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(54) **METHOD AND DEVICE FOR MEASUREMENTS IN BLOOD**

VERFAHREN UND VORRICHTUNG FÜR MESSUNGEN IM BLUT

PROCEDE ET DISPOSITIF POUR EFFECTUER DES MESURES SANGUINES

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US-B1- 6 388 752

EP 1 579 196 B1

Description

Background of the invention

[0001] Hematocrit is the concentration of red blood cells (RBC) in blood. The measurement of hematocrit values is of great importance in the assessment of the condition of a patient. The established method of measuring hematocrit is by drawing blood from the subject (patient). Various methods to optically measure hematocrit by optical or ultrasonic means have been attempted, e.g., during a dialysis treatment of a patient. In these situations, not only the level of hematocrit is of high importance but also the relative variation of this parameter. In order to provide an optimized but still safe dialysis treatment the change of the hematocrit or relative blood volume has to be monitored during the treatment. The attempts to monitor this have so far not resulted in any product that can measure the hematocrit without a special cuvette integrated in the transport tubing. The methods used so far have therefore increased the cost of every dialysis treatments since the transport tubing must be equipped with this single-use cuvette. The invention presented here does not require any special cuvette, instead it provides the possibility to measure the hematocrit, or monitor the change of relative blood volume directly on any standard dialysis transport tubing on the market without increasing the cost of each treatment.

Technical field

[0002] The invention relates to measuring various blood constituents with optical means. Blood is irradiated with - preferably - near infrared or infrared light. Light scattering and attenuation of the light is measured and novel compensations for optical variations in the receptacle walls, flow etc. is used to calculate blood constituents such as hematocrit. The invention makes it possible to add the feature of hematocrit measurement without major alterations into any dialysis system. The addition of this feature makes blood volume measurements at hand.

Prior art

[0003] Hematocrit has been measured with various methods since the early hood of medical diagnosis. Continuous measurement is particularly useful during dialysis treatment. During the process of dialysis, liquids are extracted from the blood stream. As a result, hematocrit increases during the process. For the assurance of good quality in the dialysis treatment, the hematocrit value should be monitored, as this provides the care provider with essential information regarding the rate of extraction of fluids from the patient's bloodstream.

[0004] Various techniques have been presented in the field of optical measurements of hematocrit in blood. Several make use of the scattering effect RBC has on light passing trough blood in a vessel, cuvette or the like. Oppenheimer presents in patent US 5,601,080 a method to measure the degree of scatter to derive blood constituents.

[0005] Other patents are US 4,745,279 to Karkar, describing scattering effect of blood in a cuvette. US 6,493,567 to Krivitski et al. describes a measuring instrument using one light emitting diode and one sensor. US 6,064,474 to Wylie et al is another description of a hematocrit measuring method using the scattering effect RBC has on light. However the known methods and devices do not provide a satisfactory precision.

[0006] From US 6 388 752 an optical measurement system for determining transmitted radiation and scattered radiation in a liquid sample contained in a capillary tube and subject to measurement radiation is known. A first detector pick up transmitted radiation and is positioned close to or on the axis of the measurement radiation. A second detector is positioned a distance from the first detector for picking up scattered radiation along the capillary axis. The two detectors lie on different sides of a plane which contains the capillary axis and is normal to the axis of the measurement radiation.

The invention

[0007] In order to overcome the drawbacks o the prior art the invention provide a sensor device comprising light emitters arranged as an array encircling an elongated vessel or tubing at longitudinally one location around said vessels' or tubings' circumference. An array of light detectors also encircle the tubing or vessel at a longitudinally different location of vessel or tubing. The light beam emitters and sensors are so directed that the sense sectors of the sensors do not intersect the beam of the light sources in the vessel or tubing.

[0008] The invention also provides a method for the measuring blood constituents, for example the density of blood cells in blood with a sensor device as described above wherein measurement samples are taken with groups comprising one light emitter and one or two detectors in one or two arrays of light detectors.

[0009] The new probe and method makes hematokrit values available with unsurpassed precision in the art even when measuring through transparent tubing that vary in thickness and shape.

[0010] One can also consider using several pairs of sensors offset along the tubing and upstream as well as downstream in order to increase precision. Also a third sensor may be added to each pair, this third sensor being placed close to the light source.

[0011] With increasing offset the sensitivity to relative changes is increased, whereas a smaller offset will provide a more accurate absolute measurement of the hematocrit value. It is thus possible to use one set of sensors to establish an absolute value and then use a set of more offset placed sensors for the monitoring and controlling of the level during dialysis.

[0012] Further preferable developments are apparent from the claims and the following description of a preferred embodiment of the invention.

Brief description of the drawings

[0013]

Fig. **1** is a cross section of an optical probe arrangement **1,** accommodating light emitting diodes 5 in holes **4** in a framework comprising two halves **2** and **3** suited to fit a receptacle **8** such as tubing for blood **9.**

Fig. **2** is a cross section of an optical probe arrangement **1,** accommodating light detectors **6** in holes **4** in a framework comprising two halves **2** and **3** suited to fit a receptacle **8** such as tubing for blood **9**.

Fig. **3** depicts the arrangement of the array of light detectors **5** and light emitting diodes **6** on the optical probe arrangement **1.** This is a suggestion where the arrays according to Fig. **1** and Fig. **2** are located with indication **"A - A"** for the light emitting diodes, and **"B - B"** for the light detectors.

Fig. **4** depicts the arrangement of a second array of light detectors **7.**

Fig. **5** depicts the optical probe arrangement **1** with the further embodiment of light emitting diodes **9,** and photo detectors **8**.

Fig. **6** depicts the resulting hematocrit values with reference to measurements performed at an accredited clinical laboratory.

Description

[0014] We have achieved very good results by using the following arrangement of light - emitting diodes (LED's) and photo detectors, when assessing hematocrit values. These values correlate very well with laboratory reference values.

[0015] Four LED's are arranged in a preferably - but not limited to - perpendicular fashion to each other around a receptacle, such as tubing, for the blood as apparent in Fig. **1.** The light detectors are arranged in a fashion where they similarly are preferably perpendicular to each other according to Fig **2,** but at a distance longitudinally away from the encirclement by the LED's, as exhibited in Fig. **3.** In a further embodiment, a second encirclement of light detectors is fitted. The arrangement is apparent in Fig. **4.**

[0016] The LED and photo detector arrangement should for best understanding be viewed as groups of LED's and photo detectors:-For instance, LED **5 a,** and photo detector **6 b** is one group. Another group can be LED **5 b,** and photo detector **6 a** and **6 c.** Note that no-LED's and photo detectors are aligned to achieve direct transmitted light. The invention does not make use of directly transmitted light, as often is the case in prior art.

[0017] A sample of light detected from a group of one or several photo detectors can be taken at any one short instance in time. Another sample can be taken from the same or another group as a second sample. Preferably, a first sample is taken from a first group comprising LED **5 a,** and light detectors **6 b** and **6 d,** a second sample is taken from a second group comprising LED **5 b,** and light detectors **6 a** and **6 c,** a third sample is taken from a third group comprising LED **5 c,** and light detectors **6 b and 6 d,** and finally a forth sample is taken from a fourth group comprising LED **5 d,** and light detectors **6 a** and **6 c.** A first result is derived from theses four sequentially acquired samples being signal processed. The process can include variations of amplification factors for the signals from the detectors, and also correlation factors between these signals, to further enhance the detection of the blood constituent to be measured. The results make a first result for blood constituents, such as hematocrit. In this process, the error occurring from variations in the cross section of the flow pattern in the vessel is reduced. Furthermore averaging may reduce the effect the vessel wall has on the measurement. This is highly beneficial if the vessel is the extracorporal circuit of a dialysis system. One of the major advancements in the disclosed invention resides in the new possibility to measure hematocrit trough the walls of dialysis extracorporal circuit, namely the so-called transport tubing of the circuit. It is highly advantageous that no special cuvettes or dedicated arrangements to the disposable bloodlines are necessary. Our process even makes it unnecessary to fit dedicated tubing to the extracorporeal circuit. This feature is considerably cost saving for the health care provider. Fitting the hereby disclosed probe on the transport tubing also has the advantage that the probe is not interfering with the ordinary functions of the dialysis system. Also, it furnishes the highly beneficial possibility to upgrade any already existing dialysis system with measurement of hematocrit, even if it is not prepared for such purpose. Subsequently blood volume changes can be calculated and displayed.

[0018] In one embodiment of the invention, two arrays of detectors are employed. Downstream (or upstream) a blood flow in a vessel such as tubing, a second array of detectors is fitted. This is apparent in Fig **4.** The mathematical signal processing can further enhance, the results by including this "second order" of detectors in the process.

[0019] In another embodiment of the invention, a second arrangement of LED's and photo detectors, including a second array of detectors is fitted. This is exhibited in Fig **5.** In this embodiment, the LED's emits a different wavelength. This allows limited spectral analysis for further calculation of blood constituents, such as saturation of hemoglobin as known in the art. The results derived from this second array, can beneficially be incorporated in a signaling process with the values derived from the aforementioned first array. Such process makes it possible not only to output all parameters from blood constituents, but also let the saturation value influence the

input of signals from the first array to the signaling process. This is beneficial, as blood saturation may influence the first results of blood constituents from the first process from the first array.

[0020] In the drawings and the above description a transparent blood transporting tubing is shown clamped between two essentially V-shaped profiles in the walls of which the led and sensors are arranged. In an alternative embodiment V-shaped groves in blocks may be used to clamp and shape the tubing so that its walls become essentially flat at LEDs and sensors.

[0021] In a further embodiment the sensors may be arranged in small holes with even smaller openings serving as collimators towards the tubing.

[0022] It is not today clear why the invented measuring method and device are so superior in relation to the prior art, one theory could be the offset between sensors and light source. Only light that has been dispersed from the volume of the blood in the path of the light and into the sense sector of the sensor and from this into the sensor will be registered. In other word only light that has been dispersed at least twice will reach the sensor. By arranging source and sensor perpendicularly blood cells in a major part of the tube cross section will have the opportunity to contribute so that the signals from the sensors become a function of the hematocrite value.

Claims

1. Sensor device for the measuring blood constituents, for instance the density of blood cells in blood, in which light has been dispersed at least twice comprising light emitters arranged as an array encircling an elongated vessel or tubing at longitudinally one location around said vessels' or tubings' circumference, an array of light detectors also encircle the tubing or vessel at a longitudinally different location of vessel or tubing, said light beam emitters and sensors being so directed that the sense sectors of the sensors do not intersect the beam of the light sources in the vessel or tubing.

2. Sensor device according to claim 1, wherein a second array of light detectors are longitudinally located at a third location encircling vessel or tubing.

3. A sensor device according to claim 2, wherein a third array of light detectors are longitudinally located at a fourth location encircling the vessel or tubing and a second array of light emitting diodes are longitudinally located at a fifth location encircling said vessel or tubing.

4. Sensor device according to any of the preceding claims, **characterized in that** it comprise a holder with V-shaped recesses for the vessel or tubing so that the tubing is given a square cross section and that light sources and sensors are arranged at the flattened surfaces of the tubing.

5. Method for the measuring of blood constituents, for instance the density of blood cells in blood, with a sensor device as described in any of the preceding claims where light emitters are arranged as an array encircling an elongated vessel or tubing at longitudinally a first location around the circumference of said vessel or tubing, and light detectors are arranged to encircle the vessel or tubing at a different circumferential location, the light emitters and detectors being so directed that the sense sectors of the light detectors do not intersect the beam of the light source in the volume, wherein measurement samples are taken with groups comprising one light emitter and one or two detectors in one or two arrays of light detectors.

6. Method according to claim 5, **characterised in** a sequential taking of samples from groups of light emitters and detectors around the tubing.

7. Method according to claim 5 or 6, **characterized in that** each group of light emitters and detectors comprising a light emitter from one and the same array of light emitters and light detectors in one and the same array of light detectors.

8. Method according to any of the claims 5-7, **characterized in that** the sensitivity to relative changes is controlled with the distance between light detecting array and light emitter relay, the sensitivity to relative changes increasing with said distance.

9. Method according to any of the claims 5 - 8, **characterized in that** a second arrangement of light emitting diods and a second array of detectors is present, these light emitting diodes emitting a different wavelength for further allowing limited spectral analyzis for further calculation of blood constituents, such as saturation of hemoglobin, and/or allow the saturation value to influence the input signals from the first array.

Patentansprüche

1. Sensorvorrichtung zur Messung von Blutbestandteilen, beispielsweise zur Messung der Dichte der Blutzellen im Blut, bei der Licht wenigstens zwei mal gestreut wird, und welche Lichtemitter aufweist, welche als eine Gruppe angeordnet sind, die ein längliches Behältnis oder eine Schlauchleitung in Längsrichtung an einer Stelle um den Umfang des Behältnisses oder der Schlauchleitung umgibt, ferner eine Gruppe von Lichtdetektoren aufweist, welche ebenfalls die Schlauchleitung oder das Behältnis an einer

in Längsrichtung unterschiedlichen Stelle des Behältnisses oder der Schlauchleitung umgeben, wobei die Lichtemitter und -sensoren derart ausgelegt sind, dass die Sensorsektoren der Sensoren nicht den Strahl der Lichtquelle in dem Behältnis oder der Schlauchleitung schneiden.

2. Sensorvorrichtung nach Anspruch 1, bei der eine zweite Gruppe von Lichtdetektoren in Längsrichtung an einer dritten Stelle angeordnet ist, welche das Behältnis oder die Schlauchleitung umgibt.

3. Sensorvorrichtung nach Anspruch 2, bei der eine dritte Gruppe von Lichtdetektoren in Längsrichtung an einer vierten Stelle angeordnet ist, die das Behältnis oder die Schlauchleitung umgibt, und bei der eine zweite Gruppe von lichtemittierenden Dioden in Längsrichtung an einer fünften Stelle angeordnet sind, welche das Behältnis oder die Schlauchleitung umgibt.

4. Sensorvorrichtung nach einem der vorangehenden Ansprüche, **dadurch gekennzeichnet, dass** sie einen Halter mit V-förmigen Ausnehmungen für das Behältnis oder die Schlauchleitung aufweist, so dass der Schlauchleitung ein quadratischer Querschnitt verliehen wird, und dass die Lichtquellen und -sensoren an den abgeflachten Flächen der Schlauchleitung angeordnet sind.

5. Verfahren zum Messen von Blutbestandteilen, beispielsweise zum Messen der Dicht von Blutzellen im Blut mit einer Sensoreinrichtung gemäß einem der vorangehenden Ansprüche, bei der Lichtemitter als eine Gruppe angeordnet sind, welche ein längliches Behältnis oder eine Schlauchleitung an einer in Längsrichtung liegenden ersten Stelle um den Umfang des Behältnisses oder der Schlauchleitung umgibt, und bei der Lichtdetektoren angeordnet sind, welche das Behältnis oder die Schlauchleitung an einer unterschiedlichen Umfangsstelle umgeben, wobei die Lichtemitter und -detektoren derart ausgerichtet sind, dass die Sensorsektoren der Lichtdetektoren nicht den Strahl der Lichtquelle im Volumen schneiden, wobei die Messproben mit Gruppen genommen werden, welche einen Lichtemitter und ein oder zwei Detektoren in ein oder zwei Gruppen von Lichtdetektoren aufweisen.

6. Verfahren nach Anspruch 5, **dadurch gekennzeichnet, dass** eine sequenzielle Probenahme von den Gruppen aus Lichtemittern und Detektoren um die Schlauchleitung erfolgt.

7. Verfahren nach Anspruch 5 oder 6, **dadurch gekennzeichnet, dass** jede Gruppe von Lichtemitter und Detektoren einen Lichtemitter aus ein und derselben Gruppe von Lichtemittern und Lichtdetektoren aus ein und derselben Gruppe von Lichtdetektoren aufweisen.

8. Verfahren nach einem der Ansprüche 5 bis 7, **dadurch gekennzeichnet, dass** die Empfindlichkeit bezüglich relativen Änderungen mit dem Abstand zwischen der Lichtdetektorgruppe und der Lichtemittergruppe gesteuert wird, wobei die Empfindlichkeit bezüglich den relativen Änderungen mit dem Abstand größer wird.

9. Verfahren nach einem der Ansprüche 5 bis 8, **dadurch gekennzeichnet, dass** eine zweite Anordnung von lichtemittierenden Dioden und eine zweite Gruppe von Detektoren vorgesehen sind, diese lichtemittierenden Dioden Licht mit einer unterschiedlichen Wellenlänge abgeben, um eine begrenzte Spektralanalyse für die weitere Ermittlung der Blutbestandteile, wie die Sättigung von Haemoglobin, zu ermöglichen, und/oder den Sättigungswert zu erfassen, welcher die Eingangssignale von der ersten Gruppe beeinflusst.

Revendications

1. Dispositif de capteurs pour mesurer des composants sanguins, par exemple la densité des cellules sanguines dans le sang, dans lequel de la lumière a été dispersée au moins deux fois, comprenant des émetteurs de lumière disposés en un arrangement encerclant un récipient allongé ou tube à un endroit longitudinal autour de la circonférence dudit récipient ou tube, un arrangement de détecteurs de lumière encercle également le tube ou récipient à un endroit longitudinal différent du récipient ou tube, lesdits émetteurs et capteurs de faisceaux lumineux étant dirigés de sorte que les secteurs sensibles des capteurs ne croisent pas le faisceau des sources lumineuses dans le récipient ou tube.

2. Dispositif de capteurs selon la revendication 1, dans lequel un second arrangement de détecteurs de lumière est situé de façon longitudinale à un troisième endroit encerclant le récipient ou tube.

3. Dispositif de capteurs selon la revendication 2, dans lequel un troisième arrangement de détecteurs de lumière est situé de façon longitudinale à un quatrième endroit encerclant le récipient ou tube ou un second arrangement de diodes électroluminescentes est situé de façon longitudinale à un cinquième endroit encerclant ledit récipient ou tube.

4. Dispositif de capteurs selon l'une quelconque des revendications précédentes, **caractérisé en ce qu'**il comprend un support avec des encoches en forme de V pour le récipient ou tube de sorte que le tube

reçoive une section transversale carrée et que les sources lumineuses et capteurs soient disposés sur les surfaces aplaties du tube.

5. Procédé pour mesurer des composants sanguins, par exemple la densité des cellules sanguines dans le sang, avec un dispositif de capteurs tel que décrit dans l'une quelconque des revendications précédentes où les émetteurs de lumière sont disposés en un arrangement encerclant un récipient allongé ou tube à un premier endroit de façon longitudinale autour de la circonférence dudit récipient ou tube, et les détecteurs de lumière sont disposés pour encercler le récipient ou tube à un endroit circonférentiel différent, les émetteurs et détecteurs de lumière étant dirigés de sorte que les secteurs sensibles des détecteurs de lumière ne coupent pas le faisceau de la source lumineuse dans le volume, dans lequel les échantillons de mesure sont pris dans les groupes comprenant un émetteur de lumière et un ou deux détecteurs dans un ou deux arrangements de détecteurs de lumière.

6. Procédé selon la revendication 5, **caractérisé en** un prélèvement séquentiel d'échantillons de groupes d'émetteurs et détecteurs de lumière autour du tube.

7. Procédé selon la revendication 5 ou 6, **caractérisé en ce que** chaque groupe d'émetteurs et détecteurs de lumière comprend un émetteur de lumière d'un seul et même arrangement d'émetteurs de lumière et des détecteurs de lumière dans un seul et même arrangement de détecteurs de lumière.

8. Procédé selon l'une quelconque des revendications 5 à 7, **caractérisé en ce que** la sensibilité à des changements relatifs est contrôlée avec la distance entre l'arrangement de détecteurs de lumière et le relais d'émetteurs de lumière, la sensibilité aux changements relatifs augmentant avec ladite distance.

9. Procédé selon l'une quelconque des revendications 5 à 8, **caractérisé en ce qu'**il comprend un second agencement de diodes électroluminescentes et un second arrangement de détecteurs, ces diodes électroluminescentes émettant une longueur d'ondes différente pour permettre ensuite une analyse spectrale limitée pour un calcul ultérieur des composants sanguins, comme la saturation de l'hémoglobine, et/ou permettre à la valeur de saturation d'influencer les signaux entrants du premier arrangement.

Fig. 1

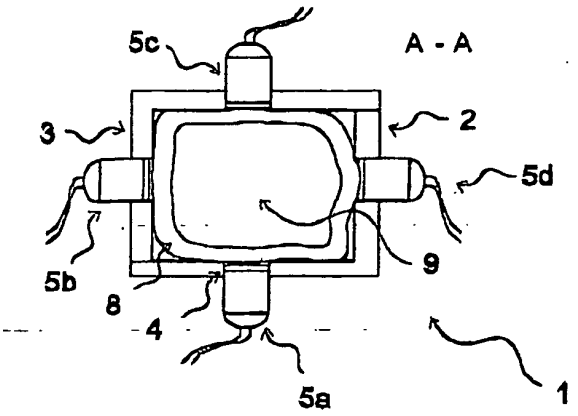


Fig. 2

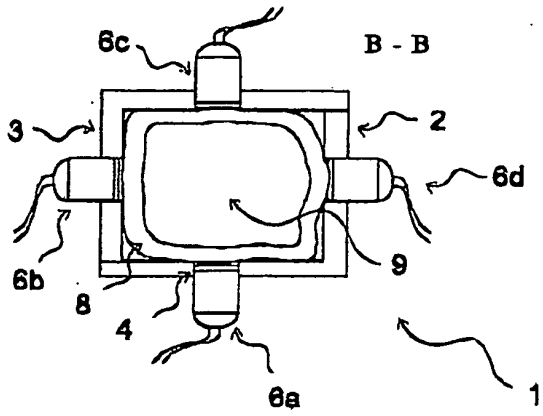


Fig. 3

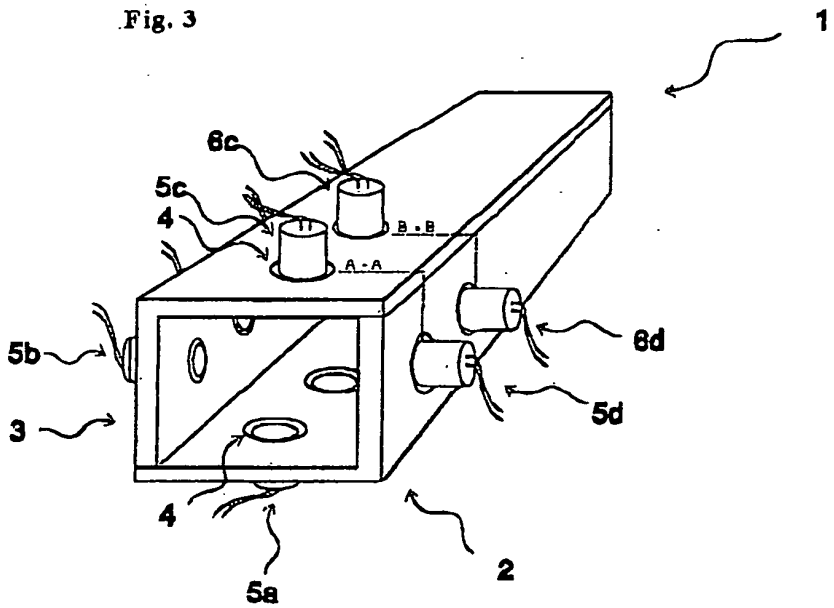


Fig. 4

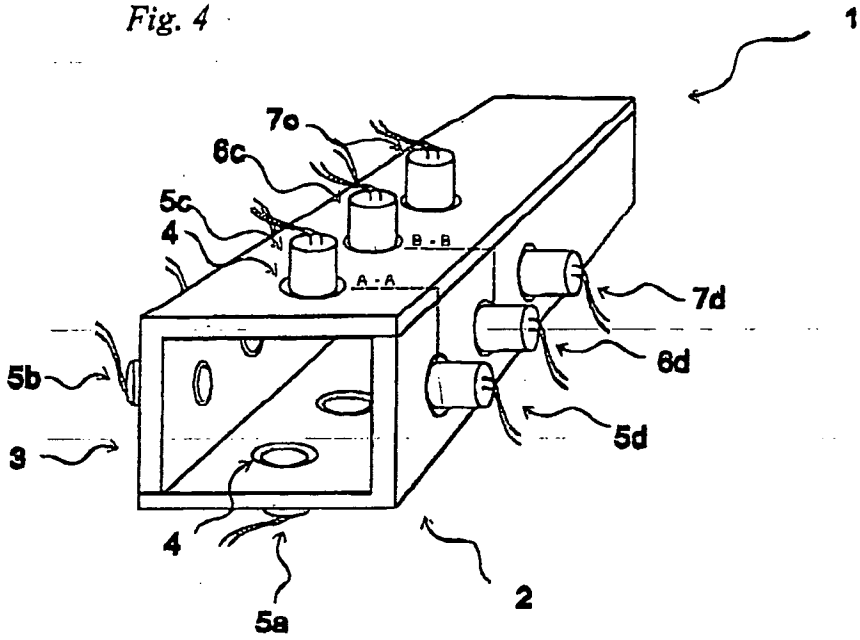
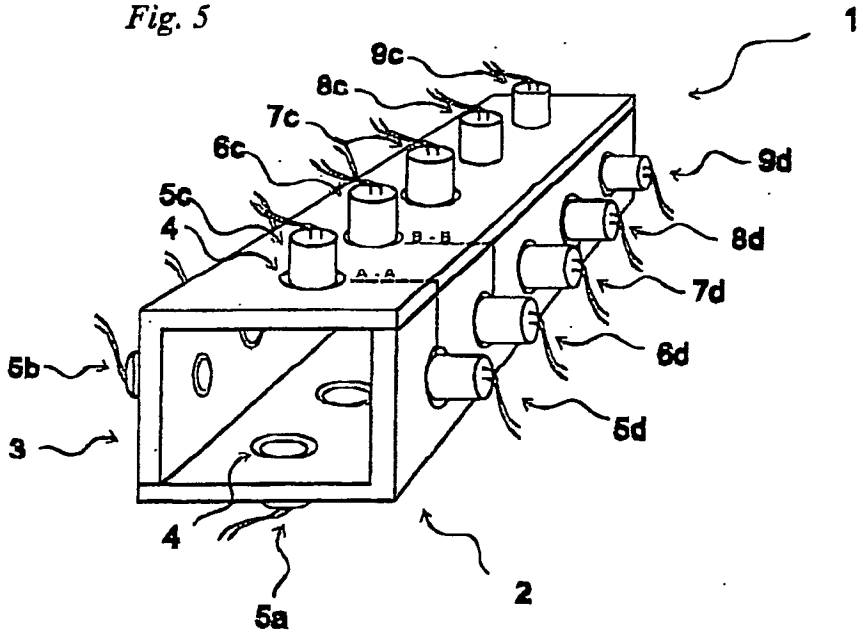

1
7c
6c
5c
4
B - B
A - A
7d
6d
5d
5b
3
4
5a
2

Fig. 5


1
9c
8c
7c
6c
5c
4
B - B
A - A
9d
8d
7d
6d
5d
5b
3
4
5a
2

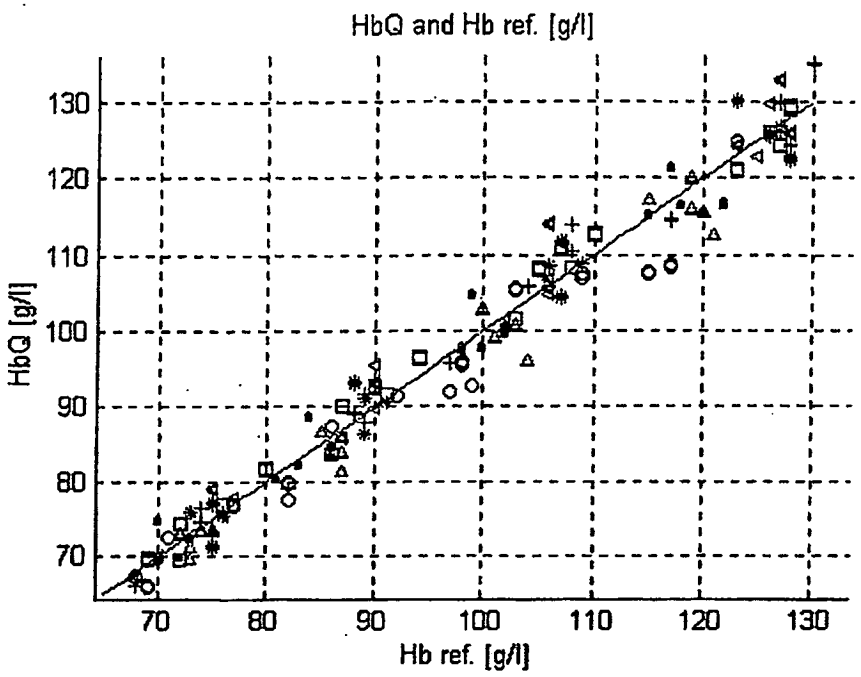

HbQ and Hb ref. [g/l]
HbQ [g/l]
130
120
110
100
90
80
70
70
80
90
100
110
120
130
Hb ref. [g/l]

Fig. 6

专利名称(译)	血液中测量的方法和装置		
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当前申请(专利权)人(译)	OPTOQ AB		
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其他公开文献	EP1579196A1		
外部链接	Espacenet		

摘要(译)

我们提出了一种围绕容器中的血液的光学探针装置。它包括LED和光检测器，其布置成克服当容器是半透明医用管等时的变化。而且，信号处理算法用于平均来自多个光检测器的信号，以在测量血细胞比容时进一步增强结果。本发明使得可以将血细胞比容测量的特征添加到透析系统中而无需对透析机或输送管进行重大改变。