Claim 27, wherein at least one additional probe (81, 82) is applied to at least an additional measurement site on the subject's skin for measuring the pulsatile arterial blood volume thereat.

39. The method according to Claim 38, wherein said probes (81, 82) are applied to measurement sites in which the vascular beds thereat have different levels of reactivity to autonomic stimulation.

40. The method according to Claim 39, wherein said probes (81, 82) are applied to measurement sites in which the vascular beds thereof have different responses to reflex eliciting events.

41. The method according to Claim 39, wherein at least one of said probes (81, 82) includes an electrode (57) for sensing the electrocardiograph (ECG) signal of the subject, and wherein said probes (81, 82) are applied to measurement sites at a known distance from each other, and the measured changes of said probes are utilized for indicating the pulse transit time and the pulse propagation velocity.

42. The method according to Claim 39, wherein one of said probes (81, 82) is applied to a subject's body surface overlying a superficial conducting artery, and another of said probes is applied to a subject's body surface overlying a predominantly microcirculatory vascular bed.

43. The method according to Claim 27, wherein said probe is applied over a skin region predominantly containing microvascular blood vessels for deriving a signal for biofeedback input.

44. The method according to Claim 27, wherein said probe is applied over a skin region overlying a superficial conducting artery for deriving a signal for biofeedback input.

45. The method according to Claim 27, wherein said probe is applied over a skin region predominantly containing microvascular blood vessels for deriving a signal in response to a physical, or mental stressor.

46. The method according to Claim 27, wherein said probe is applied over a skin region overlying a superficial conducting artery for deriving a signal in response to a physical, or mental stressor or stimulus.

47. The method recited in Claim 27, wherein said detecting comprises viewing the time-course of a peripheral arterial tone signal.

48. The method recited in Claim 27, wherein said detecting comprises viewing variations in a peripheral arterial tone signal.

49. The method of Claim 39, wherein a multiplicity of different sensors are used for detecting changes in the pulsatile arterial blood volume at said measurement sites.

50. The method of Claim 39, wherein detecting of changes in the pulsatile arterial blood volume at said measurement sites is performed for deriving a signal for biofeedback input.

51. The method of Claim 39, wherein detecting of changes in the pulsatile arterial blood volume at said measurement sites is performed for deriving a signal in response to a physical, or mental stressor or stimulus.

52. The method according to Claim 27, wherein said pressure applicator (22, 32, 42) applies said static pressure to an area which extends in area beyond the region of said sensor (23, 33, 43) to extend the effective boundary of the pressure field overlying the sensing region, to substantially prevent venous distention and blood pooling at said measurement site and extended effective boundary of the pressure field by applying sufficient external counter pressure to effectively collapse the underlying veins and limit the local venous blood flow to the arterial throughput while permitting free venous drainage with respect to said measurement site through tissues surrounding said measurement site.

Patentansprüche

1. Sonde (20, 30, 40) zum Anlegen an einen ausgewählten Bereich der Haut einer Person, der ein Körperteil bedeckt, wobei der ausgewählte Bereich als Messstelle zum Messen von Änderungen des pulsierenden arteriellen Blutvolumens dort dient, umfassend:

ein Unterteil (21, 31, 41) zum Anlegen auf den ausgewählten Bereich der Haut der Person an der Messstelle;
einen Druckapplikator (22, 32, 42), der vom Unterteil (21, 31, 41) getragen wird, um an der Messstelle einen statischen Druck an die Haut der Person anzulegen, wenn das Unterteil daran angelegt wird;
und einen Sensor (23, 33, 43), der vom Druckapplikator (22, 32, 42) getragen wird, um Änderungen des pulsierenden arteriellen Blutvolumens an der Messstelle zu erfassen, wenn das Unterteil daran angelegt ist;
eine Klebeschicht (24, 34, 44), die so angeordnet ist, dass sie an einer Oberfläche des Unterteils (21, 31, 41) haftet, in dem der Druckapplikator (22, 32, 42) zentral zum ausgewählten Bereich der Haut der Person getragen wird, sodass der Druckapplikator (22, 32, 42) die Messstelle des ausgewählten Bereichs mit einem vorgegebenen statischen Druck beaufschlagt;
dadurch gekennzeichnet, dass der Druckapplikator (22, 32, 42) ein elastisches Material umfasst, das konfiguriert ist, um an der Messstelle durch Anhaften der Haftschicht des Unterteils (21, 31, 41) daran einen vorgegebenen statischen Druck anzulegen, wobei ein vorgegebener statischer Druck so ausgewählt ist, dass er eine ausreichende Stärke aufweist, um die Wandspannung der Arterien an der Messstelle teilweise zu entlasten, aber die Arterien an der Messstelle nicht zu verschließen, sodass im Wesentlichen eine Venendehnung und Blutansammlung an der Messstelle verhindert wird, indem ein ausreichender äußerer Gegendruck angelegt wird, um die darunter liegenden Venen wirksam zusammenzudrücken und den lokalen venösen Blutfluss auf den arteriellen Durchsatz zu begrenzen und gleichzeitig einen freien venösen Abfluss in Bezug auf die Messstelle durch Gewebe zu ermöglichen, die die Messstelle umgeben;
und dadurch, dass der Druckapplikator (22, 32, 42) konfiguriert ist, um den statischen Druck an einen relativ begrenzten Bereich der Haut der Person anzulegen, wobei dieser Bereich einen kleinen Bruchteil des Oberflächenumfangs des jeweiligen Körperteils an der Messstelle einnimmt, um dadurch einen freien Venenabfluss von der Messstelle über eine breite Region uneingeschränkter Durchgänge zu ermöglichen, die die Messstelle umgeben.

2. Sonde nach Anspruch 1, wobei der Druckapplikator (22, 32, 42) an der Messstelle einen statischen Druck anlegt, der über dem lokalen Venendruck der Person und geringfügig unter dem diastolischen Blutdruck der Person liegt.

3. Sonde nach Anspruch 1, wobei der Druckapplikator eine Flüssigkeitskammer umfasst, die eine elastische Wand (25) aufweist, die so aufgebaut ist, dass sie eine Flüssigkeit vollständig enthält, sodass der durch die Sonde angelegte Druck im Wesentlichen unbeeinflusst von den mechanischen Eigenschaften der darunter liegenden Gewebe ist.

4. Sonde nach Anspruch 1, wobei der Druckapplikator (32) ein Gehäuse (36) mit einer Feder (35) zum Anlegen des statischen Drucks an die Messstelle umfasst.

5. Sonde nach Anspruch 4, wobei die Feder (35) zum Anlegen des statischen Drucks an die Messstelle eine Schraubenfeder mit nicht komprimierter Länge ist, sodass der durch sie erzeugte wirksame Druck beim Komprimieren im Wesentlichen unbeeinflusst von relativ kleinen Schwankungen der komprimierten Länge ist, die durch die mechanischen Eigenschaften der darunter liegenden Gewebe hervorgerufen werden.

6. Sonde nach Anspruch 1, wobei der Druckapplikator (42) ein elastisches Elastomermaterial (45) zum Anlegen des statischen Drucks an die Messstelle umfasst.

7. Sonde nach Anspruch 6, wobei das elastische Elastomermaterial zum Anlegen des statischen Drucks an die Messstelle eine relativ große nicht komprimierte Länge aufweist, sodass der durch das Elastomermaterial erzeugte wirksame Druck im komprimierte Zustand des Elastomermaterials im Wesentlichen unbeeinflusst von relativ kleinen Schwankungen der komprimierten Länge ist, die durch die mechanischen Eigenschaften der darunterliegenden Gewebe hervorgerufen werden.

8. Sonde nach Anspruch 1, wobei das Unterteil (21, 31, 41) aus einem nicht dehnbaren Material besteht und den Druckapplikator (22, 32, 42) und den Sensor (23, 33, 43) in dessen Mitte trägt.

9. Sonde nach Anspruch 1, wobei das Unterteil (21, 31, 41) die Klebeschicht (24, 34, 44) auf seiner dem Druckapplikator (22, 32, 42) und dem Sensor (23, 33, 43) zugewandten Oberfläche beinhaltet, um das

Unterteil an der Messstelle an der Haut der Person anzuhaften.

10. Sonde nach Anspruch 1, wobei die Sonde (50) außerdem einen optischen Sensor (53a, 53b) zum Erfassen des Blutsauerstoffsättigungspegels beinhaltet.

11. Sonde nach Anspruch 1, wobei die Sonde (50) außerdem eine Elektrode (57) zum Erfassen eines elektrischen Potenzials beinhaltet, beispielsweise des Elektrokardiographensignals (EKG-Signals) der Person.

12. Sonde nach Anspruch 1, wobei die Sonde außerdem einen akustischen Sensor zum Erfassen eines Tonsignals der Person beinhaltet.

13. Kombination einer Sonde nach Anspruch 1 mit einer Klemmvorrichtung (61) zum Anlegen einer Klemmkraft (über den Schenkel 62) an das Unterteil der Sonde (62), wenn es an die Messstelle angelegt wird, und einer Gegenkraft (über Schenkel 63) an das jeweilige Körperteil der Person an der gegenüberliegenden Seite der Messstelle.

14. Vorrichtung zum Erkennen und Anzeigen eines medizinischen Zustands oder einer Änderung des physiologischen Zustands einer Person, umfassend:

eine Sonde (20, 30, 40) nach Anspruch 1 zum Anlegen an eine Messstelle auf der Haut der Person und zum Erzeugen einer Ausgabe, die gemessenen Änderungen des pulsierenden arteriellen Blutvolumens daran entspricht;
und ein Datenverarbeitungssystem (85) zum Verwenden der gemessenen Änderungen, um einen medizinischen Zustand oder eine Änderung des physiologischen Zustands der Person zu erkennen und anzuzeigen.

15. Vorrichtung nach Anspruch 14, wobei das Datenverarbeitungssystem (85) die gemessenen Änderungen des pulsierenden Arterienvolumens verwendet, um den peripheren Arterientonus der Person anzuzeigen.

16. Vorrichtung nach Anspruch 14, wobei das Datenverarbeitungssystem die gemessenen Änderungen im pulsierenden Arterienvolumen verwendet (85), um Änderungen des systemischen Blutdrucks der Person anzuzeigen.

17. Vorrichtung nach Anspruch 14, wobei das Datenverarbeitungssystem (85) die gemessenen Änderungen verwendet, um die Pulsfrequenz der Person anzuzeigen.

18. Vorrichtung nach Anspruch 14, wobei das Datenverarbeitungssystem (85) die gemessenen Änderungen des pulsierenden arteriellen Blutvolumens verwendet, um das Niveau des Gefäßtonus an der Messstelle anzuzeigen.

19. Vorrichtung nach Anspruch 14, wobei der Sensor ein optischer Sensor (53a, 53b) ist und das Datenverarbeitungssystem (85) die gemessenen Änderungen im pulsierenden Arterienvolumen verwendet, um eine Messung des Sauerstoffsättigungsgrads des Blutes zu erzeugen.

20. Vorrichtung nach Anspruch 14, wobei die Vorrichtung ferner mindestens eine weitere Sonde (80, 81) nach Anspruch 1 zum Anlegen an einer weiteren Messstelle auf der Haut der Person und zur Messung von Änderungen des pulsierenden arteriellen Blutvolumens dort umfasst; wobei das Datenverarbeitungssystem (85) die gemessenen Änderungen beider Sonden zum Erfassen und Anzeigen des medizinischen Zustands oder der Änderung des physiologischen Zustands der Person verwendet.

21. Vorrichtung nach Anspruch 20, wobei die Sonden (81, 82) zum Anlegen an Messstellen konstruiert sind, bei denen die Gefäßbetten unterschiedliche Aktivitäts- oder Empfindlichkeitsniveaus des autonomen Nervensystems aufweisen.

22. Vorrichtung nach Anspruch 20, wobei die Sonden (81, 82) zum Anlegen an Messstellen konstruiert sind, bei denen die Gefäßbetten dort hauptsächlich aus Leitarterien (leitenden Arterien) bzw. Mikrozirkulationsgefäßbetten bestehen.

23. Vorrichtung nach Anspruch 20, wobei die Sonden (81, 82) zum Anlegen an Messstellen konstruiert sind, bei denen das pulsierende Volumen der Gefäßbetten jeweils vorwiegend durch die Aktivität des autonomen Nervensystems oder durch das Niveau des systemischen Blutdrucks beeinflusst wird.

24. Vorrichtung nach Anspruch 20, wobei die Sonden (81, 82) zum Anlegen an Messstellen konstruiert sind, bei denen das pulsierende Volumen der Gefäßbetten durch die Aktivität des autonomen Nervensystems ungleichmäßig beeinflusst wird; und wobei das Datenverarbeitungssystem (85) die Ausgaben der Sonden vergleicht, um den medizinischen Zustand oder die Änderung des physiologischen Zustands der Person anzuzeigen.

25. Vorrichtung nach Anspruch 20, wobei die Sonden (81, 82) zum Anlegen an zwei oder mehr Messstellen in einem bekannten Abstand voneinander konstruiert sind; und wobei das Datenverarbeitungssystem die Ausgaben der Sonden zum Anzeigen der Pul-

sausbreitungsgeschwindigkeit verwendet.

26. Vorrichtung nach Anspruch 20, wobei mindestens eine der Sonden eine Elektrode (57) zum Erfassen des Elektrokardiographensignals (EKG-Signals) einer Person beinhaltet;
und wobei das Datenverarbeitungssystem (85) die gemessenen Änderungen des pulsierenden arteriellen Blutvolumens und des EKG-Signals verwendet, um die Pulslaufzeit und/oder die Pulsausbreitungsgeschwindigkeit zu ermitteln.

27. Verfahren zum Erkennen und Anzeigen einer Änderung des physiologischen Zustands einer Person, umfassend:

Anlegen einer Sonde (20, 30, 40) nach Anspruch 1 an eine Messstelle auf der Haut der Person zum Messen von Änderungen des pulsierenden arteriellen Blutvolumens daran;
und Verwenden der gemessenen Änderungen, um eine Änderung des physiologischen Zustands der Person zu erkennen und anzuzeigen.

28. Verfahren nach Anspruch 27, wobei die Sonde (20, 30, 40) an einen relativ begrenzten Bereich der Haut der Person angelegt wird, der im Wesentlichen eine Arterie mittlerer bis großer Größe überlagert.

29. Verfahren nach Anspruch 27, wobei die Sonde (20, 30, 40) an einen relativ begrenzten Bereich der Haut der Person angelegt wird, der relativ reich an arteriovenösen Anastamosengefäßen ist.

30. Verfahren nach Anspruch 27, wobei die Sonde (20, 30, 40) an einen relativ begrenzten Bereich der Haut der Person angelegt wird, der relativ arm an arteriovenösen Anastamosengefäßen ist.

31. Verfahren nach Anspruch 27, wobei die Sonde (20, 30, 40) an einen relativ begrenzten Bereich der Haut der Person an der Stirn der Person angelegt wird.

32. Verfahren nach Anspruch 27, wobei die Sonde (20, 30, 40) an einen relativ begrenzten Bereich der Haut der Person am Unterarm der Person angelegt wird.

33. Verfahren nach Anspruch 27, wobei die Sonde (20, 30, 40) an einen relativ begrenzten Bereich der Haut der Person am Handgelenk der Person angelegt wird.

34. Verfahren nach Anspruch 27, wobei die Sonde an einen relativ begrenzten Bereich der Haut der Person an der Handfläche der Person oder an der Fußsohle der Person angelegt wird.

35. Verfahren nach Anspruch 27, wobei der Sensor ein optischer Sensor (53a, 53b) ist und das Datenverarbeitungssystem (85) die gemessenen Änderungen des pulsierenden Arterienvolumens verwendet, um eine Messung des Sauerstoffsättigungsgrads des Blutes zu erzeugen.

36. Verfahren nach Anspruch 27, wobei die Sonde (20, 30, 40) über einer oberflächlichen Arterie zur Bewertung einer endothelialen Funktion der Person angelegt wird.

37. Verfahren nach Anspruch 27, wobei die Sonde (20, 30, 40) über einer Hautregion angelegt wird, die vorwiegend mikrovaskuläre Blutgefäße enthält, um eine endotheliale Funktion der Person zu bewerten.

38. Verfahren nach Anspruch 27, wobei mindestens eine weitere Sonde (81, 82) an mindestens eine weitere Messstelle auf der Haut der Person angelegt wird, um das pulsierende arterielle Blutvolumen dort zu messen.

39. Verfahren nach Anspruch 38, wobei die Sonden (81, 82) an Messstellen angelegt werden, bei denen die Gefäßbetten unterschiedliche Reaktivitätsgrade gegenüber autonomer Stimulation aufweisen.

40. Verfahren nach Anspruch 39, wobei die Sonden (81, 82) an Messstellen angelegt werden, bei denen die Gefäßbetten davon unterschiedliche Reaktionen auf reflexauslösende Ereignisse aufweisen.

41. Verfahren nach Anspruch 39, wobei mindestens eine der Sonden (81, 82) eine Elektrode (57) zum Erfassen des Elektrokardiographensignals (EKG-Signals) der Person beinhaltet, und wobei die Sonden (81, 82) in einem bekannten Abstand zueinander an Messstellen angelegt und die gemessenen Änderungen der Sonden zum Anzeigen der Pulslaufzeit und der Pulsausbreitungsgeschwindigkeit verwendet werden.

42. Verfahren nach Anspruch 39, wobei eine der Sonden (81, 82) an die Körperoberfläche einer Person angelegt wird, die eine oberflächlich leitende Arterie überlagert, und eine weitere der Sonden an die Körperoberfläche einer Person angelegt wird, die über einem vorwiegend mikrozirkulatorischen Gefäßbett liegt.

43. Verfahren nach Anspruch 27, wobei die Sonde über einer Hautregion angelegt wird, die vorwiegend mikrovaskuläre Blutgefäße enthält, um ein Signal für die Biofeedback-Eingabe abzuleiten.

44. Verfahren nach Anspruch 27, wobei die Sonde über einer Hautregion angelegt wird, die über einer ober-

flächlichen Leitarterie liegt, um ein Signal für die Biofeedback-Eingabe abzuleiten.

45. Verfahren nach Anspruch 27, wobei die Sonde über einer Hautregion angelegt wird, die vorwiegend mikrovaskuläre Blutgefäße enthält, um ein Signal als Reaktion auf einen physischen oder mentalen Stressfaktor abzuleiten.

46. Verfahren nach Anspruch 27, wobei die Sonde über einer Hautregion angelegt wird, die über einer oberflächlich leitenden Arterie liegt, um ein Signal als Reaktion auf einen physischen oder mentalen Stressfaktor oder Stimulus abzuleiten.

47. Verfahren nach Anspruch 27, wobei das Erkennen das Betrachten des zeitlichen Verlaufs eines Tonussignals einer peripheren Arterie umfasst.

48. Verfahren nach Anspruch 27, wobei das Erkennen das Betrachten von Schwankungen eines Tonussignals einer peripheren Arterie umfasst.

49. Verfahren nach Anspruch 39, wobei an den Messstellen eine Vielzahl verschiedener Sensoren zum Erkennen von Änderungen des pulsierenden arteriellen Blutvolumens verwendet wird.

50. Verfahren nach Anspruch 39, wobei das Erkennen von Änderungen des pulsierenden arteriellen Blutvolumens an den Messstellen durchgeführt wird, um ein Signal für die Biofeedback-Eingabe abzuleiten.

51. Verfahren nach Anspruch 39, wobei das Erkennen von Änderungen des pulsierenden arteriellen Blutvolumens an den Messstellen durchgeführt wird, um ein Signal als Reaktion auf einen physischen oder mentalen Stressfaktor oder Stimulus abzuleiten.

52. Verfahren nach Anspruch 27, wobei der Druckapplikator (22, 32, 42) den statischen Druck an einen Bereich anlegt, der sich in einem Bereich jenseits des Bereichs des Sensors (23, 33, 43) erstreckt, um die wirksame Grenze des Druckfeldes zu erweitern, das über der Erfassungsregion liegt, um im Wesentlichen eine Venenausdehnung und Blutansammlung an der Messstelle zu verhindern und die wirksame Grenze des Druckfeldes zu erweitern, indem ein ausreichender äußerer Gegendruck angelegt wird, um die darunter liegenden Venen wirksam zu komprimieren und den lokalen venösen Blutfluss auf den arteriellen Durchsatz zu begrenzen und gleichzeitig einen freien venösen Abfluss in Bezug auf die Messstelle durch Gewebe zu ermöglichen, die die Messstelle umgeben.

Revendications

1. Sonde (20, 30, 40) destinée à être appliquée sur une zone sélectionnée de la peau d'un sujet recouvrant une partie du corps, laquelle zone sélectionnée sert de site de mesure pour mesurer les variations du volume sanguin artériel pulsatile au niveau de celui-ci, comprenant :

une base (21, 31, 41) destinée à être appliquée sur la zone sélectionnée de la peau du sujet au niveau dudit site de mesure ;
un applicateur de pression (22, 32, 42) porté par ladite base (21, 31, 41) pour appliquer une pression statique sur la peau du sujet au niveau dudit site de mesure lorsque ladite base y est appliquée ;
et un capteur (23, 33, 43) porté par ledit applicateur de pression (22, 32, 42) pour détecter des variations du volume sanguin artériel pulsatile au niveau dudit site de mesure lorsque la base y est appliquée ;
une couche adhésive (24, 34, 44) agencée pour adhérer à une surface de la base (21, 31, 41) dans laquelle l'applicateur de pression (22, 32, 42) est porté centralement sur la zone sélectionnée de la peau du sujet de sorte que l'applicateur de pression (22, 32, 42) mette sous pression ledit site de mesure de zone sélectionnée à une pression statique prédéterminée ;
caractérisé en ce que ledit applicateur de pression (22, 32, 42) comprend un matériau élastique conçu pour appliquer sur ledit site de mesure, par adhérence de la couche adhésive de la base (21, 31, 41) à celui-ci, à une pression statique prédéfinie, la pression statique prédéfinie étant choisie pour être d'une amplitude suffisante pour décharger partiellement la tension de la paroi des artères sur ledit site de mesure, sans toutefois les bloquer, de manière à empêcher sensiblement la distension veineuse et l'accumulation de sang au niveau dudit site de mesure par l'application d'une contre-pression externe suffisante pour collaber efficacement les veines sous-jacentes et limiter l'afflux sanguin veineux local au débit artériel tout en permettant un drainage veineux libre par rapport audit site de mesure à travers les tissus entourant ledit site de mesure ;
et **en ce que** ledit applicateur de pression (22, 32, 42) est conçu pour appliquer ladite pression statique sur une zone relativement restreinte de la peau du sujet, laquelle zone occupe une petite fraction du périmètre de surface de la partie de corps respective au niveau dudit site de mesure, pour permettre ainsi un drainage veineux libre depuis ledit site de mesure via une large région de passages non restreints entourant le site de

mesure.

2. Sonde selon la revendication 1, dans laquelle ledit applicateur de pression (22, 32, 42) applique audit site de mesure une pression statique qui est supérieure à la pression veineuse locale du sujet et légèrement inférieure à la pression artérielle diastolique du sujet.

3. Sonde selon la revendication 1, dans laquelle ledit applicateur de pression comprend une chambre de fluide ayant une paroi élastique (25) conçue pour contenir complètement un fluide à l'intérieur de celle-ci de sorte que la pression appliquée par ladite sonde ne soit sensiblement pas affectée par les caractéristiques mécaniques des tissus sous-jacents.

4. Sonde selon la revendication 1, dans laquelle ledit applicateur de pression (32) comprend un logement (36) comprenant un ressort (35) pour appliquer ladite pression statique audit site de mesure.

5. Sonde selon la revendication 4, dans laquelle ledit ressort (35) destiné à appliquer ladite pression statique audit site de mesure est un ressort hélicoïdal de longueur non comprimée, de sorte que la pression effective générée par celui-ci lorsqu'il est comprimé ne soit sensiblement pas affectée par des variations relativement faibles de la longueur comprimée dues aux caractéristiques mécaniques des tissus sous-jacents.

6. Sonde selon la revendication 1, dans laquelle ledit applicateur de pression (42) comprend un matériau élastomère élastique (45) pour appliquer ladite pression statique audit site de mesure.

7. Sonde selon la revendication 6, dans laquelle ledit matériau élastomère élastique destiné à appliquer ladite pression statique audit site de mesure présente une longueur non comprimée relativement importante, de sorte que la pression effective générée par celui-ci, lorsqu'il est comprimé, ne soit sensiblement pas affectée par des variations relativement faibles de la longueur comprimée dues aux caractéristiques mécaniques des tissus sous-jacents.

8. Sonde selon la revendication 1, dans laquelle ladite base (21, 31, 41) est en un matériau non étirable et porte lesdits applicateur de pression (22, 32, 42) et capteur (23, 33, 43) au centre de celle-ci.

9. Sonde selon la revendication 1, dans laquelle ladite base (21, 31, 41) comprend la couche adhésive (24, 34, 44) sur sa surface faisant face à l'applicateur de pression (22, 32, 42) et au capteur (23, 33, 43) pour faire adhérer la base à la peau du sujet au niveau du site de mesure.

10. Sonde selon la revendication 1, ladite sonde (50) comprenant également un capteur optique (53a, 53b) destiné à détecter le niveau de saturation en oxygène du sang.

11. Sonde selon la revendication 1, ladite sonde (50) comprenant également une électrode (57) pour détecter un potentiel électrique tel que le signal électrocardiographique (ECG) du sujet.

12. Sonde selon la revendication 1, ladite sonde comprenant également un capteur acoustique pour détecter un signal sonore du sujet.

13. Combinaison d'une sonde selon la revendication 1, avec un dispositif de serrage (61) pour appliquer une force de serrage (via un montant 62) à ladite base de la sonde (62) lorsqu'elle est appliquée audit site de mesure et une force inverse (via un montant 63) à la partie de corps respective du sujet du côté opposé audit site de mesure.

14. Appareil pour détecter et indiquer une affection médicale ou un changement d'état physiologique d'un sujet, comprenant :

    une sonde (20, 30, 40) selon la revendication 1 à appliquer sur un site de mesure sur la peau du sujet et pour produire une sortie correspondant à des variations mesurées du volume de sang artériel pulsatile au niveau de celui-ci ;
    et un système de traitement de données (85) destiné à utiliser lesdites variations mesurées pour détecter et indiquer une affection médicale ou un changement d'état physiologique du sujet.

15. Appareil selon la revendication 14, dans lequel ledit système de traitement de données (85) utilise lesdites variations mesurées du volume artériel pulsatile pour indiquer le tonus artériel périphérique du sujet.

16. Appareil selon la revendication 14, dans lequel ledit système de traitement de données utilise (85) lesdites variations mesurées du volume artériel pulsatile pour indiquer des variations de la pression sanguine systémique du sujet.

17. Appareil selon la revendication 14, dans lequel ledit système de traitement de données (85) utilise lesdites variations mesurées pour indiquer le pouls du sujet.

18. Appareil selon la revendication 14, dans lequel ledit système de traitement de données (85) utilise lesdites variations mesurées du volume de sang artériel pulsatilr pour indiquer le niveau de tonus vasculaire au niveau du site de mesure.

19. Appareil selon la revendication 14, dans lequel ledit capteur est un capteur optique (53a, 53b) et ledit système de traitement de données (85) utilise lesdites variations mesurées du volume artériel pulsatile pour produire une mesure du niveau de saturation en oxygène du sang.

20. Appareil selon la revendication 14, ledit appareil comprenant en outre au moins une sonde supplémentaire (80, 81) selon la revendication 1 pour une application sur un site de mesure supplémentaire sur la peau du sujet et destiné à mesurer les variations du volume sanguin artériel pulsatile ; ledit système de traitement de données (85) utilisant les variations mesurées des deux dites sondes pour détecter et indiquer l'affection médicale ou le changement d'état physiologique du sujet.

21. Appareil selon la revendication 20, dans lequel lesdites sondes (81, 82) sont conçues pour une application sur des sites de mesure au niveau desquels les lits vasculaires ont des niveaux d'activité ou de réactivité du système nerveux autonome différents.

22. Appareil selon la revendication 20, dans lequel lesdites sondes (81, 82) sont conçues pour une application sur des sites de mesure au niveau desquels les lits vasculaires sont principalement constitués d'artères de conduit (conductrices) et de lits vasculaires microcirculatoires, respectivement.

23. Appareil selon la revendication 20, dans lequel lesdites sondes (81, 82) sont conçues pour une application sur des sites de mesure dans lesquels le volume pulsatile des lits vasculaires est affecté principalement respectivement par l'activité du système nerveux autonome ou par le niveau de pression sanguine systémique.

24. Appareil selon la revendication 20, dans lequel lesdites sondes (81, 82) sont conçues pour une application sur des sites de mesure dans lesquels le volume pulsatile des lits vasculaires est affecté de manière inégale par une activité du système nerveux autonome ; et dans lequel ledit système de traitement de données (85) compare les sorties desdites sondes pour indiquer l'affection médicale ou le changement d'état physiologique du sujet.

25. Appareil selon la revendication 20, dans lequel lesdites sondes (81, 82) sont conçues pour une application sur au moins deux sites de mesure à une distance connue les uns des autres ; et dans lequel ledit système de traitement de données utilise les sorties desdites sondes pour indiquer la vitesse de propagation du pouls.

26. Appareil selon la revendication 20, dans lequel au moins l'une desdites sondes comprend une électrode (57) pour détecter le signal électrocardiographique (ECG) d'un sujet ; et dans lequel ledit système de traitement de données (85) utilise lesdites variations mesurées du volume sanguin artériel pulsatile et ledit signal ECG, pour déterminer le temps de transit du pouls et/ou la vitesse de propagation du pouls.

27. Procédé de détection et d'indication d'un changement d'état physiologique d'un sujet, comprenant :

l'application d'une sonde (20, 30, 40) selon la revendication 1 sur un site de mesure sur la peau du sujet pour mesurer des variations du volume sanguin artériel pulsatile au niveau de celui-ci ; et l'utilisation desdites variations mesurées pour détecter et indiquer un changement de l'état physiologique du sujet.

28. Procédé selon la revendication 27, dans lequel ladite sonde (20, 30, 40) est appliquée sur une zone relativement restreinte de la peau du sujet recouvrant sensiblement une artère de taille moyenne à grande.

29. Procédé selon la revendication 27, dans lequel ladite sonde (20, 30, 40) est appliquée sur une zone relativement restreinte de la peau du sujet qui est relativement riche en vaisseaux d'anastomoses artérioveineuses.

30. Procédé selon la revendication 27, dans lequel ladite sonde (20, 30, 40) est appliquée sur une zone relativement restreinte de la peau du sujet qui est relativement pauvre en vaisseaux d'anastomoses artérioveineuses.

31. Procédé selon la revendication 27, dans lequel ladite sonde (20, 30, 40) est appliquée sur une zone relativement restreinte de la peau du sujet sur le front du sujet.

32. Procédé selon la revendication 27, dans lequel ladite sonde (20, 30, 40) est appliquée sur une zone relativement restreinte de la peau du sujet sur l'avant-bras du sujet.

33. Procédé selon la revendication 27, dans lequel ladite sonde (20, 30, 40) est appliquée sur une zone relativement restreinte de la peau du sujet au niveau du poignet du sujet.

34. Procédé selon la revendication 27, dans lequel ladite sonde est appliquée sur une zone relativement restreinte de la peau du sujet sur la paume de la main du sujet ou sur la plante du pied du sujet.

35. Procédé selon la revendication 27, dans lequel ledit capteur est un capteur optique (53a, 53b) et ledit

système de traitement de données (85) utilise lesdites variations mesurées du volume artériel pulsatile pour produire une mesure du niveau de saturation en oxygène du sang.

36. Procédé selon la revendication 27, dans lequel ladite sonde (20, 30, 40) est appliquée sur une artère superficielle pour évaluer une fonction endothéliale du sujet.

37. Procédé selon la revendication 27, dans lequel ladite sonde (20, 30, 40) est appliquée sur une région de peau contenant principalement des vaisseaux sanguins microvasculaires pour évaluer une fonction endothéliale du sujet.

38. Procédé selon la revendication 27, dans lequel au moins une sonde supplémentaire (81, 82) est appliquée sur au moins un site de mesure supplémentaire sur la peau du sujet pour mesurer le volume de sang artériel pulsatile au niveau de celui-ci.

39. Procédé selon la revendication 38, dans lequel lesdites sondes (81, 82) sont appliquées sur des sites de mesure au niveau desquels les lits vasculaires ont des niveaux de réactivité à la stimulation autonome différents.

40. Procédé selon la revendication 39, dans lequel lesdites sondes (81, 82) sont appliquées sur des sites de mesure au dans lesquels les lits vasculaires ont des réponses différentes aux événements de déclenchement réflexe.

41. Procédé selon la revendication 39, dans lequel au moins l'une desdites sondes (81, 82) comprend une électrode (57) pour détecter le signal électrocardiographique (ECG) du sujet et dans lequel lesdites sondes (81, 82) sont appliquées sur des sites de mesure à une distance connue les uns des autres et les variations mesurées desdites sondes sont utilisées pour indiquer le temps de transit du pouls et la vitesse de propagation du pouls.

42. Procédé selon la revendication 39, dans lequel l'une desdites sondes (81, 82) est appliquée sur la surface corporelle d'un sujet recouvrant une artère conductrice superficielle et une autre desdites sondes est appliquée sur la surface corporelle d'un sujet recouvrant un lit vasculaire principalement microcirculatoire.

43. Procédé selon la revendication 27, dans lequel ladite sonde est appliquée sur une région de peau contenant principalement des vaisseaux sanguins microvasculaires pour dériver un signal pour une entrée de rétroaction biologique.

44. Procédé selon la revendication 27, dans lequel ladite sonde est appliquée sur une région de peau recouvrant une artère conductrice superficielle pour dériver un signal pour une entrée de rétroaction biologique.

45. Procédé selon la revendication 27, dans lequel ladite sonde est appliquée sur une région de peau contenant principalement des vaisseaux sanguins microvasculaires pour dériver un signal en réponse à un facteur de stress physique ou mental.

46. Procédé selon la revendication 27, dans lequel ladite sonde est appliquée sur une région de peau recouvrant une artère conductrice superficielle pour dériver un signal en réponse à un facteur de stress ou un stimulus physique ou mental.

47. Procédé selon la revendication 27, dans lequel ladite détection comprend la visualisation de la durée d'un signal de tonus artériel périphérique.

48. Procédé selon la revendication 27, dans lequel ladite détection comprend la visualisation de variations d'un signal de tonus artériel périphérique.

49. Procédé selon la revendication 39, dans lequel une multiplicité de capteurs différents sont utilisés pour détecter des variations du volume sanguin artériel pulsatile au niveau desdits sites de mesure.

50. Procédé selon la revendication 39, dans lequel la détection de variations du volume sanguin artériel pulsatile au niveau desdits sites de mesure est effectuée pour dériver un signal pour une entrée de rétroaction biologique.

51. Procédé selon la revendication 39, dans lequel la détection de variations du volume sanguin artériel pulsatile au niveau desdits sites de mesure est effectuée pour dériver un signal en réponse à un facteur de stress ou un stimulus physique ou mental.

52. Procédé selon la revendication 27, dans lequel ledit applicateur de pression (22, 32, 42) applique ladite pression statique sur une zone qui s'étend dans une zone située au-delà de la région dudit capteur (23, 33, 43) pour prolonger la limite effective du champ de pression recouvrant la région de détection, pour empêcher sensiblement la distension veineuse et l'accumulation de sang au niveau dudit site de mesure et de la limite effective prolongée du champ de pression par l'application d'une contre-pression externe suffisante pour collaber efficacement les veines sous-jacentes et limiter l'afflux sanguin veineux local au débit artériel tout en permettant un drainage veineux libre par rapport audit site de mesure à travers les tissus entourant ledit site de mesure.

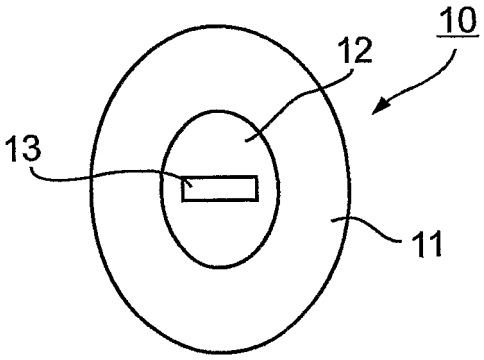


Fig. 1a

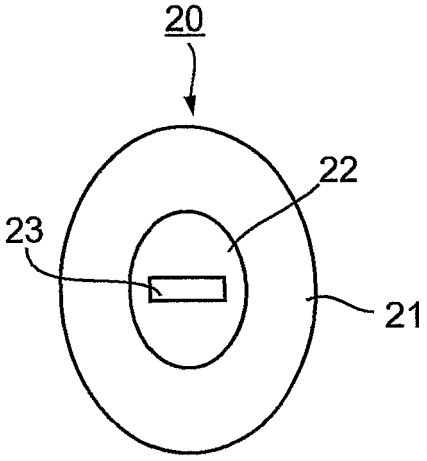


Fig. 2a

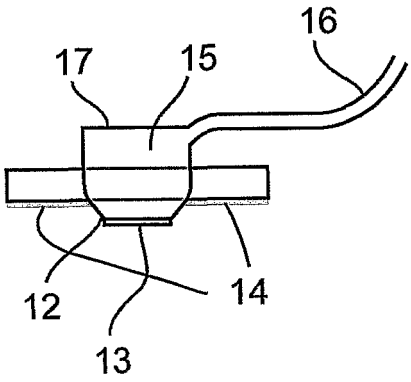


Fig. 1b

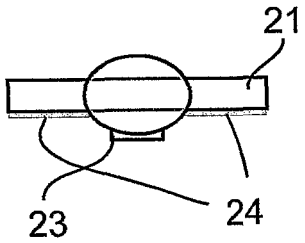


Fig. 2b

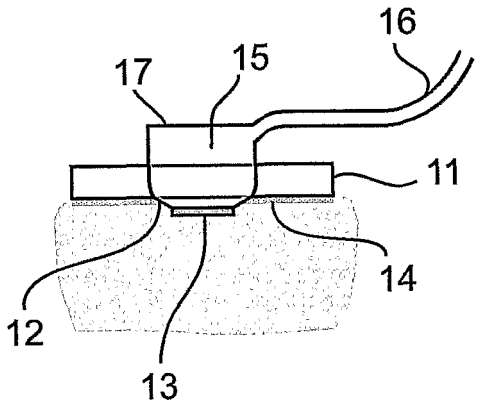


Fig. 1c

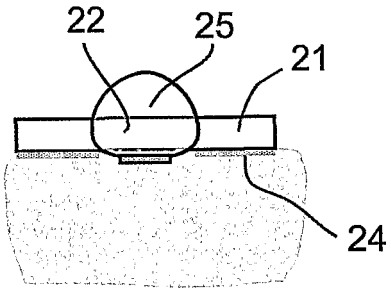


Fig. 2c

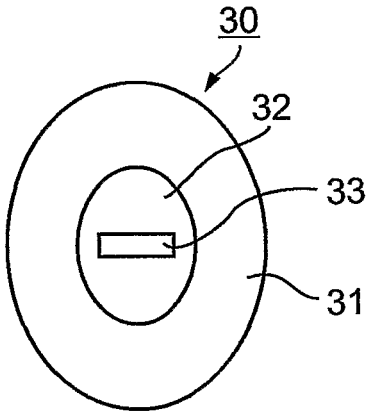


Fig. 3a

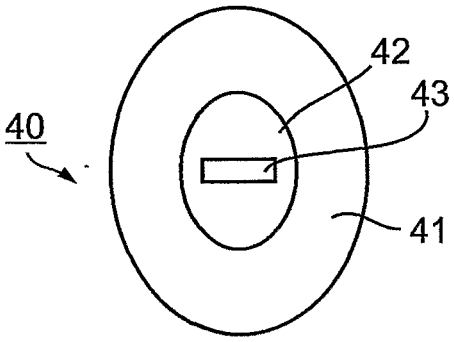


Fig. 4a

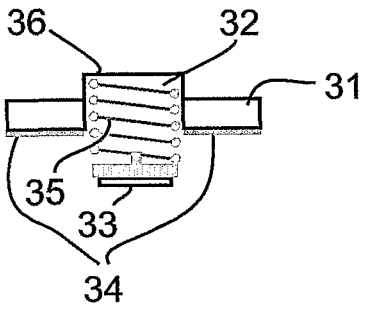


Fig. 3b

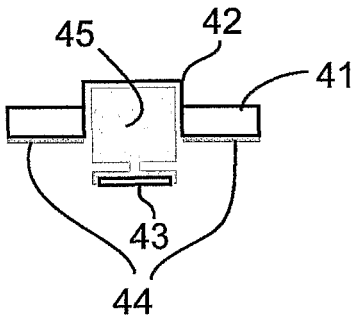


Fig. 4b

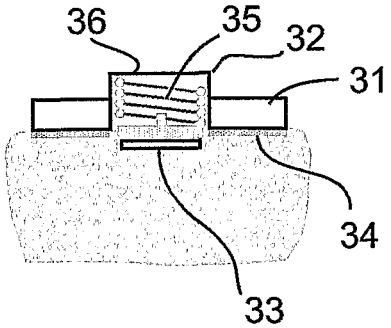


Fig. 3c

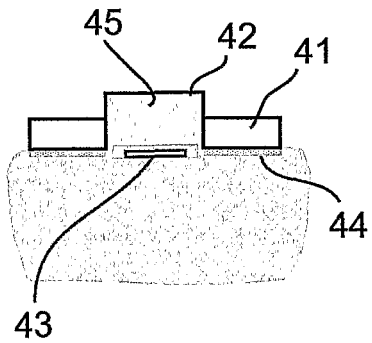


Fig. 4c

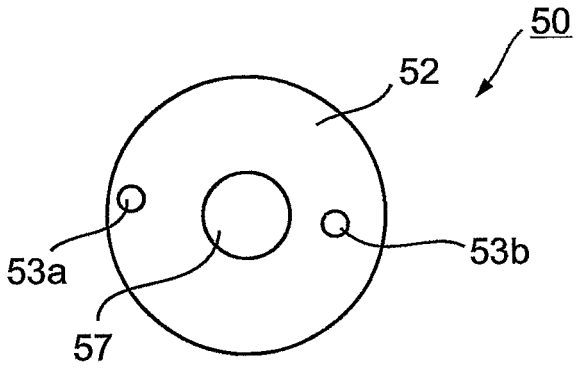


Fig. 5a

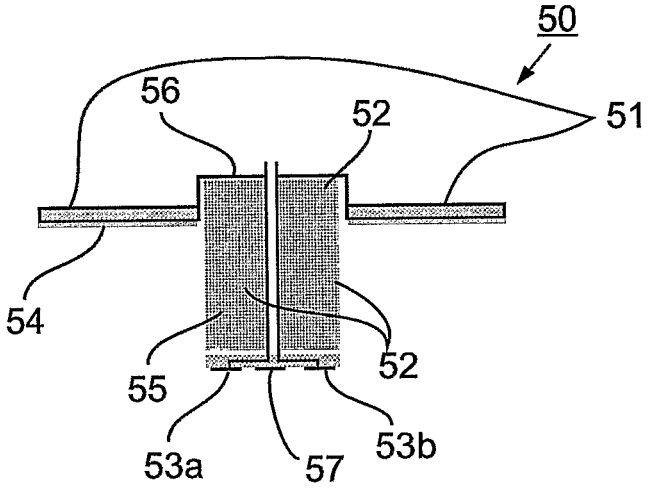


Fig. 5b

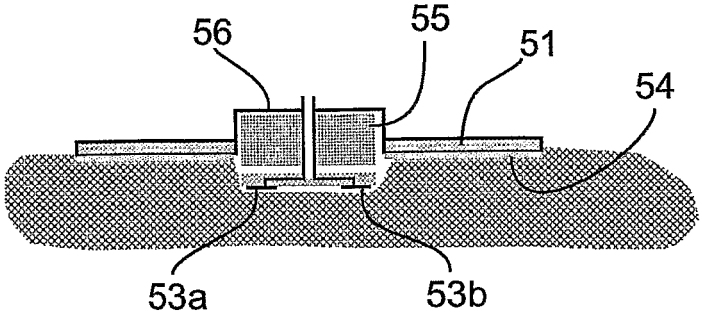


Fig. 5c

Fig. 6

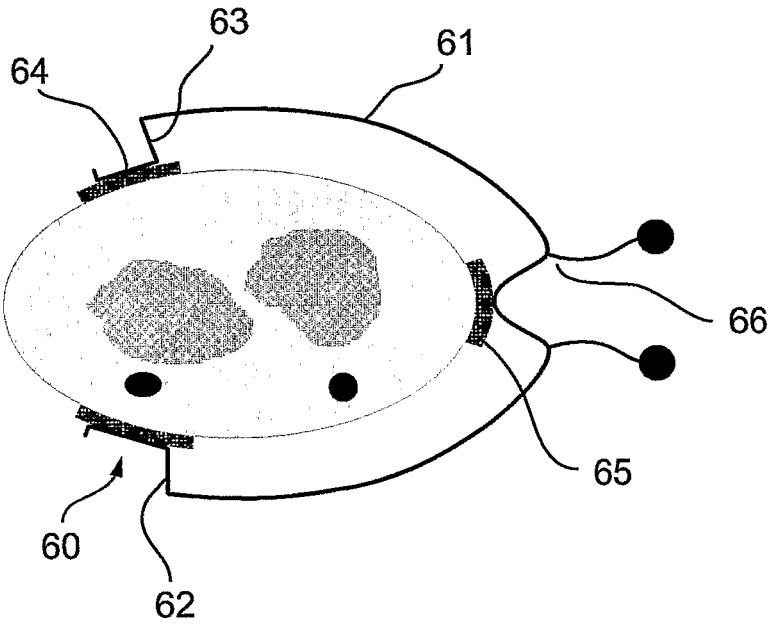


Fig. 7

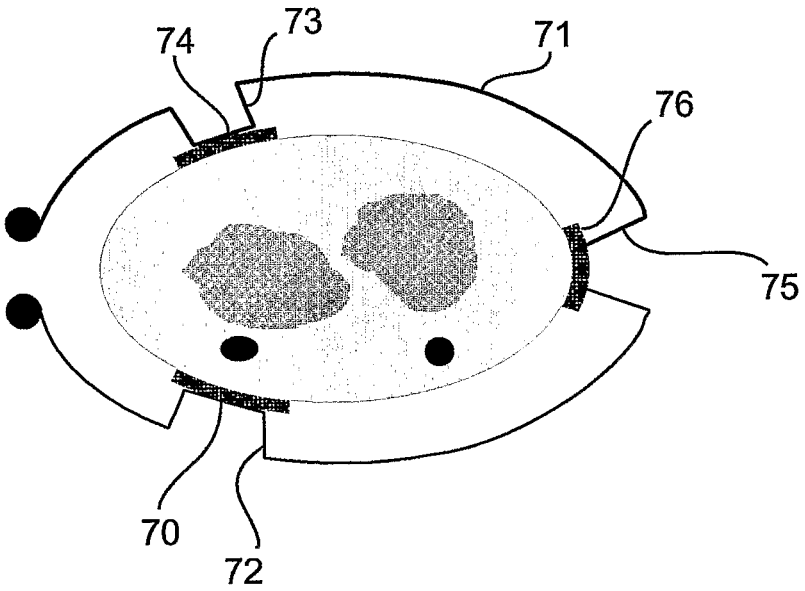
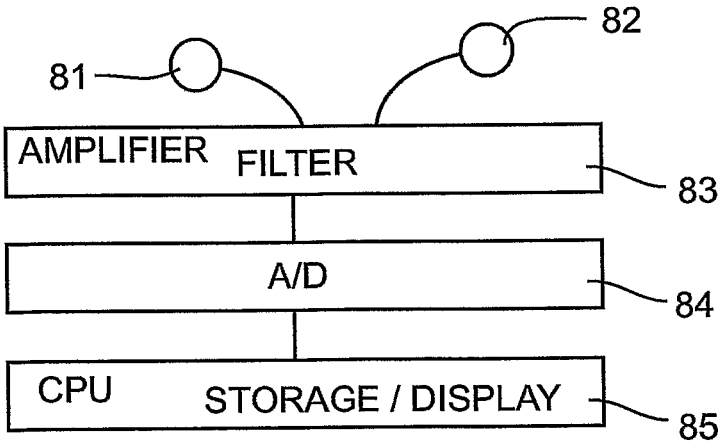


Fig. 8



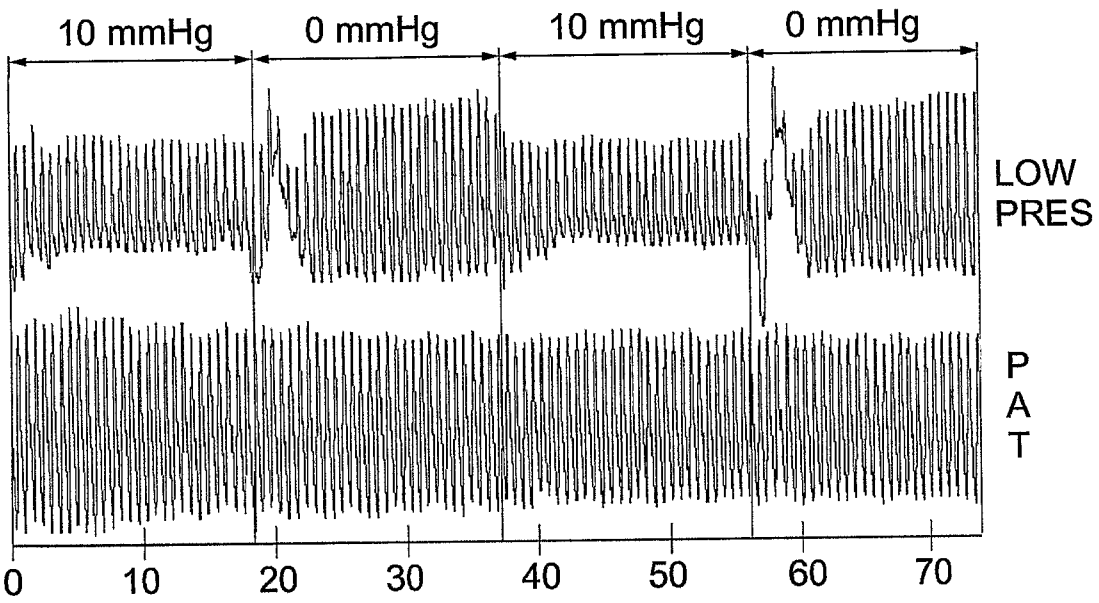

10 mmHg
0 mmHg
10 mmHg
0 mmHg
LOW PRES
PAT
0
10
20
30
40
50
60
70

Fig. 9

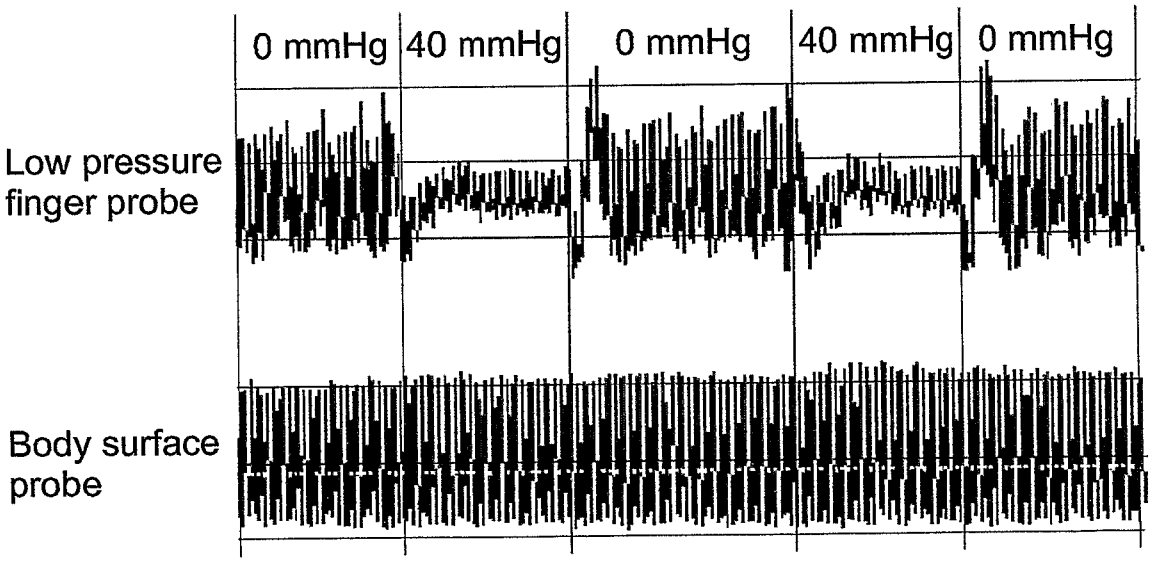

0 mmHg
40 mmHg
0 mmHg
40 mmHg
0 mmHg
Low pressure finger probe
Body surface probe

Fig. 10

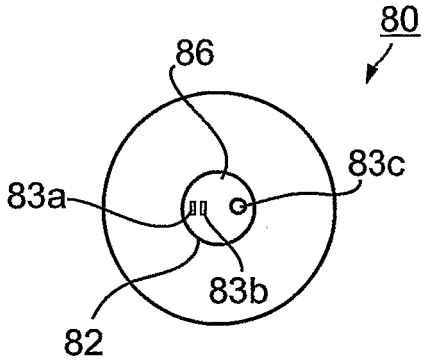


Fig. 11a

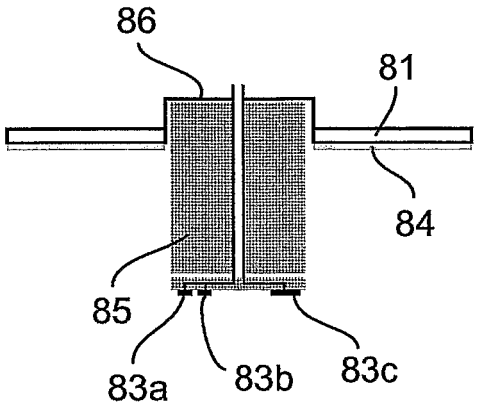


Fig. 11b

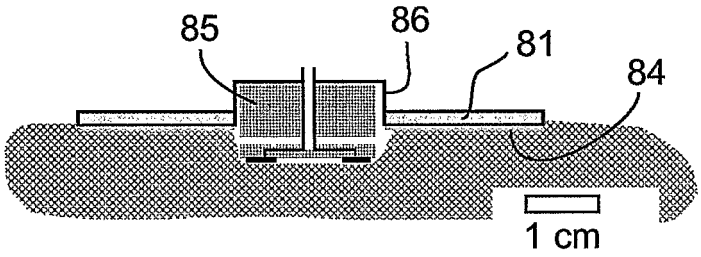


Fig. 11c

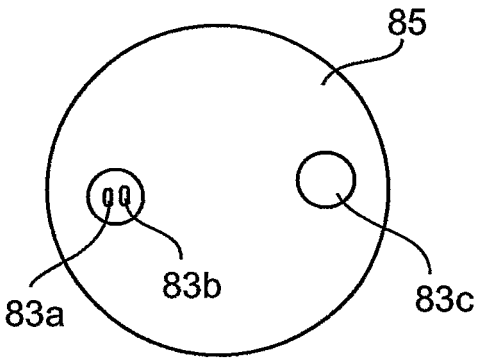


Fig. 11d

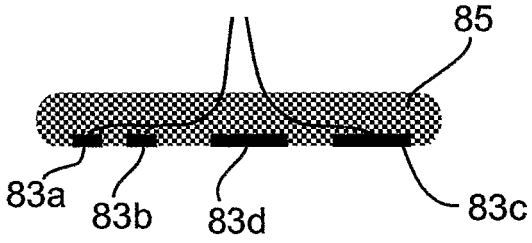


Fig. 11e

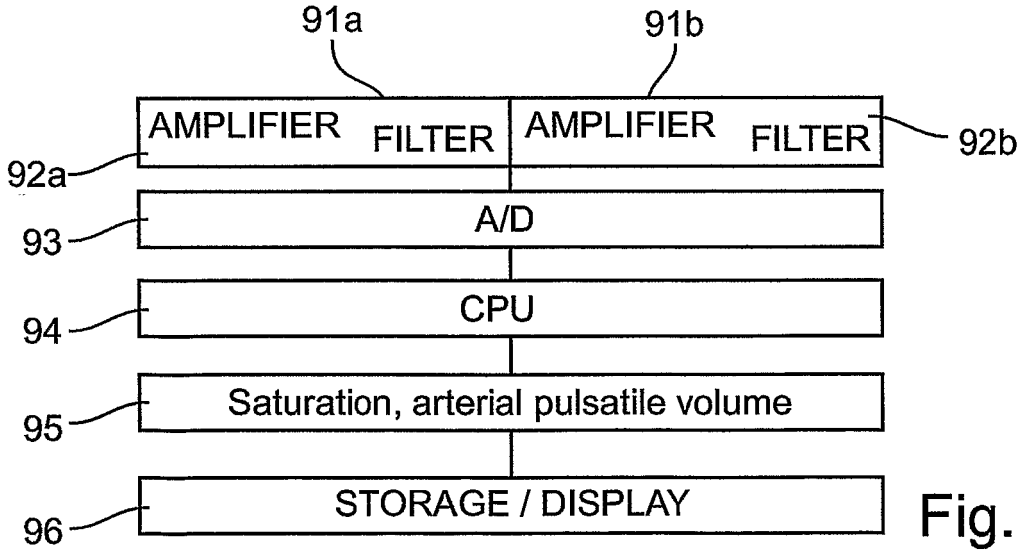


Fig. 12

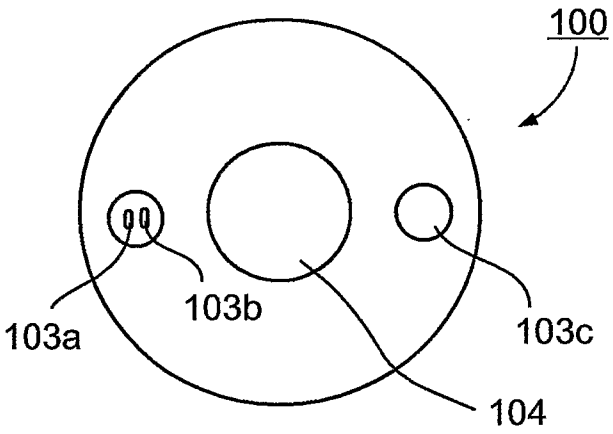


Fig. 13a

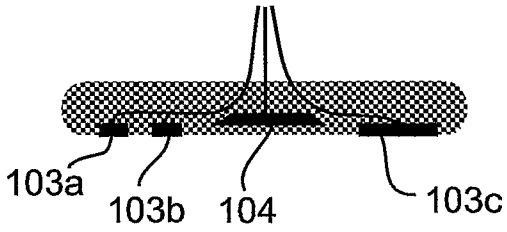


Fig. 13b

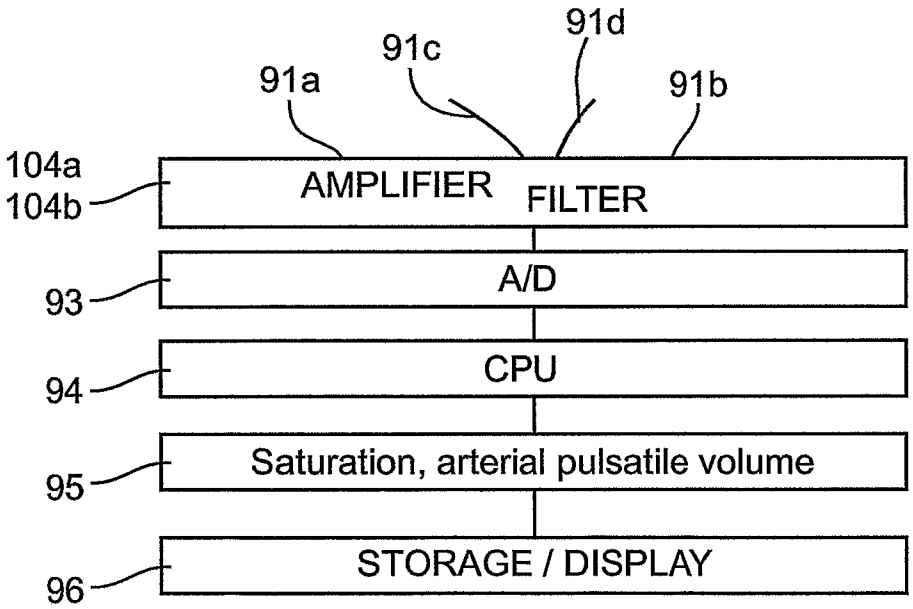


Fig. 14

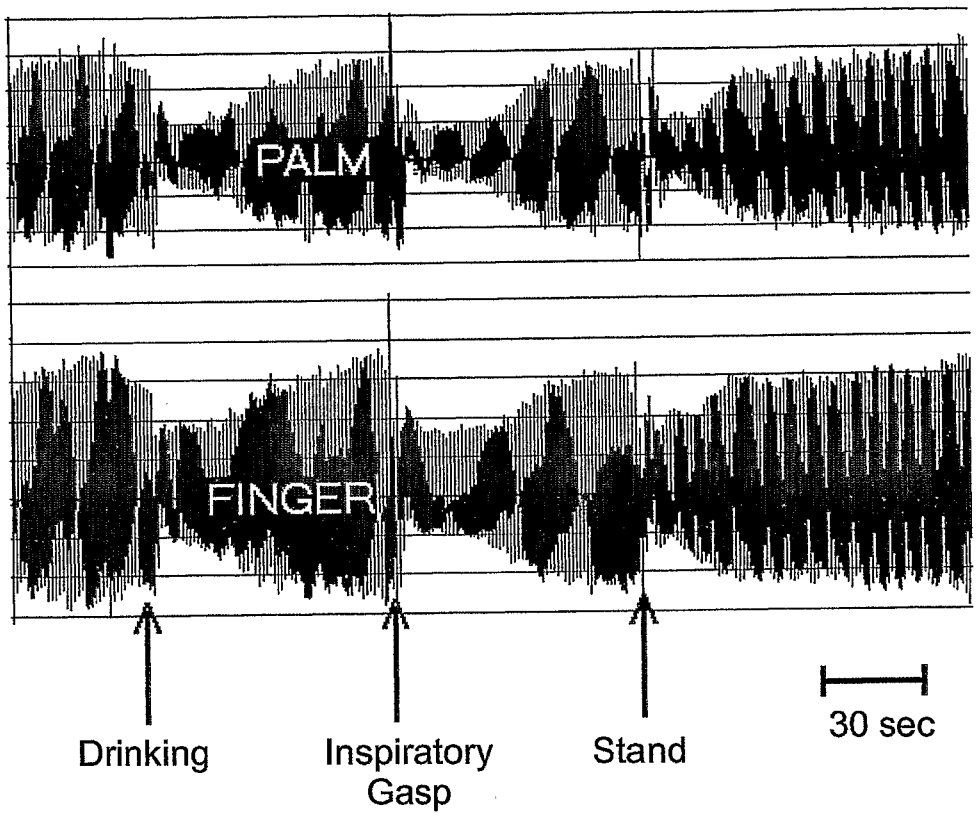

PALM
FINGER
Drinking
Inspiratory Gasp
Stand
30 sec

Fig. 15

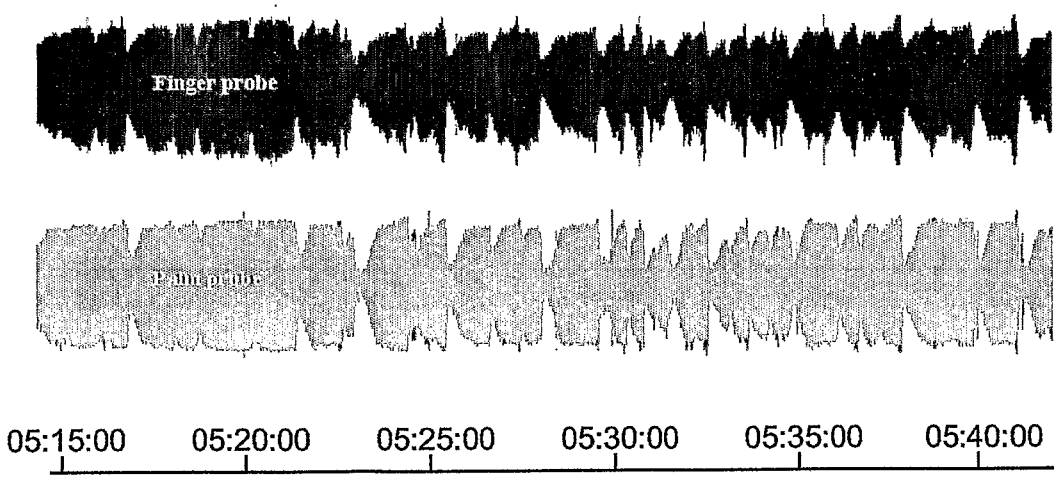

Finger probe
05:15:00
05:20:00
05:25:00
05:30:00
05:35:00
05:40:00

Fig. 16

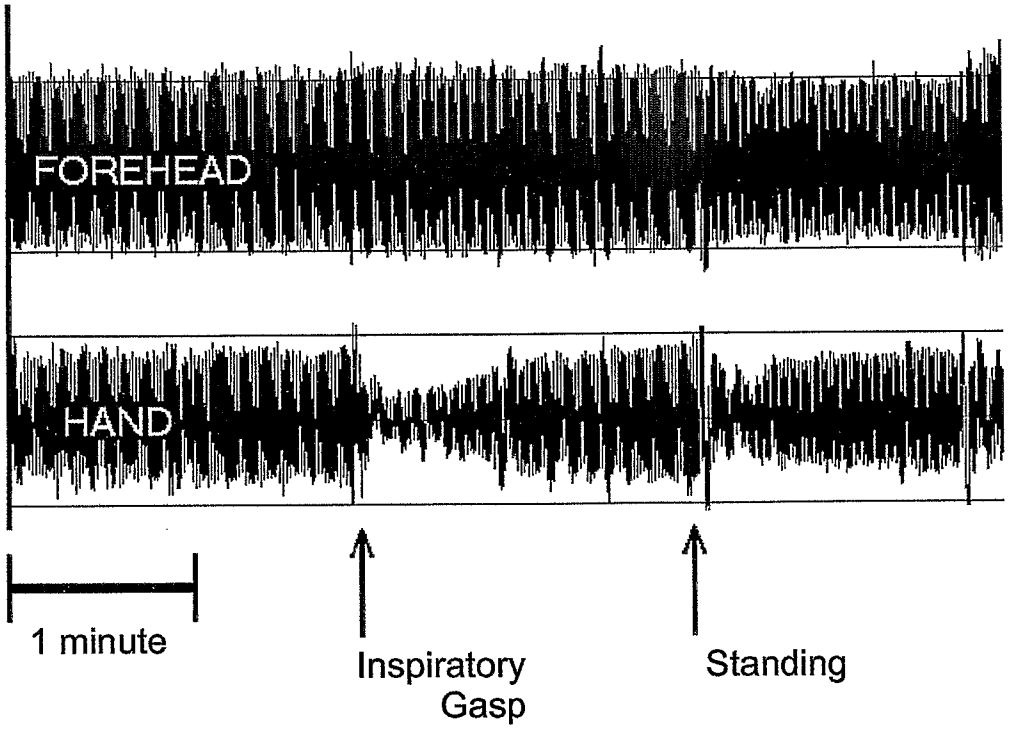

FOREHEAD
HAND
1 minute
Inspiratory Gasp
Standing

Fig. 17

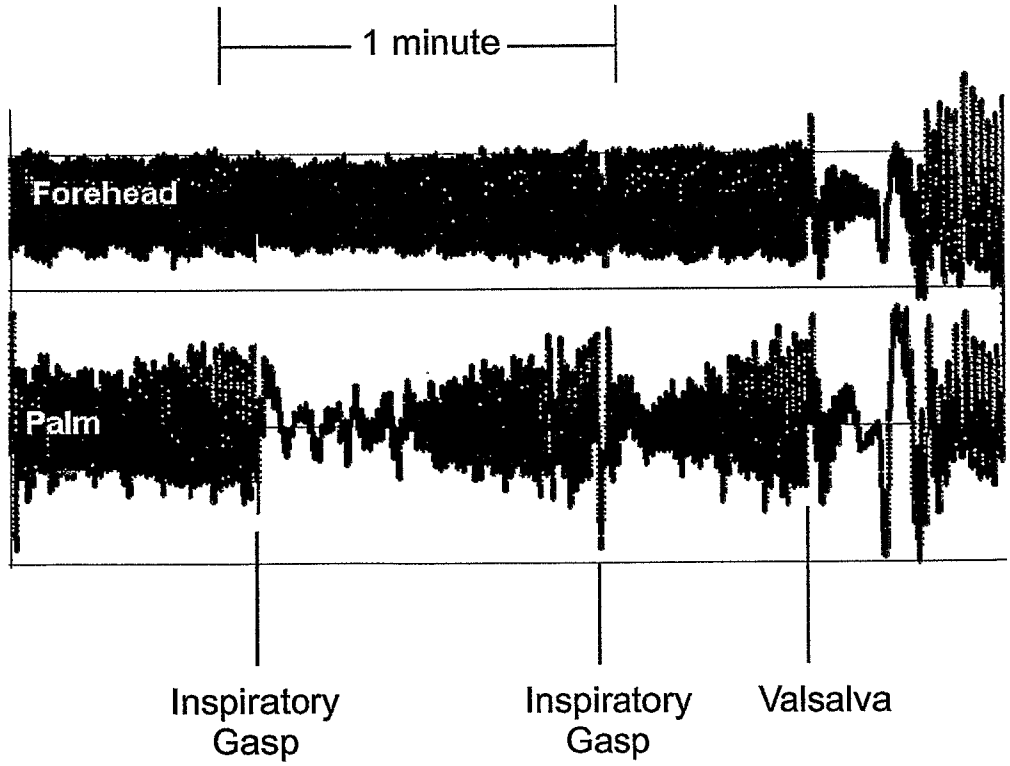

1 minute
Forehead
Palm
Inspiratory Gasp
Inspiratory Gasp
Valsalva

Fig. 18

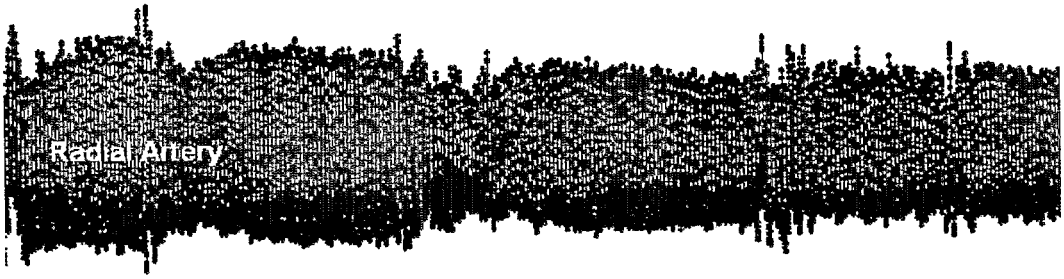


Fig. 19

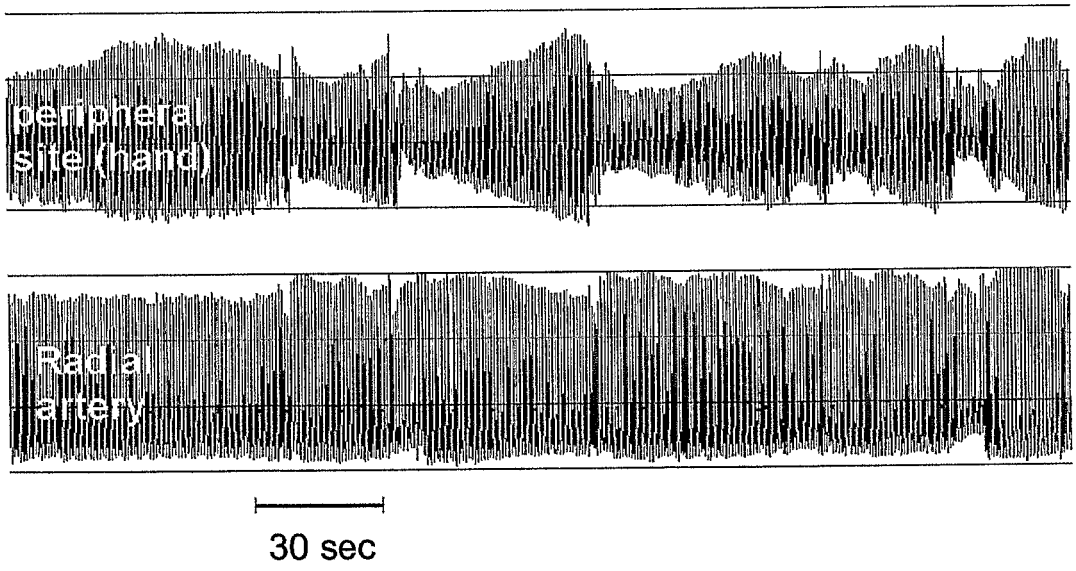


Fig. 20

REFERENCES CITED IN THE DESCRIPTION

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- WO 118976 A **[0034]**
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- WO 0234105 A **[0068]**

专利名称(译)	用于非侵入性地检测医疗状况的体表探针，装置和方法		
公开(公告)号	EP1534115B1	公开(公告)日	2018-10-31
申请号	EP2003764109	申请日	2003-07-15
申请(专利权)人(译)	伊塔马尔MEDICAL LTD		
当前申请(专利权)人(译)	伊塔马尔MEDICAL LTD		
[标]发明人	SCHNALL ROBERT P		
发明人	SCHNALL, ROBERT, P.		
IPC分类号	A61B5/021 A61B5/00 A61B5/02 A61B A61B5/022 A61B5/026 A61B5/0402 A61B5/0408 A61B5/103 A61B5/145 A61B8/00		
CPC分类号	A61B5/02007 A61B5/02116 A61B5/02241 A61B5/4035 A61B5/6843		
代理机构(译)	丹麦美国律师协会		
优先权	60/395613 2002-07-15 US		
其他公开文献	EP1534115A2 EP1534115A4		
外部链接	Espacenet		

摘要(译)

用于覆盖身体部位的受试者皮肤的选定区域的探针，该选定区域用作测量脉动动脉血容量变化的测量部位，包括：用于施用于受试者皮肤的选定区域的基部在测量现场;压力施加器，用于在测量部位向受试者的皮肤施加静压;以及用于检测测量部位的脉动动脉血量变化的传感器。压力施加器设计成在测量部位施加一定幅度的静压，以部分地卸载动脉的壁张力但不阻塞动脉的壁张力。压力施加器构造成通过允许通过测量部位周围的组织的自由静脉引流来基本上防止测量部位处的静脉扩张和血液汇集。这通过配置压力施加器以将静压施加到受试者皮肤的相对受限区域来完成，该区域占据测量部位处的相应身体部分的表面周长的相对小部分，从而允许自由静脉引流从测量站点经过测量站点周围的大范围无限制通道。

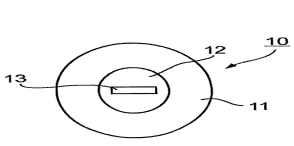

Fig. 1a

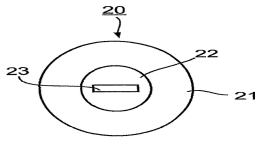

Fig. 2a

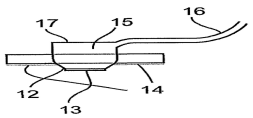

Fig. 1b

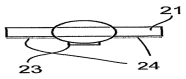

Fig. 2b

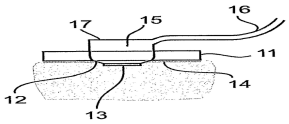

Fig. 1c

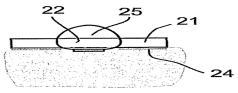

Fig. 2c