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(54) **Method for non-invasive measurements of blood related parameters**

Verfahren für nicht-invasive Messungen von blutbezogenen Parametern

Procédé pour des mesures non-invasives de paramètres sanguins

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EP-A- 0 227 119
WO-A-99/65384
US-A- 5 111 817
US-A- 5 827 181

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Description

FIELD OF THE INVENTION

[0001] This invention is generally in the field of non-invasive optical measurement techniques for measuring blood parameters.

BACKGROUND OF THE INVENTION

[0002] Non-invasive techniques for measuring various blood parameters, such as blood oxygen saturation and the concentration of substances contained in the blood (hemoglobin, glucose and other substances) have become very popular, since they do not require the withdrawal of a blood sample from a patient's body. Optical monitoring techniques of the kind specified typically utilize the detection of light transmitted or reflected from the location on the patient's body under measurement, and are based on spectrophotometric measurements enabling the indication of the presence of various blood constituents based on known spectral behaviors of these constituents. Most of these techniques utilize a measurement optical device or probe, designed in a manner to be attached to the patient's finger, which includes an optical assembly for irradiating the finger with light and detecting its light response.

[0003] US Patent No. 5,810,723 discloses an apparatus for the non-invasive monitoring of a patient's carboxyhemoglobin level. The patient breathes oxygen to saturate his blood hemoglobin prior to detection. The apparatus utilizes a clamp with arms holding the patient's finger: one arm supports a light emitting source and the other supports a detector. A microprocessor controls the measurements and processes the detected signals.

[0004] US Patent 5,638,816 and its continuation, US Patent 5,860,919, disclose an apparatus for the non-invasive monitoring of blood parameters by applying pressure to the patient's finger, thus inducing an active pulse therein. The induced change of blood volume enables a better signal-to-noise ratio to be obtained.

[0005] US 5,782,757 discloses a measuring devices in the form of disposable, folded adhesive sensors with optics embedded therein. The probe is designed so as to fit comfortably onto a patient's fingertip.

[0006] All the conventional devices of the kind specified are aimed at measuring enhanced optical pulsatile signals caused by the changes in the volume of the blood containing medium (finger). It is known that a regular optical pulsatile signal is typically 2-3% of the total transmission. The above devices are capable of obtaining the enhanced pulsatile signal that reach 8-10% of the total light transmission intensity. This enhancement of the natural pulsatile signal is a boundary of all conventional techniques of the kind specified.

[0007] A different technique is disclosed in a PCT application, International Publication No. WO 99/65384, assigned to the assignee of the present application. This is an occlusion based technique, where the measured signals are not pulsatile. According to this technique, the state of blood cessation is created in a medium under measurement, and measurements are taken during this state. This enables to obtain a significantly enhanced light response of the medium, as compared to that of the previously described techniques dealing with the pulsatile signals. To create such a state of blood cessation, over-systolic pressure needs to be applied to the patient's finger at a location upstream of the area under measurement, with respect to the direction of normal blood flow. Once the blood flow cessation state is established, the optical characteristics start to change dramatically, such that they differ from those of the fleshy medium with a normal blood flow by about 25 to 45%, and sometimes even by 60 %. At least two timely separated measurement sessions are performed, each including at least two measurements with different wavelengths of incident radiation. None of the conventional probes is suitable for these purposes. A probe in the form of a finger holder, suitable for applying over systolic pressure to a first location on the patient's finger and applying optical measurements to a second location downstream of the first location, is disclosed in a co-pending US application Serial No. 09/407390, assigned to the assignee of the present application.

[0008] U.S. Patent n. 5 111 817 A discloses a non-invasive system and method for monitoring arterial oxygen saturation levels which may also be used to continuously and non-invasively monitor blood pressure, including the generation of a continuous blood pressure waveform. During calibration periods pressure is applied to the body part and the systolic and mean blood pressures are determined and the arterial oxygen saturation level in the body part is determined. The pressure is then released from the body part and another arterial oxygen saturation level is determined. The difference between the two oxygen saturation levels is used as a calibration factor during later monitoring periods to remove the effect of non arterial oxygen saturation levels on the values obtained during the subsequent monitoring period. The systolic and mean arterial pressures measured during a calibration period are used to develop a Hardy model compliance curve wherein the pressure volume relationship of the arteries is determined.

SUMMARY OF THE INVENTION

[0009] There is a need in the art to further improve non-invasive measurements of blood parameters, by enabling the application of a variable controlled pressure to the patient's organ (e.g., his finger) in the vicinity of a measurement location.

[0010] It is a major object of the present invention to provide a method and a system that optimizes the finger tissue and blood volume, thereby providing conditions for measurements with maximum accuracy.

[0011] It was found by the inventors that the accuracy

of the measured signal can be improved even more by applying certain under-systolic pressure (0-250mmHg) to a region in the vicinity of a measurement location. This pressure, required for significantly improving the accuracy of measurements, may be different for different patients, depending *inter alia* on the internal blood pressure of the specific patient, and individual peculiarity of the finger size, shape and physiological conditions. This optimal pressure value depends also on the rigidity of the construction of probe device itself. Therefore means should be provided enabling to controllably vary the magnitude of the applied pressure.

[0012] Generally speaking, the present invention provides an active sensing means that enables to select an optimal pressure for a specific patient, such that the application of this pressure provides an optimal optical measurement signal for deriving therefrom the correct value of the parameter to be measured. In other words, the present invention enables to adjust the conditions of a measurement location on the patient's organ to the optimal signal determination.

[0013] The present invention provides for a method as claimed in claim 1 and a control system as set out in claim 14.

[0014] Thus, according to one broad aspect of the present invention, there is provided a method of non-invasive optical measurement of at least one parameter of the patient's blood, the method comprising the steps of:

(a) applying a probe device to the patient's blood perfused fleshy medium, wherein the probe device carries an optical measurement unit and a pressurizing assembly operable to apply controllably varying substantially under-systolic pressure to a measurement location on said medium;

(b) performing several measurement sessions to a measurement location on said medium to detect light response of the medium and generate measured data indicative thereof, and simultaneously varying the pressure applied to the vicinity of said measurement location, wherein each measurement session utilizes at least two different wavelength of incident light;

(c) analyzing the light response of the medium corresponding to different wavelengths of the incident light and different pressure values, and determining an optimal pressure value, so as to utilize the corresponding light response of the medium for deriving therefrom said at least one blood parameter.

[0015] The method according to the invention also comprises the application of over-systolic pressure to a location upstream of the measurement location, with respect to the direction of normal blood flow in the medium, so as to create the state of blood flow cessation. In this case, the measurements are taken during this state. Several time-separated measurement sessions can be performed either during the single blood-cessation state, or during the sequential blood cessation state. The latter operational mode is actually the so-called "multiple-occlusion", obtained by sequentially applying and releasing the over-systolic pressure.

[0016] Parameters that can be measured include oxygen saturation and the concentration of substance in blood, such as hemoglobin, glucose, etc. The present invention may utilize a calibration stage, during which various patients undergo measurements, and calibration curves corresponding to different blood parameters as functions of the applied under-systolic pressure are plotted.

[0017] The wavelengths of incident light are selected in accordance with the parameter to be measured. Preferably, several different wavelengths are sequentially applied, so as to obtain data from which different blood parameters can be derived within the same measurement session.

[0018] The probe device utilizes a finger holder carrying a measurement unit and a pressurizing assembly, all operated by a control system. The measurement unit typically comprises illumination and detection systems, arranged so as to detect reflected or transmitted light, as the case may be. The pressurizing assembly is designed so as to apply variable controlled pressure to the tissue in the vicinity of the measurement location.

[0019] Generally, the probe device may be associated with any other suitable patient's organ, such as his hand or wrist. If the patient's hand is considered, the rigid connector engages the patient's arm to prevent its folding at the elbow joint. It is more practical, however, to apply the device to the patient's finger.

[0020] The finger holder is in the form of a clip securing the fingertip between its legs and carrying the measurement unit. The clip may be formed with one pair or two pairs of legs. The four-leg design advantageously enables to provide four-sided support for the finger, thereby preventing its folding at the distal phalanx. A pair of manipulating arms is used for opening and closing the clip when putting the device in operation. In the case of the two-legged design, the extensions of the legs serve as the manipulating arms. In the case of the four-legged design, the manipulating arms are coupled to the legs through any suitable mechanism, enabling the simultaneous pivotal movement of all the legs.

[0021] The pressurizing assembly is of a pneumatic type. According to one embodiment of the invention, the pressurizing assembly comprises a bellow-like cushion, which is interconnected between the manipulating arms by its opposite ends and is coupled to the drive operated by the control system. The expansion and squeezing of the sleeve thus operates the pivotal movement of the manipulating arms, thereby weakening or enhancing the clamping effect of the clip legs. According to another embodiment of the invention, the pressurizing assembly comprises a balloon-like flat cushion attached to the inner side of the clip between its upper leg and a flexible cushion-like member contacting the patient's finger, so as to press on the finger portion below the clip. In this case a

locking device is provided to prevent the opening of the clip. According to yet another embodiment of the invention, the pressurizing assembly comprises a ring-like cushion attached to the inner side of the clip so as to wrap the finger, when putting the device into operation. The control system operates the expansion and squeezing of the cushion.

- There is thus provided a probe device to be used in non-invasive optical measurements of a patient's blood parameters, the probe device comprising a finger holder having a clip member that secures a fingertip between its clamping legs, wherein the finger holder supports a measuring unit for applying optical measurements to a measurement location on the finger, and carries a pressurizing assembly operable for applying controllably variable, substantially under-systolic pressure to the finger in the vicinity of said measurement location.

[0022] The probe device may be used with a pulse oxymeter, wherein the application of the controllably varied under-systolic pressure enables to derive more information from measured signals. This information contains the maximal amplitude of a pulsatile signal and/or AC/DC ratio.

[0023] Thus, according to yet another aspect, there is provided a pulse-oxymeter utilizing the above probe device and a control system that operates the pressurizing assembly and the measurement unit and generates data indicative of the measured parameters.

[0024] Preferably, the probe device also comprises an additional pressurizing assembly, which may also be of a pneumatic type, and operated by the same drive means as the above-described pressurizing assembly. The additional pressurizing assembly is aimed at applying over-systolic pressure, so as to cause the state of blood flow cessation and enable the occlusion-based measurements. The over-systolic pressure is applied to a location upstream of the measurement location, with respect to a normal blood flow direction.

[0025] Preferably, the additional pressurizing assembly is coupled to the clip through a substantially rigid connector engaging the finger along its middle phalanx and proximal intephalangeal joint. This is associated with the fact that occlusion-based measurements are non-volumetric, and the changes in volume of blood in the finger portion undergoing measurement are undesirable for such measurements. However, it is a natural tendency of the finger under pressure (over-systolic pressure) to fold at the proximal intephalangeal joint, thereby causing undesirable changes in blood volume. By providing a substantially rigid support for the finger at the region of the middle phalanx during measurement, such undesirable folding can be avoided.

[0026] There is also provided an optical measurement device for the non-invasive measurement of patient's blood parameters, the device comprising:

- a finger holder for attaching to the patient's finger, wherein the finger holder is in the form of a clip member, which secures a fingertip between its clamping legs and supports a measuring unit in a manner allowing to apply optical measurements to a measurement location on the finger;
- a first pressurizing assembly operable for applying over-systolic pressure to a location on the patient's finger upstream of said measurement location with respect to a normal blood flow direction, so as to create a state of blood flow cessation at said measurements location;
- a second pressurizing assembly associated with the finger holder and operable for applying desired pressure to the finger in the vicinity of said measurement location; and
- a control system selectively operating the first and second pressurizing assembly, and selectively operating the measuring unit, the control system having a processor that received data indicative of measured signals coming from the measuring unit and analyzes said data.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic illustration of a probe device according to one embodiment of the invention;
Fig. 2 is a schematic illustration of a probe device according to another embodiment of the invention;
Fig. 3 is a schematic illustration of a probe device according to yet another embodiment of the invention
Figs. 4a to 4d graphically illustrate experimental results obtained with different operational modes of the probe device according to the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0028] Referring to Fig. 1, there is illustrated a probe device, generally designated **10**, applied to a patient's finger **F** for performing the non-invasive measurement of the patient's blood parameters, such as oxygen saturation, blood pressure or the concentration of various substances, such as hemoglobin, glucose, cholesterol and other analyte concentrations. The probe **10** is in the form of a finger holder **12** mounted on the patient's finger **F,** and is coupled to a control system **14.**

[0029] The finger holder **12** is in the form of a clip member **16** having clamping legs - two legs **16A** and **16B** in the present example, pivotal about an axis **17**, for securing the patient's finger **F** therebetween. A pair of manip-

ulating arms **18A** and **18B** operates the pivotal movement of the clamping legs to attach the device to the patient's finger. The clip member **16** carries a measuring unit **20** mounted on its inner side so as to apply optical measurements to a measurement location L_1 on the patient's finger. Further provided in the probe device **10** is a pressurizing assembly **24** associated with the finger holder **12.** In the present example, the probe device **10** is used for occlusion-based measurements. To this end, an additional pressurizing assembly **22** is provided for applying over-systolic pressure to the blood perfuzed fleshy medium therebelow. When dealing with pulse-oxymetry based measurements, the provision of the pressurizing assembly **22** could be omitted.

[0030] The pressurizing assembly (first assembly) **22** is composed of an air cushion cuff **25** in the form of a ring wrapping the patient's finger **F** and a pneumatic drive **26** coupled to the cuff **25** through a pipe **27**. The ring wraps the finger **F** at a location L_2 upstream of the measurement location L_1 with respect to the direction of the normal blood flow. The pressurizing assembly **22**, when actuated, operates to apply over-systolic pressure, e.g., 220-300mmHg (generally, adjustable for each specific patient), at the location L_2, thereby causing the state of blood-flow cessation at the measurement location L_1. The cuff **25** is coupled to the clip member **16** by a substantially rigid connector **28**. The rigid plate-like connector **28** engages the finger along its middle phalanx, preventing its folding at the proximal intephalangeal joint, thereby avoiding undesirable changes in blood volume. The connector **28** is shaped like a plate, and is designed in a manner to enable reciprocating sliding movement of the cuff **25** relative to the clip **16** along the axis of the connector **28.** This enables to adjust the length of the entire finger holder **12** to that of the finger of a specific patient. For example, although not specifically shown, the plate-like connector could be formed with an elongated slot, while the cuff-ring be formed with a projection installed in this slot for reciprocating sliding movement along its axis.

[0031] In the present example of Fig. 1, the other (second) pressurizing assembly **24** is composed of a bellow-like air cushion **29** coupled to its pneumatic drive **30** through a pipe **31**. By appropriately expanding or squeezing the cushion **29**, the clamping affect of the legs is adjusted so as to apply a desired pressure onto the patient's finger in the vicinity of the measurement location L_1. It should, however, be noted that a common pneumatic drive could operate both the cushions 25 and **29**.

[0032] As further shown in Fig. 1, a pair of flexible, thermoconductive pads **32** (or pads with built-in heaters), made for example of rubber or silicone, is provided at the inner surfaces of the legs **16A** and **16B.** The pads **32** are coupled to a power source (not shown) operated by a corresponding utility of the control system **14** for applying appropriate, substantially low voltages (e.g., in the range 1V-24V) to the pads **32,** enabling heating the finger portion at the measurement location up to 36-38°. The heating ability of the device increases the accuracy of the non-invasively derived blood-related parameters. The substantially low voltage supply required for heating is, on the one hand, acceptable for medical devices, and, on the other hand, allows for using batteries, thereby rendering the entire device conveniently portable.

[0033] The measuring unit **20** does not form part of the present invention, and therefore need not be specifically illustrated and described, except to note that it comprises such main constructional parts as illumination and detection assemblies, generally at **34,** and generates data indicative of the light response of the finger. Generally, the illumination and detection assemblies could be accommodated either at one side of the finger when operating in a reflection mode, or at opposite sides of the finger when operating in a transmission mode. These reflected or transmitted signals present light response of the finger to incident radiation. According to the occlusion-based technique disclosed in the above-indicated PCT application, the measuring unit provides illumination of the finger with at least two different wavelengths, and detects light transmitted therethrough.

[0034] Preferably, the illumination unit comprises a plurality of light sources (e.g., LEDs) for illuminating the measurement location with a plurality of different wavelengths in the near infrared spectra. This enables the simultaneous determination of different blood parameters. The wavelengths are selected in accordance with the parameter to be determined. For example, if the hemoglobin concentration is to be determined, the selected wavelengths are in the ranges, where the absorption properties of the hemoglobin and plasma are more sharply expressed, namely are in the ranges 600-1000nm and 1100-1400nm. If the oxygen saturation is to be determined, the selected wavelengths lie in the range where the difference in the absorption of hemoglobin (Hb) and oxyhemoglobin (HbO_2) are more sharply expressed, namely are in the ranges 600-780nm (where the difference in the sensitivity of HbO_2 and Hb is maximal) and 820-980nm (reference range). When dealing with the glucose concentration, the spectral ranges of 1500-1600nm may be added to the above-mentioned range of 600-1300nm for selecting the operational wavelengths.

[0035] The generated data indicative of the detected light (light response of the illuminated medium) is transmitted to the control system **14** for processing and analyzing. To this end, the control system **14** includes a processor **36** operated by suitable software for analyzing the detected signals and determining the desired parameter of the patient's blood, as will be described more specifically further below with reference to Figs. **4a-4d**.

[0036] Thus, each of the drives **26** and **30** of the first and second pressurizing assemblies **22** and **24**, respectively, whilst being actuated by a corresponding utility of the control system **14**, operates to apply required pressure to the finger portion at locations L_2 and L_1. The pressurizing assembly **24** is first actuated, and when a certain under-systolic pressure is applied to the vicinity of the

measurement location L_1, the control system **14** actuates the pressurizing assembly **22** to apply the over-systolic pressure to the location L_2. When the blood flow cessation state is created, the control system **14** operates the measurement unit **20** to illuminate the measurement location with different wavelengths and detect the light response. The application of over-systolic pressure (location L_2) is maintained for a period of time, so as not to cause irreversible changes in the finger, and then, the control system operates the drive **26** to release this pressure. The pressurizing assembly **24** applies a different value of the under-systolic pressure, the pressurizing assembly 22 is operated to perform a further occlusion-release session. During each such occlusion-release session, the light response of the measurement location as a function of time is determined. The effective measurements, i.e., the results that have to be analyzed, are those taken at the state of blood flow cessation.

[0037] The operational mode of the device **10** may be such that the control system **14** actuates the measuring unit **20** for performing continuous measurements starting prior to the application of over-systolic pressure. In this case, only those signals, which are associated with the state of blood cessation, are taken into consideration. Measurements taken during the time period prior to the establishment of this state should be disregarded, due to the unavoidable influence of motional and/or other artifacts causing non-monotonic fluctuations of the light transmission. According to an alternative operational mode of the device **10**, the control system **14** actuates the measuring unit **20** a small period of time after the application of the over-systolic pressure. During the time period corresponding to the existence of the state of blood cessation, relative light transmission of blood is observed, which reaches its maximum and may last generally from one second to several minutes.

[0038] To obtain meaningful results, either at least two timely separated measurement sessions should be considered, at least one of them being that taken during the state of blood cessation, or a single long continuous measurement session should be considered starting after the establishment of the state of blood cessation. During the first measurement session, the control system **14** operates to maintain the cuff **25** and the cushion **29** in their squeezed position, and operates the heating element **32** to heat the finger in the vicinity of the measurement location. The control system **14** then operates the pneumatic drives **26** and **30** to release the pressure. The squeezing action of the cuff **25** is ceased, and after a short delay preset by the respective software in the control unit, the blood flow sharply increases until it reaches new steady state. Then, the control system **14** actuates the second measurement session at a state of the transitional blood flow. The illumination assembly continues to illuminate the finger, but squeezing is halted. The detection assembly, being synchronized by the control system **14**, detects the light response of the finger. In other words, the control system **14** selectively operates the measuring unit **20** and the pressurizing assemblies **22** and **24**, and analyzes data coming from the measuring unit, as will be described further below.

[0039] Reference is made to Fig. 2, illustrating a probe device 100 according to another embodiment of the invention. To facilitate understanding, the same reference numbers are used for identifying those components which are common in the devices **10** and **100**. The device **100** is constructed generally similar to the device **10,** but has a somewhat different design of a finger holder **112.** Here, a pressurizing assembly **124** utilizes a cuff-like cushion **129** coupled to a pneumatic drive **30** through a pipe **31.** In other words, the second pressurizing assembly **124** is constructed generally similar to the first assembly **22,** but is associated with the measurement location L_1 for applying under-systolic pressures thereto. The heating element **32** may be attached to the surface of the cushion **129** contacting the finger skin. The operation of the device **100** is similar to that of the device **10.** It should, however, be noted, that the pressurizing assembly **124** can be used in combination with the assembly 24 (Fig. 1), rather than replacing it.

[0040] Fig. 3 illustrates a probe device **200** having a somewhat different design as compared to the previously described examples. Here, a pressurizing assembly **224**, that applies under-systolic pressures to the measurement location L_1, includes a balloon-like flat cushion **229,** which is accommodated either between the flexible pad **32** and the inner surface of the clamping leg **16B,** or inside the pad **32**, and is coupled to the drive **30** through the pipe **31**. To prevent the opening of the clip member, when in the expanded position of the cushion **229**, a lock mechanism **230** is appropriately provided.

[0041] It should be noted, although not specifically shown, that the clip member may have a four-legged design, in which case one pair of legs engages the finger at its top and bottom thereof, and the other pair of legs engages the opposite sides of the finger. Such four-sided support of the fingertip prevents its folding at the distal phalanx, thereby avoiding undesirable blood volume changes.

[0042] It should also be noted that the rigid connector **28** may be located at either side of the patient's finger. Alternatively, a pair of such connectors can be used located at opposite sides of the finger. Additionally, the processor may be accommodated within the cuff **25**, and wires, if any, connecting the processor to the output circuit of the measuring unit **20**, may pass through the rigid connector.

[0043] Turning now to Figs. 4a-4d, the advantageous features of the present invention are graphically illustrated. Figs. 4a and 4b illustrate, respectively, graphs G_1 and G_2 presenting experimental results obtained with two different modes of the probe device 10, namely, when the pressurizing assembly **24** is in its active (operational) and passive (non-operational) modes. Each of the graphs G_1 and G_2 corresponds to the concentration of hemoglobin derived from measurement data obtained

with the measurement unit **20** as the function of the hemoglobin concentration obtained with one of the conventional techniques (invasive). To plot each of the graphs, ten measurement points were used. The results show that with the active mode of the pressurizing assembly, when a desired, optimal under-systolic pressure is applied to the measurement location, the measured correlation between the concentration values obtained with different techniques is about 0.91, and the standard deviation is 0.9. While with the passive mode of the pressurizing assembly, these parameters are, respectively, 0.79 and 1.3.

[0044] Figs. 4c and 4d illustrate examples of the technique of the present invention enabling the determination of the desired, optimal pressure to be applied by the pressurizing assembly **24** to a specific patient. Fig. 4c illustrates four graphs $\mathbf{H_1}$, $\mathbf{H_2}$, $\mathbf{H_3}$ and $\mathbf{H_4}$. Graphs $\mathbf{H_1}$ and $\mathbf{H_2}$ correspond to the parametric slopes as functions of the pressure applied by the assembly **24**, wherein the parametric slopes were obtained for two different pairs of wavelengths: (1) λ_1=660 and λ_2=940nm, and (2) λ_1=1300 and λ_2=940nm, respectively.

[0045] The slope-based technique of determining the blood substance concentration is disclosed in the above-indicated PCT application assigned to the assignee of the present application. A parametric slope is determined as the transmission logarithm at the wavelength λ_2, i.e., Log(λ_2), versus the transmission logarithm at the wavelength λ_1, i.e., Log(λ_1), over a certain time interval (e.g., long occlusion) or at timely separated occlusion stages (i.e., multiple occlusion-release sessions). It should be understood that the slope-based technique may be applied with the pulse-oxymetry as well. In this case such a slope correspond to AC/DC ratio that enables the determination of blood-related parameters. In other words, the parametric slope is a linear function of Log(λ_2) versus Log(λ_1), whose slope can be determined, for example, by a known linear regression algorithm.

[0046] Graphs $\mathbf{H_3}$ and $\mathbf{H_4}$ correspond to the slope-error (i.e., standard deviation) as the function of pressure, for the above parametric slopes, respectively. To determine the slope-error, several measurement sessions were taken with the same pairs of wavelengths, corresponding parametric slopes were calculated, and standard deviation values were determined. As clearly seen in the figure, the maximum value (0.55) of the slope in graph $\mathbf{H_1}$, which represents certain results criteria for the determination of the oxygen saturation, corresponds to the minimum value (0.04) of the respective slope-error in graph $\mathbf{H_3}$ at the pressure value of about 100mmHg. Similarly, the minimum value (0.35) of the slope in graph $\mathbf{H_2}$, which represents another results criteria, corresponds to the minimum value (0.04) of the respective slope-error in graph $\mathbf{H_4}$ at the pressure value of about 100mmHg. Thus, this pressure is the optimal pressure for this specific patient, and should be applied to the vicinity of the measurement location on his finger during the optical measurements

[0047] Fig. 4d illustrates the amplitude of the measured signal as the function of the applied pressure. As shown, at a certain pressure value (about 120mmHg), the amplitude reaches its maximal value.

[0048] Hence, the experimental results show that optical parameters of the patient's blood, such as slope and amplitude of the light response, changes with the pressure variations. This enables to select the optimal pressure value (or range) to increase the accuracy of measurements, and obtain better results. Generally speaking, the determination of the optimal pressure value is based on a certain optical criteria, such as minimum of the standard deviation, maximum amplitude of the measured optical signal, AC/DC ratio, parametric slope, etc. It should be understood that the pressure values in the above examples are relevant only for the specific design of the probe used in the experiments, and may be different for different patients and different probe configurations. As indicated above, the rigidity of the constructional elements of the probe also affects the optimal pressure value to be used for optimizing the measurement results.

[0049] Those skilled in the art will readily appreciate that various modifications and changes can be applied to the preferred embodiments of the invention as hereinbefore exemplified without departing from its scope defined in and by the appended claims.

Claims

1. A method for controlling non-invasive optical determination of at least one parameter of a human body, the method comprising:

(a) operating a first pressurizing assembly (24; 124; 224) to apply a controllably varying pressure to a vicinity of a measurement location (L_1) on a medium of said human body and concurrently operating an optical measuring unit (20) to apply optical measurements to the measurement location (L_1) by illuminating the measurement location (L_1) with incident light of at least two different wavelengths and detecting light responses of the medium at the measurement location (L_1) for said at least two different wavelengths,

(b) analyzing data indicative of the detected light responses of the medium as a function of time, the wavelength of said incident light and the value of said controllably varying pressure, and

(c) selecting an optimal pressure value for the specific human body as that corresponding to the detected light response **characterized by** at least one of the following: a minimum of standard deviation, a maximal intensity of the light response and an AC/DC radio in the detected light responses,

the method being **characterized in**:

(d) operating said first pressurizing assembly

(24; 124; 224) to apply a pressure at said optimal pressure value and operating a second pressurizing assembly (22) to apply a second over-systolic pressure to the medium at a location (L_2) and concurrently operating said optical measurement unit (20) to detect at least two light responses of the medium to said at least two different wavelengths, respectively, thereby enabling determination of said at least one parameter of the specific human body derived from said at least two light responses obtained under said optimal pressure and said second over-systolic pressure.

2. The method according to Claim 1, wherein the controllably varying pressure is substantially under-systolic pressure.

3. The method according to Claim 1 or 2, wherein the analyzed data is indicative of time variation of the light response for each of said at least two wavelengths.

4. The method according to any one of preceding Claims, wherein the measured data is indicative of time variation of the light response for each of said at least two wavelengths while at a state of blood flow cessation at the measurement location (L_1), resulted from application of the second over-systolic pressure to the medium at the location (L_2) upstream of the measurement location (L_1) with respect to a normal blood flow direction in the body.

5. The method according to any one of preceding Claims, wherein said at least one parameter of the human body comprised at least one blood parameter including at least one of the following: oxygen saturation, Hb, Glucose, cholesterol, concentration of one or more substance in blood.

6. The method according to Claim 5, wherein said one or more substance includes at least one of hemoglobin and glucose.

7. The method according to any one of preceding Claims, wherein said analyzing of the measured data comprises utilizing calibration data indicative of different blood parameters.

8. The method according to any one of preceding Claims, for use in oximetry measurements.

9. The method according to any one of preceding Claims, for use in pulse oximetry measurements.

10. The method according to any one of preceding Claims, wherein said light response is due to at least one of transmission of light through said medium and reflection thereof.

11. The method according to any one of preceding Claims, wherein said medium is a body part.

12. The method according to any one of preceding Claims, wherein said medium is a fleshy medium.

13. The method according to any one of preceding Claims, wherein said medium is an individual's finger.

14. A control system (14) for carrying out the method of any one of preceding Claims, the control system (14) being connectable to a first pressurizing assembly (24; 124; 224) and a second pressurizing assembly (22) and configured for operating said first and second pressurizing assemblies (24; 124; 224, 22) for applying respectively a first, controllably varying, under-systolic pressure and a second over-systolic pressure, said control system (14) comprising a processor unit (36) which is connectable to a measurement unit (20) for receiving measured data, and which processor unit (36) is configured for identifying and analyzing said measured data indicative of light response of a measurement location (L_1) on a body's medium to certain incident light of at least two different wavelengths during the application of the controllably varying under-systolic pressure to a vicinity of said measurement location (L_1) and application of said over-systolic pressure at a location (L2) on said medium, the processor unit (36) being configured for determining the light response of the medium as a function of time, the wavelengths of said incident light and a value of said first under-systolic pressure and for determining an optimal value of the first under-systolic pressure for the specific human body as a pressure value corresponding to at least one of the following: a minimum of standard deviation, a maximal intensity of the light response and an AC/DC ratio in the detected light response, said processor unit (36) being further configured for utilizing at least two light responses of the medium for said at least two different wavelengths, respectively, measured under the application of said optimal under-systolic pressure to said vicinity and for deriving from said at least two light responses at least one parameter of the human body.

Patentansprüche

1. Ein Verfahren zur Steuerung der nicht invasiven optischen Bestimmung mindestens eines Parameters eines menschlichen Körpers, wobei das Verfahren Folgendes umfasst:

(a) Betätigung eines ersten Druckbeaufschla-

gungsaufbaus (24; 124; 224), um einen steuerbar variierenden Druck auf eine Umgebung einer Messstelle (L_1) auf einem Medium des menschlichen Körpers auszuüben, und gleichzeitige Betätigung einer optischen Messeinheit (20), um optische Messungen auf die Messstelle (L_1) anzuwenden, durch Beleuchtung der Messstelle (L_1) mit einfallendem Licht mit mindestens zwei verschiedenen Wellenlängen und Erfassung von Lichtantworten des Mediums an der Messstelle (L_1) für die mindestens zwei verschiedenen Wellenlängen,

(b) Analyse der Daten, welche die erfassten Lichtantworten des Mediums anzeigen, als eine Funktion der Zeit, der Wellenlänge des einfallenden Lichts und dem Wert des steuerbar variierenden Drucks, und

(c) Auswahl eines optimalen Druckwerts für den spezifischen menschlichen Körper als denjenigen, der der erfassten Lichtantwort entspricht, **gekennzeichnet durch** mindestens eines der Folgenden: ein Minimum der Standardabweichung, eine maximale Intensität der Lichtantwort und ein WS/GS-Verhältnis in den erfassten Lichtantworten,

wobei das Verfahren **gekennzeichnet ist durch**:

(d) Betätigung des ersten Druckbeaufschlagungsaufbaus (24; 124; 224), um einen Druck mit dem optimalen Druckwert auszuüben, und Betätigung eines zweiten Druckbeaufschlagungsaufbaus (22), um einen zweiten übersystolischen Druck auf das Medium an einer Stelle (L_2) auszuüben, und gleichzeitige Betätigung der optischen Messeinheit (20), um mindestens zwei Lichtantworten des Mediums jeweils auf die mindestens zwei verschiedenen Wellenlängen zu erfassen, wodurch die Bestimmung des mindestens einen Parameters des spezifischen menschlichen Körpers ermöglicht wird, und zwar abgeleitet von den mindestens zwei Lichtantworten, die unter dem optimalen Druck und dem zweiten übersystolischen Druck erhalten werden.

2. Das Verfahren gemäß Anspruch 1, worin der steuerbar variierende Druck im Wesentlichen untersystolischer Druck ist,

3. Das Verfahren gemäß Anspruch 1 oder 2, worin die analysierten Daten die zeitliche Variation der Lichtantwort für jede der mindestens zwei Wellenlängen anzeigen.

4. Das Verfahren gemäß einem beliebigen der obigen Ansprüche, worin die gemessenen Daten die zeitliche Variation der Lichtantwort für jede der mindestens zwei Wellenlängen während eines Zustands des Stillstands des Blutflusses an der Messstelle [L_1) anzeigen, der aus der Ausübung des zweiten übersystolischen Drucks auf das Medium an der Stelle (L_2) stromaufwärts von der Messstelle (L_1) mit Bezug auf eine normale Richtung des Blutflusses im Körper resultiert.

5. Das Verfahren gemäß einem beliebigen der obigen Ansprüche, worin der mindestens eine Parameter des menschlichen Körpers mindestens einen Blutparameter umfasst, der mindestens eines der Folgenden einschließt: Sauerstoffsättigung, Hb, Glukose, Cholesterin, Konzentration einer oder mehrerer Substanzen im Blut.

6. Das Verfahren gemäß Anspruch 5, worin die eine oder mehreren Substanzen mindestens eines von Hämoglobin und Glukose einschließen.

7. Das Verfahren gemäß einem beliebigen der obigen Ansprüche, worin die Analyse der gemessenen Daten die Nutzung der Kalibrierungsdaten umfasst, die verschiedene Blutparameter anzeigen.

8. Das Verfahren gemäß einem beliebigen der obigen Ansprüche zur Verwendung in Oximetrie-Messungen.

9. Das Verfahren gemäß einem beliebigen der obigen Ansprüche zur Verwendung in Pulsoximetrie-Messungen.

10. Das Verfahren gemäß einem beliebigen der obigen Ansprüche, worin die Lichtantwort auf mindestens eines von Folgendem zurückzuführen ist: Durchlassen von Licht durch das Medium und Reflexion desselben.

11. Das Verfahren gemäß einem beliebigen der obigen Ansprüche, worin das Medium ein Körperteil ist.

12. Das Verfahren gemäß einem beliebigen der obigen Ansprüche, worin das Medium ein fleischiges Medium ist.

13. Das Verfahren gemäß einem beliebigen der obigen Ansprüche, worin das Medium der Finger eines Individuums ist.

14. Ein Steuersystem (14) zur Durchführung des Verfahrens gemäß einem beliebigen der obigen Ansprüche, wobei das Steuersystem (14) mit einem ersten Druckbeaufschlagungsaufbau (24; 124; 224) und einem zweiten Druckbeaufschlagungsaufbau (22) verbunden werden kann und ausgebildet ist, um den ersten und den zweiten Drucheaufschlagungskaufbau (24; 124; 224, 22) zu betätigen, um einen ersten, steuerbar variierenden, untersystolischen Druck be-

ziehungsweise einen zweiten übersystolischen Druck auszuüben, wobei das Steuersystem (14) eine Prozessoreinheit (36) umfasst, die für den Empfang von Messdaten mit einer Messeinheit (20) verbunden werden kann, und wobei die Prozessoreinheit (36) konfiguriert ist, um die Messdaten, die die Lichtantwort einer Messstelle (L_1) auf dem Medium eines Körpers auf bestimmtes einfallendes Licht mit mindestens zwei verschiedenen Wellenlängen während der Ausübung des steuerbar variierenden untersystolischen Drucks auf eine Umgebung der Messstelle (L_1) und der Ausübung des übersystolischen Drucks auf eine Stelle (L_2) auf dem Medium anzeigen, zu bestimmen und zu analysieren, wobei die Prozessoreinheit (36) konfiguriert ist, um die Lichtantwort des Mediums als eine Funktion der Zeit, der Wellenlänge des einfallenden Lichts und einem Wert des ersten untersystolischen Drucks zu bestimmen und um einen optimalen Wert des ersten untersystolischen Drucks für den spezifischen menschlichen Körper als Druckwert zu bestimmen, der mindestens einem von Folgendem entspricht: einer minimalen Standardabweichung, einer maximalen Intensität der Lichtantwort und einem WS/GS-Verhältnis in der erfassten Lichtantwort, wobei die Prozessoreinheit (36) weiter konfiguriert ist, um mindestens zwei Lichtantworten des Mediums jeweils für die mindestens zwei verschiedenen Wellenlängen zu nutzen, und zwar gemessen unter der Ausübung des optimalen untersystolischen Drucks auf die Umgebung, und um von den mindestens zwei Lichtantworten mindestens einen Parameter des menschlichen Körpers abzuleiten.

Revendications

1. Procédé pour contrôler la détermination optique non-invasive d'au moins un paramètre du corps humain, le procédé comprenant:

(a) de faire fonctionner un premier ensemble de pressurisation (24; 124; 224) pour appliquer une pression variant d'une manière contrôlée à proximité d'un emplacement de mesure (L1) sur un moyen dudit corps humain et en même-temps d'actionner une unité de mesure optique (20) pour appliquer des mesures optiques à l'emplacement de mesure (L1) en éclairant l'emplacement de mesure (L1) par une lumière incidente d'au moins deux différentes longueurs d'onde et détectant les réponses lumineuses du moyen à l'emplacement de mesure (L1) pour lesdites au moins deux différentes longueurs d'onde,
(b) d'analyser des données indicatives des réponses lumineuses détectées du moyen en fonction du temps, de la longueur d'onde de ladite lumière incidente et de la valeur de ladite pression variant d'une manière contrôlée, et
(c) de sélectionner une valeur de pression optimale pour le corps humain spécifique comme celle correspondant à la réponse lumineuse détectée, **caractérisé par** au moins l'un des suivants : un minimum de déviation standard, une intensité maximale de la réponse lumineuse et un rapport AC/DC dans les réponses lumineuses détectées,
le procédé étant **caractérisé par** le fait :
(d) d'e faire fonctionner ledit premier ensemble de pressurisation (24; 124; 224) de sorte à appliquer une pression à ladite valeur optimale de pression et d'actionner un second ensemble de pressurisation (22) pour appliquer une seconde pression sur-systolique au moyen à un emplacement (L2) et en même-temps d'actionner ladite unité de mesure optique (20) pour détecter au moins deux réponses lumineuses du moyen auxdites au moins deux longueurs d'onde différentes, respectivement, de sorte à permettre de déterminer ledit au moins un paramètre du corps humain spécifique issu desdites au moins deux réponses lumineuses obtenues sous ladite pression optimale et ladite seconde pression sur-systolique.

2. Procédé selon la revendication 1, dans lequel la pression variant de manière contrôlée est essentiellement une pression sous-systolique.

3. Procédé selon la revendication 1 ou 2, dans lequel les données analysées sont indicatives de la variation temporelle de la réponse lumineuse pour chacune desdites au moins deux longueurs d'onde.

4. Procédé selon l'une quelconque des revendications précédentes, dans lequel les données mesurées sont indicatives de la variation temporelle de la réponse lumineuse pour chacune desdites au moins deux longueurs d'onde pendant une condition d'interruption du flux sanguin à l'emplacement de mesure (L1), dérivant de l'application de la seconde pression sur-systolique au moyen à l'emplacement (L2) en amont de l'emplacement de mesure (L1) par rapport à la direction normale du flux sanguin dans le corps.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit au moins un paramètre du corps humain comprend au moins un paramètre sanguin incluant au moins un des suivants : saturation d'oxygène, Hb, Glucose, cholestérol, concentration de une ou plusieurs substances dans le sang.

6. Procédé selon la revendication 5, dans lequel ladite

(lesdites) une ou plusieurs substances inclut(incluent) au moins l'un de hémoglobine et glucose.

7. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite analyse des données mesurées comprend d'utiliser des données de calibration indicatives de différents paramètres sanguins.

8. Procédé selon l'une quelconque des revendications précédentes, pour être utilisé dans les mesures oxymètriques.

9. Procédé selon l'une quelconque des revendications précédentes, pour être utilisé dans les mesures oxymètriques d'impulsions.

10. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite réponse lumineuse est due à au moins une des transmissions de lumière à travers ledit moyen et à sa réflexion.

11. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit moyen est une partie du corps.

12. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit moyen est un moyen charnu.

13. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit moyen est un doigt d'un individu.

14. Système de contrôle (14) pour réaliser le procédé selon l'une quelconque des revendications précédentes, le système de contrôle (14) étant connectable à un premier ensemble de pressurisation (24; 124; 224) et à un second ensemble de pressurisation (22) et configuré pour faire fonctionner lesdits premier et second ensembles de pressurisation (24 ; 124 ; 224 ; 22) de sorte à appliquer respectivement une première pression sous-systolique, variant de manière contrôlée, et une seconde pression sur-systolique, ledit système de contrôle (14) comprenant une unité de processeur (36) connectable à une unité de mesure (20) afin de recevoir des données mesurées, et cette unité de processeur (36) est configurée de sorte à identifier et analyser lesdites données de mesure indicatives de la réponse lumineuse d'un emplacement de mesure (L1) sur un moyen corporel à une certaine lumière incidente de au moins deux longueurs d'onde pendant l'application de la pression sous-systolique variant de manière contrôlée à proximité dudit emplacement de mesure (L1) et l'application de ladite pression sur-systolique à un emplacement (L2) sur ledit moyen, l'unité de processeur (36) étant configurée de sorte à déterminer la réponse lumineuse du moyen en fonction du temps, de la longueur d'onde de ladite lumière incidente et d'une valeur de ladite première pression sous-systolique et afin de déterminer une valeur optimale de la première pression sous-systolique pour le corps humain spécifique comme une valeur de pression correspondant à au moins l'un des suivants : une déviation standard minime, une intensité maximale de la réponse lumineuse et un rapport AC/DC dans la réponse lumineuse détectée, ladite unité de processeur (36) étant en outre configurée de sorte à utiliser au moins deux réponses lumineuses du moyen pour lesdites au moins deux différentes longueurs d'onde, respectivement, mesurées sous application de ladite pression sous-systolique optimale à ladite proximité et de sorte à dériver desdites au moins deux réponses lumineuses au moins un paramètre du corps humain.

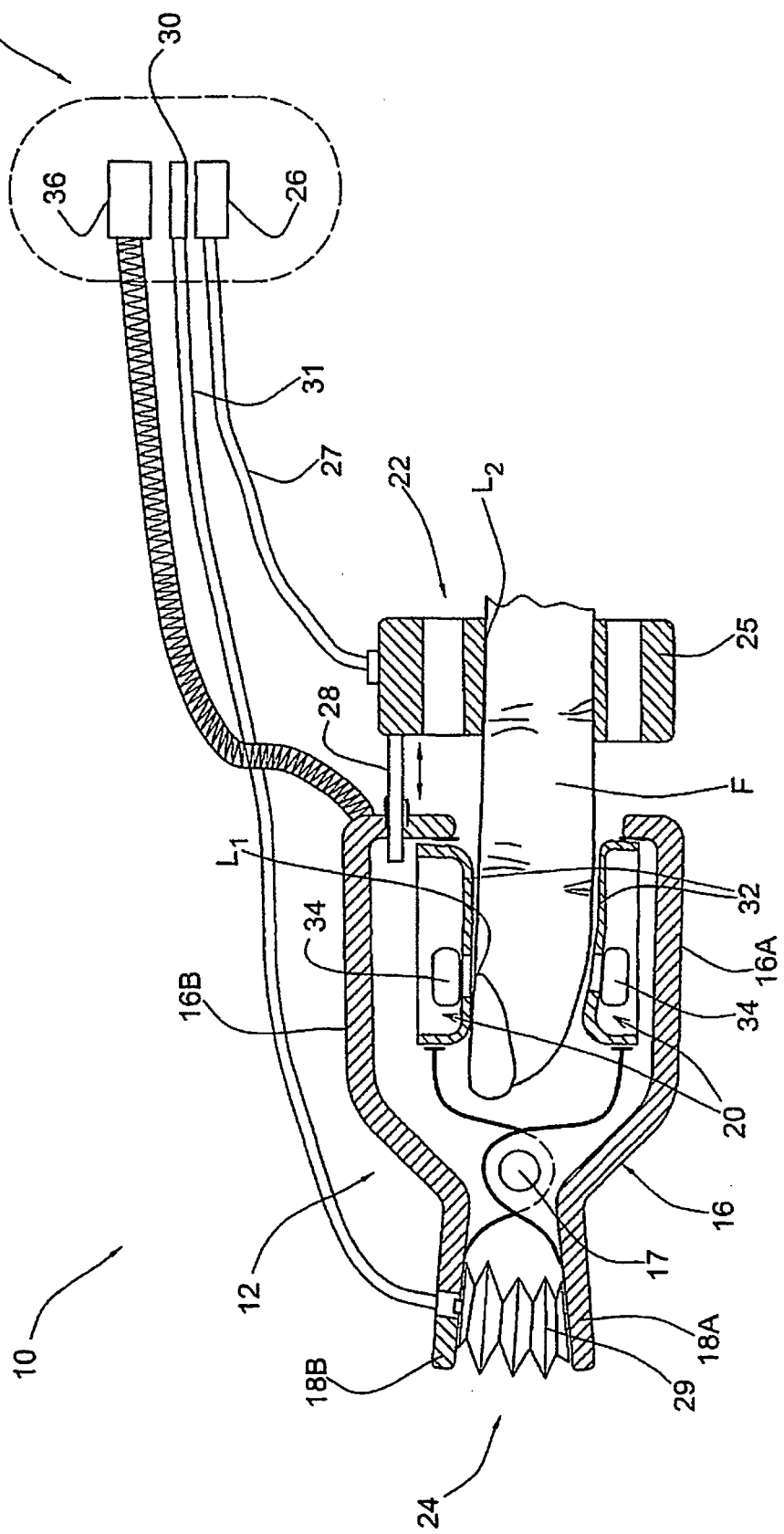
14
30
36
26
31
27
22
L_2
25
28
F
L_1
32
34
16A
16B
34
20
16
17
12
10
18A
18B
29
24

FIG. 1

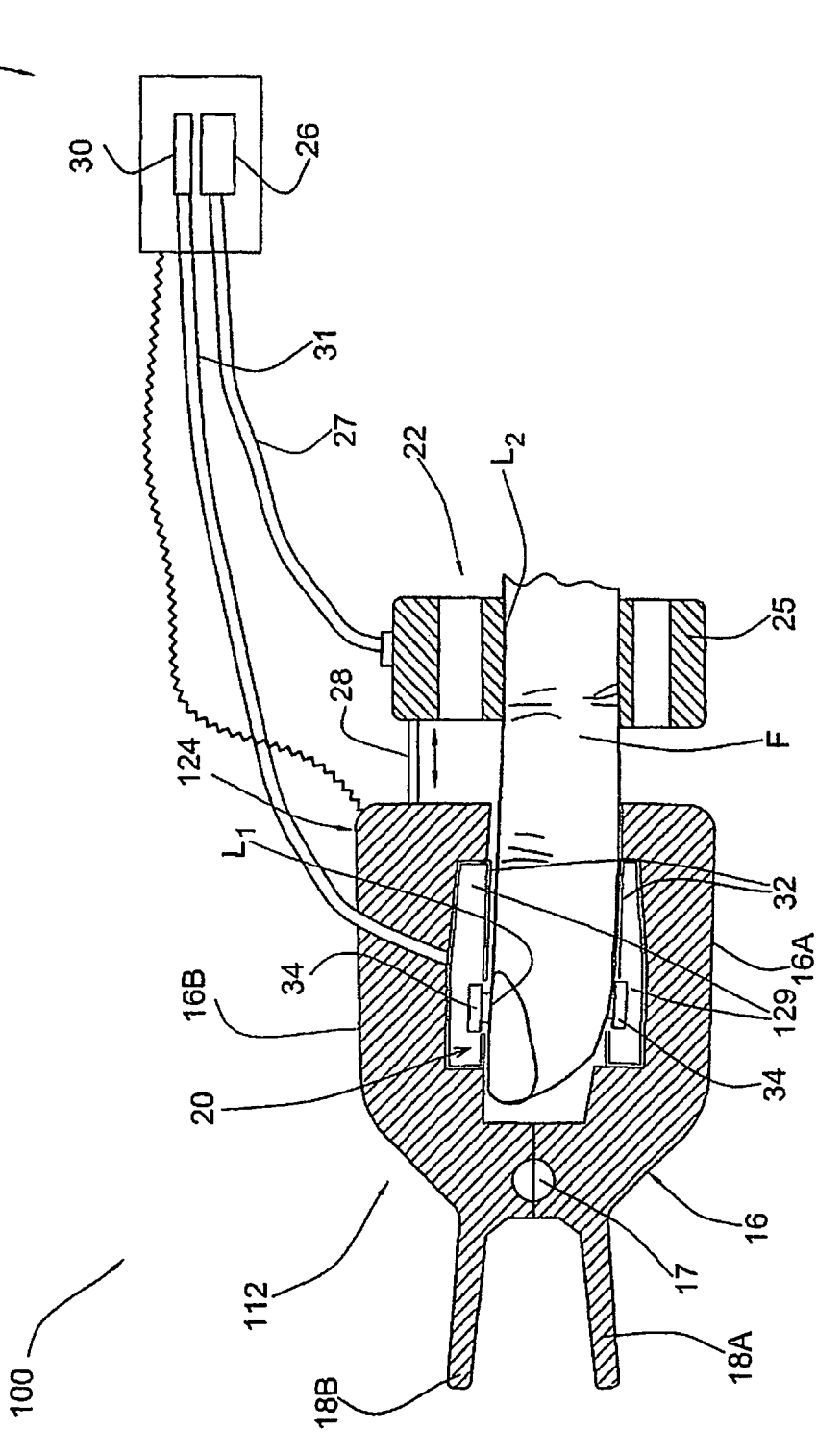
14
30
26
31
27
22
L_2
25
28
F
124
L_1
32
16A
34
16B
129
20
34
112
16
17
18A
100
18B

FIG. 2

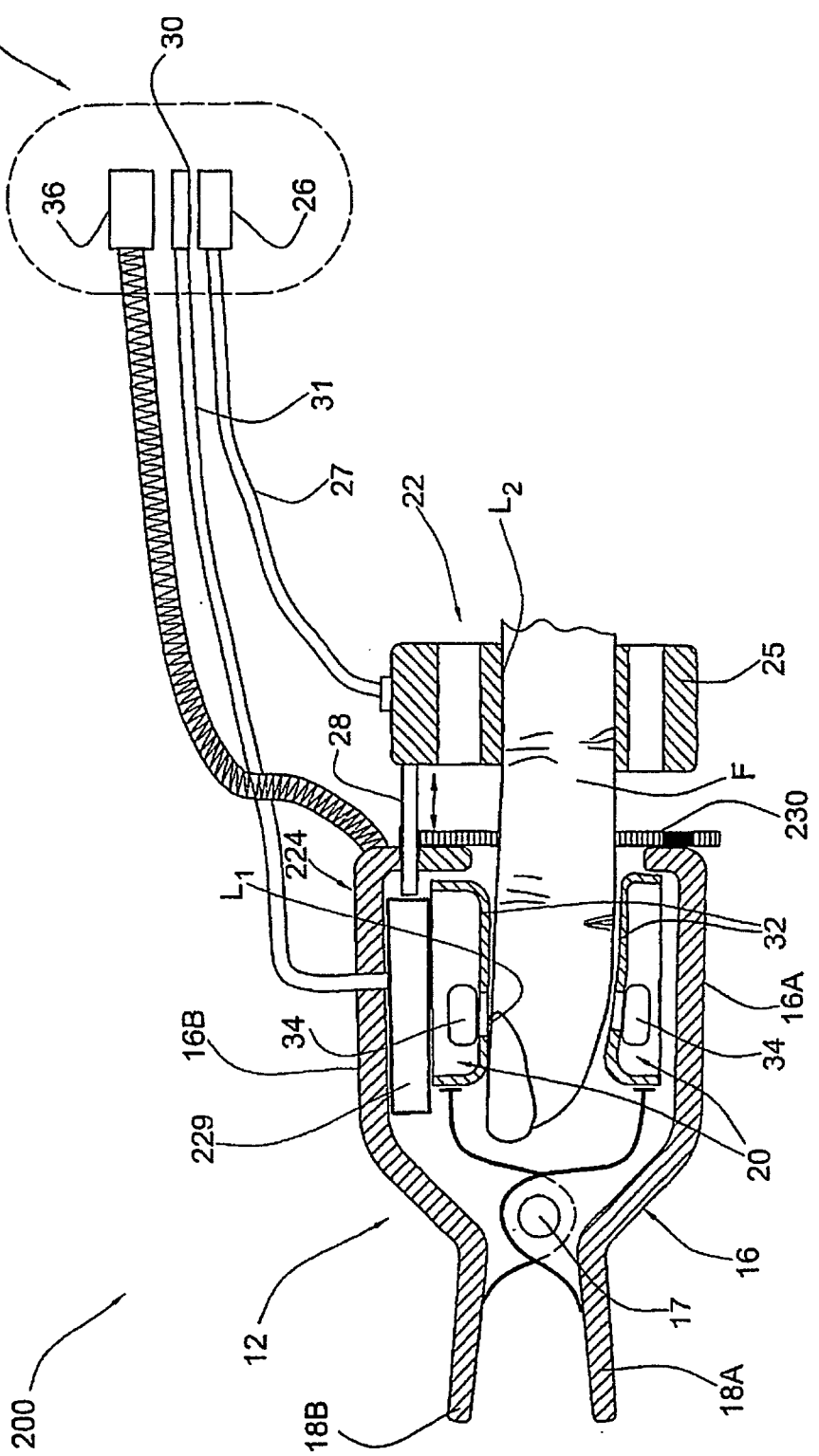
14
30
36
26
31
27
22
L_2
25
28
F
230
224
L_1
32
16A
16B
34
34
229
20
16
17
12
18A
18B
200

FIG. 3

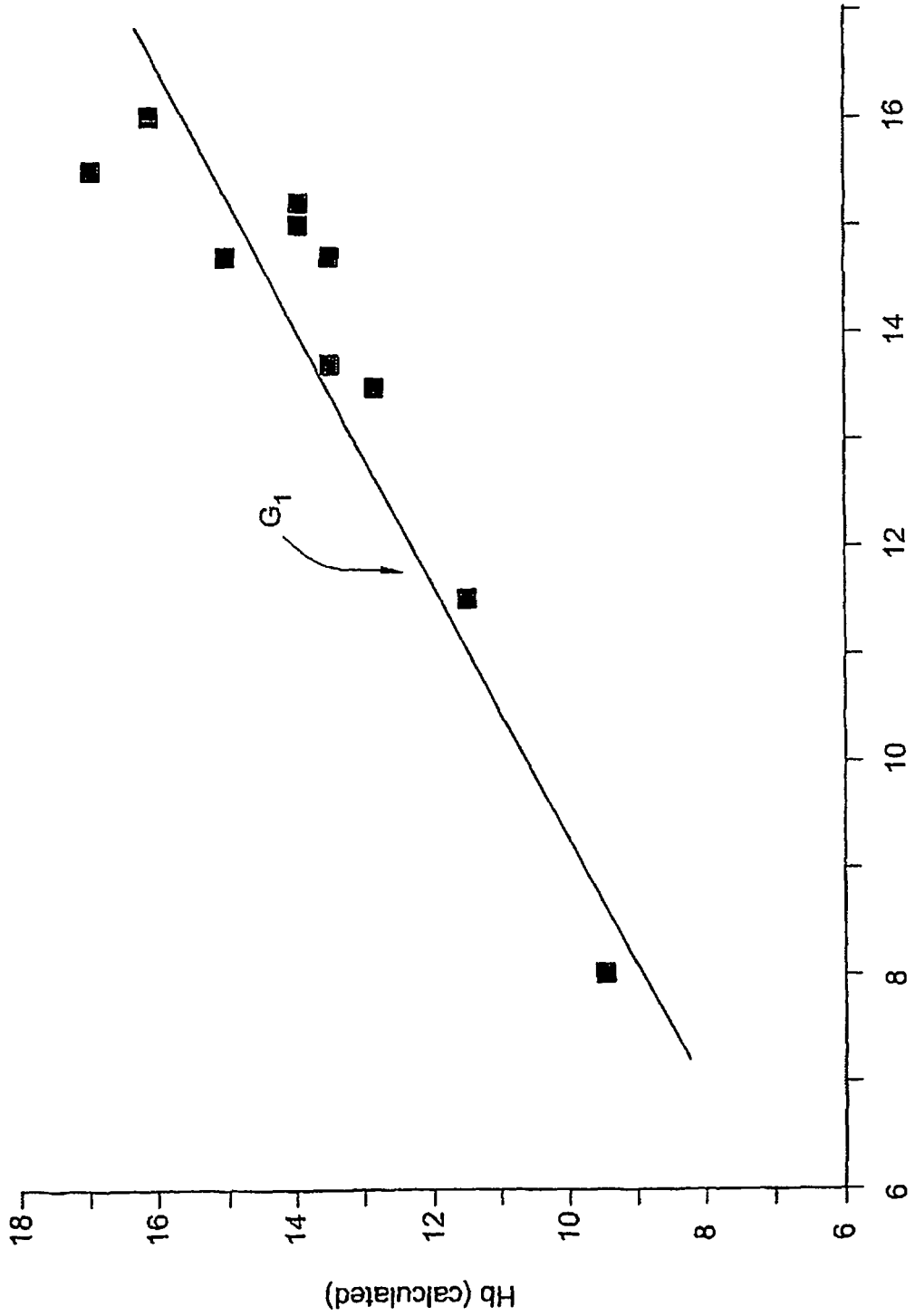
Hb (calculated)
18
16
14
12
10
8
6
G_1
6
8
10
12
14
16
Hb (g/dl) by Hemocue - capillary blood

FIG. 4A

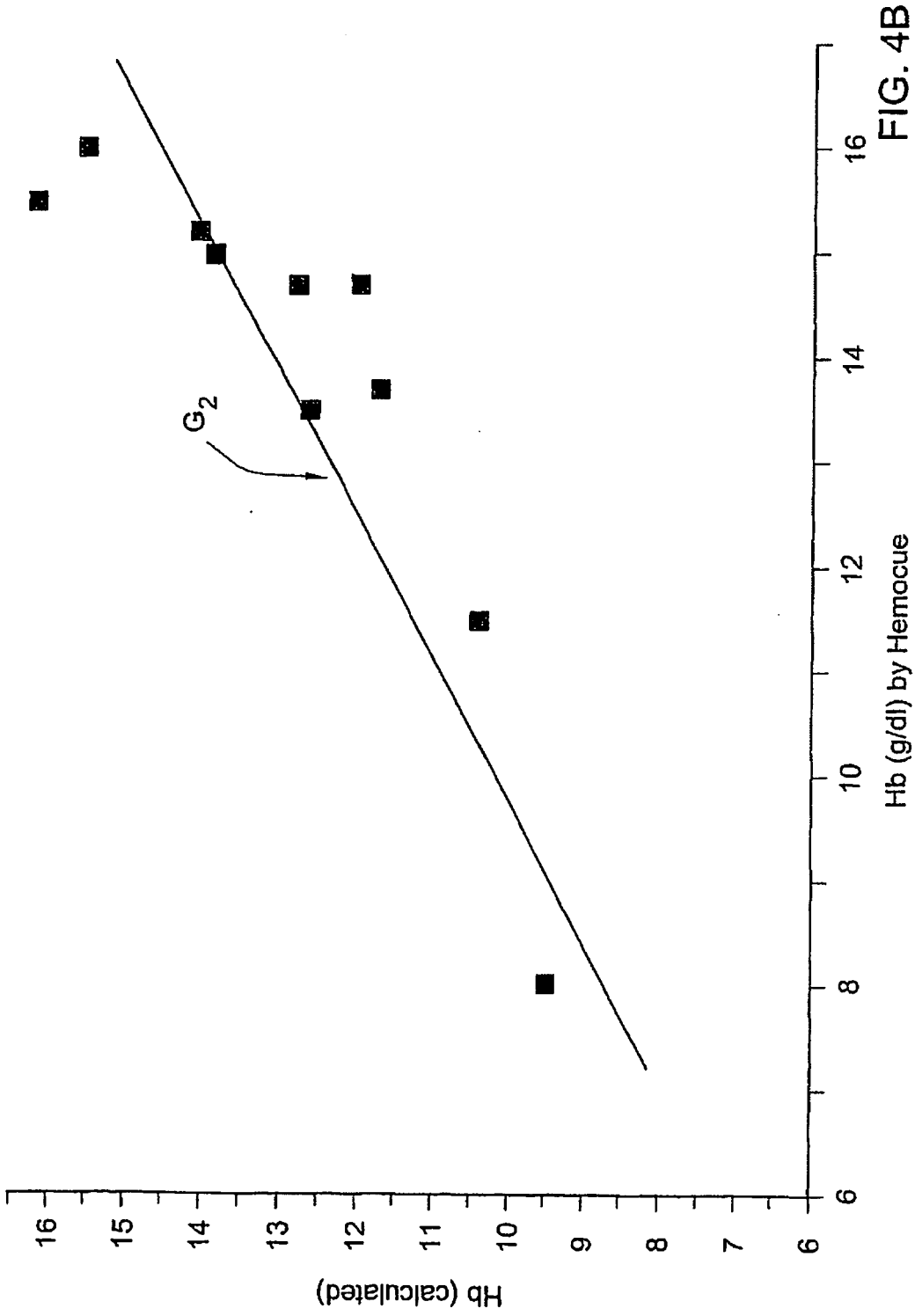
Hb (calculated)
16
15
14
13
12
11
10
9
8
7
6
Hb (g/dl) by Hemocue
6
8
10
12
14
16
G_2

FIG. 4B

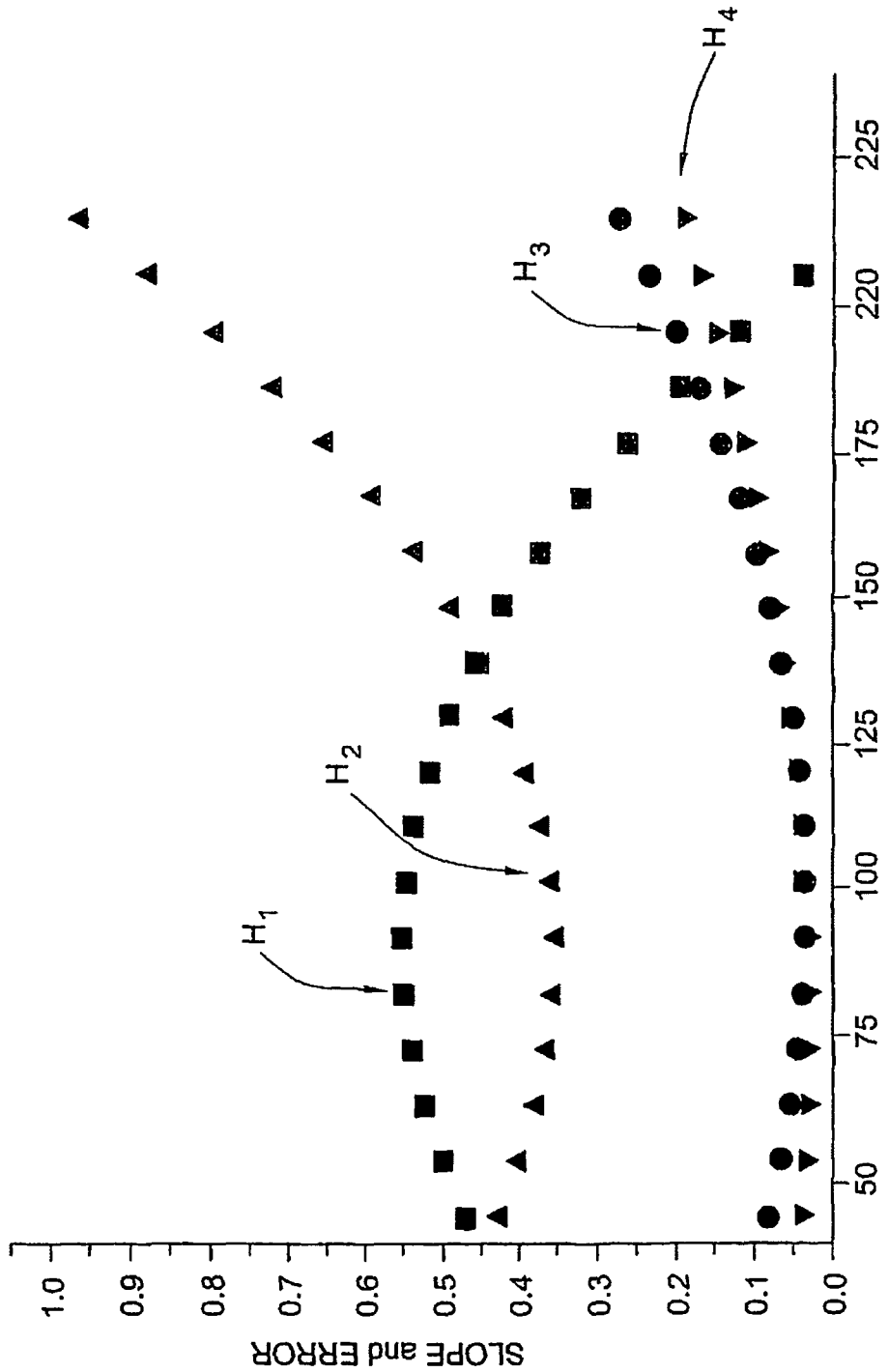
SLOPE and ERROR
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
50
75
100
125
150
175
220
225
PRESSURE mm Hg
H1
H2
H3
H4

FIG. 4C

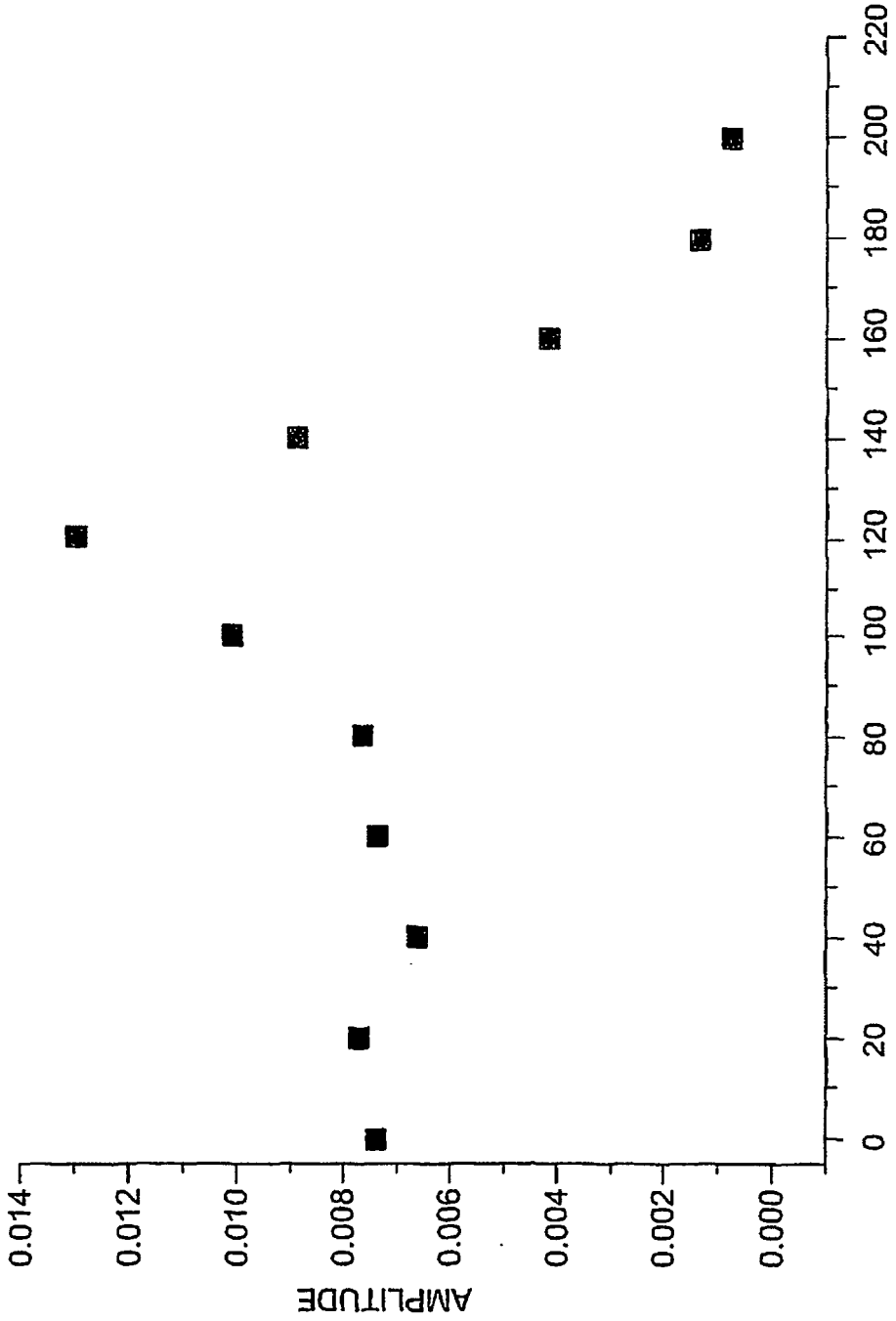
AMPLITUDE
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
0
20
40
60
80
100
120
140
160
180
200
220
PRESSURE mm Hg

FIG. 4D

REFERENCES CITED IN THE DESCRIPTION

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- US 5638816 A **[0004]**
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- US 5782757 A **[0005]**
- WO 9965384 A **[0007]**
- US 407390 A **[0007]**
- US 5111817 A **[0008]**

专利名称(译)	用于血液相关参数的非侵入式测量的方法		
公开(公告)号	EP1618839B1	公开(公告)日	2013-01-23
申请号	EP2005110198	申请日	2001-03-15
申请(专利权)人(译)	ORSENSE LTD.		
当前申请(专利权)人(译)	ORSENSE LTD.		
[标]发明人	FINE ILYA FINAROV ALEXANDER		
发明人	FINE, ILYA FINAROV, ALEXANDER		
IPC分类号	A61B5/00 A61B5/022 A61B5/0225 G01N21/27 A61B5/145 A61B5/1455 G01N21/35		
CPC分类号	A61B5/02255 A61B5/0053 A61B5/02241 A61B5/14532 A61B5/14552 A61B5/1491 A61B5/6824 A61B5/6825 A61B5/6843		
优先权	135077 2000-03-15 IL		
其他公开文献	EP1618839A1		
外部链接	Espacenet		

摘要(译)

一种探针装置，用于对患者血液的至少一个参数进行非侵入性光学测量。探针装置包括夹子构件形式的手指保持器，其将指尖固定在其夹紧腿之间。探针装置支撑测量单元，用于将光学测量值施加到手指上的测量位置，并且携带加压组件，该加压组件可操作用于将可控制地可变的，基本收缩不足的压力施加到测量位置附近的手指。在测量位置处利用至少两种不同波长的入射光执行若干测量会话以检测介质的光响应并产生指示其的测量数据，并且在测量期间同时改变施加到测量位置附近的压力。介质的光响应对应于入射光的不同波长和测量期间的不同压力值。分析对应于入射光的不同波长和不同压力值的介质的光响应，并确定最佳压力值，以利用介质的相应光响应从而得到至少一个血液参数。

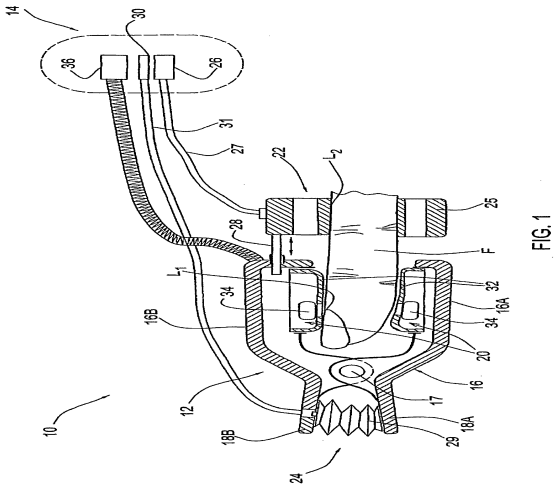

FIG. 1