

(19) **DANMARK**



Patent- og
Varemærkestyrelsen

(12)

Oversættelse af europæisk patentskrift

(10) **DK/EP 2999402 T3**

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- (51) Int.Cl.: **A 61 B 5/00 (2006.01)** **A 61 B 5/03 (2006.01)** **A 61 B 5/1455 (2006.01)**
G 01 N 21/31 (2006.01)
- (45) Oversættelsen bekendtgjort den: **2023-03-06**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2023-01-04**
- (86) Europæisk ansøgning nr.: **14725192.0**
- (86) Europæisk indleveringsdag: **2014-05-21**
- (87) Den europæiske ansøgnings publiceringsdag: **2016-03-30**
- (86) International ansøgning nr.: **EP2014060414**
- (87) Internationalt publikationsnr.: **WO2014187849**
- (30) Prioritet: **2013-05-22 CH 9972013**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
- (73) Patenthaver: **Luciole Medical AG, Baslerstrasse 30, 8048 Zürich, Schweiz**
- (72) Opfinder: **MUSER, Markus Hugo, Luftstrasse 40, CH-8820 Wädenswil, Schweiz**
FRÖHLICH, Jürg Hans, Sonneggstrasse 60, CH-8006 Zürich, Schweiz
BAUMANN, Dirk, Paulstrasse 6, CH-8008 Zürich, Schweiz
- (74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**
- (54) Benævnelse: **MÅLESYSTEM OG -FREM GANGSMÅDE TIL MÅLING AF PARAMETRE I ET LEGEMSVÆV**
- (56) Fremdragne publikationer:
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Description

This present invention relates to a measurement system and a method for measuring parameters of a bodily tissue, such as the determination of blood volume and blood flow in the brain and the muscles or the measurement of the intracranial pressure.

5 In particular, the invention relates to a non-invasive measurement of cerebral and muscular parameters.

The content of the cranium is composed of the non-compressible components brain, cerebral blood volume (CBV) and liquor cerebrospinalis (cerebrospinal fluid). After exhaustion of the intracranial compensation mechanisms, such as e.g. reduction of the cerebrospinal fluid production, decrease of the CBV, processes requiring space lead to an increase in intracranial pressure. These circumstances follow e.g. from the Monroe-Kellie doctrine. With increase of the intracranial pressure (ICP) over 50 mmHg, the cerebral perfusion pressure (CPP) can no longer be maintained, and additional damage to brain areas results through a global brain ischemia, such as e.g. is known from "Analysis of
10 Intracranial Pressure: Past, Present and Future", A. Di Ieva et al; The Neuroscientist; 6 Feb. 2013. The CPP is thereby identified as the difference between the mean arterial pressure and the ICP. Understood by intracranial pressure, ICP, is by definition the supratentorial cerebrospinal fluid pressure, i.e. the pressure in the lateral ventricles and in the subarachnoid space over the cerebral convexity. According to the conventional view, ICP rises are due to a swelling of the brain, e.g. in the case of a defective blood-cerebral
15 barrier, or a cytotoxic cerebral oedema, such as an intracellular water accumulation, an additional space requirement, e.g. through tumour, haemorrhage, etc., or a cerebrospinal fluid, circulatory or respectively absorption disorder.

Known from the state of the art are various methods of measuring the intracranial pressure in the skull and of measuring parameters derived indirectly therefrom. For this purpose, invasive methods are conventionally used in which a measuring probe is introduced through the skull into the brain tissue. Invasive methods have however various drawbacks, such as undesired bleeding, complicated execution of the method, locally limited measuring regions, etc.

30 Furthermore, non-invasive measuring methods are used which are based e.g. on ultrasound and Doppler effect and use a correlation between an increased intracranial pressure and the pulsatility. However, there is a great variation in the pulsatility index, even in healthy people. In another method, principles of fluid mechanics and

neurophysiology are combined with results from magnetic resonance images, as described for example in "Non-invasive intracranial compliance and pressure based on dynamic magnetic resonance imaging of blood flow and cerebrospinal flow," Patricia B. Raksin et al., Neurosurg. Focus, Volume 14. From EP 0933061 B1 a measuring configuration is known in which a proportionality between the intracranial pressure and a pressure existing in the external auditory canal is used for determining the intracranial pressure. Furthermore, shown in US 2012/0136240 A1 is a system in which a controlled constriction of the jugular vein leads to a change in the blood outflow and the pressure of the blood outflow is measured, wherein the intracranial pressure is determined from the relationship between constriction and blood flow. Used thereby are e.g. near-infrared (NIR) sensors for determining the blood outflow. Furthermore, absorption measuring methods in the near-infrared range are known for monitoring constituents of an organ, e.g. of the brain, in particular for monitoring oxygenated and deoxygenated blood, or for determining a concentration of oxygenated and deoxygenated blood e.g. in the brain, such as shown in US 6195574 or US 5706821. JP 2002-010986 A describes the simultaneous measurement of intracranial pressure and a plethysmogram. The elastic properties of the blood vessels in the brain can be deduced from the two measurement curves. US 2008/077023 A1 describes an optical measurement method from which an internal cranial pressure is deduced with the aid of additional measurements or the determination of wavelength variations.

A comparable situation is to be found with injuries and traumas of muscles that are tightly disposed in fascia, such as e.g. a lower leg or lower arm muscle. After a trauma, owing to compartmentally increased pressure inside a fascia, there exists a high risk that the muscle dies since blood circulation through the muscle is diminished by the pressure increase. The patients suffer a loss of muscles or even a life-threatening rhabdomyolysis syndrome. It is thus desirable to determine and to be able to monitor the pressure parameters in the muscles.

With the known methods, complicated algorithms and complex measurement configurations are required for determining pressure parameters in the bodily tissue. Moreover, they are focused on specific parameters and are limited to few measurement sites, such as e.g. the ear. For measuring various parameters of a bodily tissue therefore different measuring systems must be used simultaneously or in succession. In addition, also the known non-invasive methods can be unpleasant and risky for the patient.

From US 2013/072807 A1, a monitoring system for a person is known, which is also arranged, among other things, to draw conclusions about the person's blood pressure from concentration values of blood parameters that can be determined non-invasively.

5 From US 2004/054290 A, an optical coupling device for non-invasively monitoring a region of living tissue is known, wherein radiation with a time-varying pattern is emitted into the tissue by a source probe and detected by a detection probe.

It is thus the object of the present invention to provide a measurement system and a method with which a simple and quick determination of parameters of a bodily tissue is possible, which get by with few system components, which can preferably measure a multiplicity of different parameters at the same time, and which make possible an application that is comfortable for a patient.

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This object is achieved by the invention through a measurement system according to claim 1 and a method according to claim 12. Advantageous embodiments and further embodiment examples are described in the dependent claims.

15 The present invention proposes a measurement system for determining at least one pressure parameter in a body tissue in a brain or a muscle, which comprises at least one measuring device to be applied to the body, an optical unit for the emitting and detecting at least four light waves with different wavelengths, wherein at least one of the wavelengths of the light waves lies in the range of the absorption of a constituent of the bodily tissue, at least one light guide between optical unit and the measuring device for transmission of light waves with different wavelengths, and an evaluation unit for evaluating measuring wave signals which are received and transmitted by the measuring device. Light waves emitted from the optical unit are radiated, by means of the measuring device, into an optical measurement volume in the bodily tissue. Measurement waves

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received by the measuring device from the measurement volume are transmitted to the evaluation unit. Thus, the body parameter can be determined by means of determination of the light absorption of a wavelength in the measurement volume of the bodily tissue.

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According to the invention, the evaluation unit is designed to process received measurement wave signals, based on the absorption of the emitted light waves, in order to determine a pulsatility of a concentration parameter measured in the measurement volume, and the evaluation unit comprises a transformation algorithm in order to determine, from the pulsatility of the concentration parameter, a pressure parameter in

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the bodily tissue, by a comparison operation of the change or the course of an amplitude of the pulsatility with a reference pressure-volume curve.

With the measurement system according to the invention, it is thus possible to obtain a multiplicity of different parameters of a bodily tissue by means of a simple absorption measurement as it is essentially known. The measurement results of the
5 absorption measurement for identification of a body parameter are further processed by the evaluation unit, in that characteristic features of the pulsatility are determined. The ascertained pulsatility is assigned a pressure parameter by means of the transformation algorithm in accordance with the respective characteristic features, which pressure
10 parameter indicates the pressure in the bodily tissue. Thus, a pressure parameter of the bodily tissue can be determined without use of additional pressure measuring devices. Moreover, determination of the pressure can take place at the same time with determination of other body parameters.

According to an example of the invention, the measurement system is designed for
15 determination of at least one concentration parameter. The transformation algorithm transforms in this case the pulsatility of a concentration parameter of the bodily tissue, measured in the measurement volume, into the parameter of the pressure in the bodily tissue. Preferably identified by the measurement system in the measurement volume is a concentration of oxygenated haemoglobin, deoxygenated haemoglobin and/or an overall
20 haemoglobin concentration. The pulsatility of this measured concentration is then transformed into the parameter of the pressure in the bodily tissue.

According to the invention, the measurement system is designed to determine a body parameter in a measurement volume in the brain. By means of the transformation algorithm, a parameter of the intracranial pressure can be determined from the pulsatility
25 of the body parameter in the brain measurement volume.

According to the invention, the measurement system is designed for determining a body parameter in a measurement volume in a muscle. By means of the transformation algorithm, a compartmental pressure parameter of the muscle can be determined from the pulsatility of the body parameter in the muscle measurement volume.

30 The invention is based on the surprising finding that various cerebral parameters can be deduced in a simple way from a combination of the teaching according to the Monro Kellie doctrine and the course of the pulsatility. In particular the intracranial pressure, the concentration of different brain constituents and the cerebral fluid volume

can be identified. Furthermore, metabolites and enzymes can also be identified. This finding can moreover be applied also to other organs. In particular, it was also possible to develop a transformation algorithm for determination of a pressure parameter in the muscle. Furthermore, the measurement system can also be used for determining parameters in bones.

The facts and circumstances on which the invention is based will be explained more closely with reference to the example of a measurement in the brain. In a first approach, the cranium can be assumed to be inelastic. Volume changes inside the skull due to the difference in blood flowing in and out are regularly within the range of 1 ml. All substances inside the cranium can be assumed to be incompressible. Furthermore, a volume increase of a constituent of the brain, e.g. a tissue volume increase through a cerebral oedema, can only be compensated by a compensatory reduction of another constituent, e.g. reduction of the cerebral fluid or of the blood volume. After these space reserves have been exhausted, there is an increase in the intracranial pressure. One speaks here of brain compliance. Although the intracranial pressure-volume relationship depends on such compensation mechanisms, it remains close to constant at least for an individual. Under pathological conditions, mass effects, such as a swelling of the brain, haemorrhage, tumour formation, etc., are more relevant, however, and, through the increase in volume, lead to the rise in the intracranial pressure. A pressure-volume curve is mono-exponential and can be determined empirically in a known way.

On the other hand, the described pathological conditions have effects on the course of the pulsatility of the blood flow. With increased intracranial pressure, for example with a swelling of the brain, the heart must increasingly pump blood into the cranium against the intracranial pressure. At the same time, with constriction of the vessels, the speed of the blood in the vessels increases. The pulse wave of the blood flow induces in the cranium a volume change and thus influences the intracranial pressure and the compliance.

It has now been observed that, by means of the pressure-volume curve, the intracranial pressure can be deduced from the course, respectively from the change, of the amplitude of the pulsatility of a blood parameter. In particular the haemoglobin content in a brain segment and hence the intracranial pressure can be identified from the course of the amplitude of the blood pulsatility. Owing to the above-mentioned effects the ICP curve configuration and thus the morphology of the ICP curve changes.

According to an embodiment of the invention, by means of optical measuring methods, the course or respectively the change of e.g. concentration values for the various constituents of a bodily tissue are captured in the form of a measurement wave or respectively an optical measuring signal for tissue water, oxygenated haemoglobin, deoxygenated haemoglobin and preferably also for the overall haemoglobin value. The morphology of values of the pressure parameter, such as e.g. the intracranial pressure, is specified from a morphology of the measurement waves for the various constituents. From the thus obtained morphology of the intracranial pressure values the compliance and the mean intracranial pressure is determined.

The pulsatility of a body parameter is characterized e.g. by the peak within a pulse, as will be explained more precisely in the description of the figures. In general the amplitude decreases with increasing intracranial pressure, as soon as the compensation mechanisms are exhausted.

The pulsatility of the blood flow and thus the course, or respectively change, of its amplitude can be determined in a simple way by means of an optical measurement system according to the invention with a measuring device for non-invasive measurement of parameters of a bodily tissue. The measuring device thereby comprises an emitter-detector system, to be applied to an organ, such as e.g. the scalp or the skin over a muscle, which system is provided for emission and detection of the various light waves. Such a measuring device is described e.g. in the Swiss patent application of the applicant entitled "Messvorrichtung zur Bestimmung zerebraler Parameter" (Measuring device for determining cerebral parameters), No. 02266/12 of 6 Nov. 2012. Such a measuring device with a sensor unit and a sensor pad is provided for removable attachment of the measuring device to a body surface, such as e.g. the surface of the head, for instance the forehead. The information relating to features of this measuring device, as well as its advantages for carrying out measurements on the bodily tissue, in particular on brain tissue, is hereby incorporated in full into the description of the present invention. Referred to in particular is the information relating to optical measurements of parameters.

Furthermore, with the aid of such a measuring device, volumes inside the cranium can be determined and thereby absolute values can be determined for the concentration of water and haemoglobin in the brain tissue. Blood is composed of blood plasma (water, proteins, etc.) and corpuscular components, among them erythrocytes with haemoglobin.

The concentration of the erythrocytes determines the haematocrit and thereby also the mass concentration of water in the blood. The cerebral blood volume is thereby determined by the relationship of mass of the brain to blood volume and by the relationship of haematocrit to the haemoglobin concentration in the brain. The intracranial volumes consist of volumes of white and grey brain matter, the blood volume and the cerebrospinal fluid (cerebral fluid). The same applies for a measurement on the muscle, wherein the volume of the muscle is composed histologically of muscle cells with myofibrils. Chemically these contain about $\frac{3}{4}$ water and $\frac{1}{4}$ solid materials. The solid components are approximately 20% proteins, above all myosin, lipids, glycogen, creatine, etc.

The measurement system can determine a volume measurement value, which is made up of the intracranial volume and extracerebral parts, such as the cerebrospinal fluid volume, bone volume and skin volume.

According to the invention, the measuring device is preferably disposed with each measurement on the same measuring site of a patient, so that with each measurement the same optical volume segment is measured. The extracranial part, or respectively the external part in the case of the muscle, can thereby be seen as constant over time. It has now been shown that the concentration of a measured volume measured with the measurement system is representative for the whole cranium, or respectively muscle. In particular a volume measured with the measurement system in the near-infrared spectroscopy (NIRS) method is approximately representative for the entire cranium or respectively muscle. Thus, with the measurement system an optical volume segment of the bodily tissue can be measured and from this the composition of the tissue portions in the entire brain or muscle can be deduced. The concentration change in the irradiated volume segment is thereby identified. The entire volume can be measured, if necessary, using known measuring methods such as e.g. CT methods. The transformation of the concentration values determined with the measuring device into volume values takes place by means of the analysis device, such as e.g. a computer, which is connected to the measuring device or to which the measurement values are able to be provided. The measurement values can be transmitted as optical signals, like the measurement waves received by the measuring device, or as electrical signals.

With a device and a method according to the present invention, it is also possible in a simple, preferably non-invasive, way to carry out a determination of the tissue water.

In so doing a multiplicity of light waves of differing wavelength are emitted from a light source of the measurement system and are conducted by the measuring device into the optical volume segment, wherein the light waves are preferably on the edge of the so-called bio-optical window. At least one wavelength lies in the range of the water absorption and is suitable and characteristic for the determination of the water concentration. By means of further wavelengths, oxygenated and deoxygenated blood as well as tissue material can be measured.

In general, different effects can be measured at the same time with a measurement system and a method according to the present invention. The spacing between the brain and skull, or respectively its change, can be identified through a transcranial measurement on the basis of an NIRS measurement. With increasing pressure, the reduction of the blood volume supplied can be measured, through the change, or respectively the course, of the amplitude of the pulsatility, as mentioned above. With the use of a multiplicity of different wavelengths, which penetrate essentially simultaneously an optical volume measurement segment of the body organ, such as e.g. the cranium, the concentration of different constituents, e.g. brain constituents, can be specified, for which their characteristic optical spectra are known. It is thereby advantageous if the weighting of the different absorptions is comparable, i.e. the product of absorption coefficient and of the concentration to be measured should be within the same order of magnitude for all constituents of the tissue to be measured. A representative measurement precision is thereby achieved.

According to the invention, the optical measurement system has a measuring device for measuring an optical volume segment of the bodily tissue, which device is supplied by a light source with lights of a multiplicity of different wavelengths. The light source preferably provides light beams with at least four different wavelengths. At least one wavelength lies in the range of the water absorption. The other wavelengths are adapted to the other tissue constituents, e.g. brain constituents.

For example, wavelengths between 750 nm and 1100 nm are used. The haemoglobin concentration and the concentration of white and grey matter can thereby be measured, for example. With a measurement of muscle, the wavelengths are preferably adapted to the absorption spectra of proteins and also of myoglobin. Proteins have, for example, optically measurable reactions at 200-300 nm, depending upon magnitude. Furthermore, the different wavelengths are selected in such a way that the

product of absorption coefficient and concentration lies within the same order of magnitude for all constituents to be measured. The measurement can take place essentially according to an NIRS method.

5 The measurement system further comprises an analysis device, in which e.g. a numerical method is implemented, which determines the concentration of the constituent in the tissue from the optical measurement by means of a linear equation system. Used for the equation system can be e.g. the generally known course of the pressure-volume curve of the cerebral or muscular pressure, which can be determined e.g. through a usual series of measurements. Or an average curve can be used as
10 reference. From the change in the pulsatility along this curve the sought parameter, in particular the pressure, can be deduced. For this purpose, for example, the pulsatility can be determined at two different pressure or respectively volume values and can be extrapolated beyond these measurement values.

15 An increase or decrease of the cerebral fluid concentration can thus be derived from the determination of the concentration of the individual constituents in the brain tissue. In this way an increase or decrease of a cerebral oedema can be determined, for example.

20 It is furthermore advantageous that, with at least one wavelength which reacts to changes in the blood concentration, the measurement system can measure a pulsatility of this parameter. For this purpose the above-mentioned measuring device identifies e.g. the light scattered or reflected in the measurement volume segment. The signal of the detected light beam, i.e. of the received measurement wave, is translated into the corresponding pulsatility of the measured parameter. The pulsatility is preferably determined based on a multiplicity of different wavelengths which react to changes in the
25 blood concentration and a mean value formed from these data. With unchanging conditions, the amplitude of the pulsatility averaged over a multiplicity of pulse waves remains approximately the same. If the amplitude changes, this indicates a change in the pressure.

30 The measurement system according to the present invention can also be used with two or more measuring devices of the above-mentioned type, which each deliver measurement signals to the evaluation unit. The measuring devices can be provided e.g. on opposite regions of the cranium or of a muscle. By means of a multiplicity of measuring

devices different brain areas can be monitored, e.g. with respect to a differing cerebral fluid content or in general with respect to the composition of the tissue.

The measurement system can also comprise a marker device, by means of which a dye, preferably an indocyanine green (ICG) dye, is able to be introduced into the blood flow. The measurement system can then be used in an ICG-dye dilution mode, with which the blood volume in the tissue can be determined. This measurement is coupled with a continuously to-be-measured parameter, such as e.g. the total haemoglobin, whereby changes in the blood volume can be detected.

Alternatively to a non-invasive measuring device of the above-described type, the principle of the present invention can be advantageously implemented using a conventional probe, preferably a minimally invasive probe, e.g. in the form of an intracranial catheter. The identification of the desired parameter can take place according to the present invention by means of the received measurement signals of the probe.

The invention has been presented with reference to a multiplicity of embodiments. The individual technical features of one embodiment can absolutely be used also in combination with another embodiment, with the explained advantages. The description of the technical features according to the invention is thus not limited to the respective embodiment. In particular the features of a measurement on the cranium can be carried over to a measurement on a muscle or bone.

An advantageous embodiment of the invention will be presented in the following with reference to the drawings, which serve merely purposes of explanation and are not to be interpreted in a limiting way. Features of the invention disclosed from the drawings should be viewed as belonging to the disclosure of the invention. In the drawings:

Fig. 1 is a pressure-volume curve of the intracranial pressure and of the intracranial volume,

Fig. 2 is a diagrammatic overview of a correlation of different pulsatility results to parameters of the intracranial pressure, and

Fig. 3 is a schematic representation of a measuring system according to the present invention.

Shown in Figure 1 with reference to a pressure-volume curve is the relationship between the intracranial pressure and the intracranial volume. The pressure is thereby indicated in torr [mmHg] and the volume in units of a pressure change ΔV . It can be seen

therefrom that in a low range of the intracranial pressure up to approximately 10 mmHg an increase in volume does not bring about any substantial increase in pressure. In this range the compensation mechanisms are able to compensate for a volume change without the pressure rising. In a still normal range between 10 mmHg and 20 mmHg the intracranial pressure begins to climb with a volume increase. Starting with a pressure of 20 mmHg, which corresponds to a pathological pressure range, even a very slight increase in volume brings about a big increase in the intracranial pressure. This correlation between intracranial pressure and intracranial volume is used in the measurement system and method according to the present invention for determining cerebral parameters, as previously described.

Along this curve a pulsatility of blood values, such as e.g. the values of oxygenated or deoxygenated blood, show a change, or respectively a characteristic course. Thus, through the determination of the pulsatility and the pressure-volume curve the intracranial pressure can be deduced. Furthermore, the concentrations of the different constituents of the brain can be determined.

Shown in Figure 2, for an examination of the brain, is a diagrammatic overview of a correlation of different pulsatility results to parameters of the intracranial pressure. Shown on a vertical axis is again the intracranial pressure in torr [mmHg]. Shown in column 1 is the morphology of a pulse of an ICP measurement curve at three different values of the intracranial pressure. Shown in column 2 is the pulse course of a concentration of oxygenated haemoglobin (Hb_{oxy}), in column 3 the pulse course of a concentration of deoxygenated haemoglobin (Hb_{deoxy}), and in column 4 the pulse course of an overall haemoglobin concentration (Hb_{tot}), in each case with three different values of the intracranial pressure. The three different values of the intracranial pressure are separated in lines A, B and C. The pulse course in line A corresponds to an intracranial pressure of approximately 10 mmHg, in line B to an intracranial pressure of approximately 20 mmHg, and in line C to an intracranial pressure of significantly above 20 mmHg.

The course of the pulsatility of the intracranial pressure is known, and is described e.g. in "Intracranial Pressure Waveform Morphology and Intracranial Adaptive Capacity", American Journal of Critical Care, 2008; 17:545-554. Under normal conditions, as in the case of a pulse course in column 1, line A, the pulse course has three peaks. Peak $P1_{1A}$ comes from the pulsation of the choroid plexus (percussion wave) with a nearly constant amplitude. Peak $P2_{1A}$ comes from a rebound after the first arterial deflection (tidal wave)

and varies in form and amplitude. Peak $P3_{1A}$ originates from a venous reaction after a dicrotic depression (dicrotic wave). Column 1, line B shows the pulse course of an ICP pulse with an increased ICP value compared with line A. Peak $P2_{1B}$ is clearly elevated, while peak $P1_{1B}$ remains substantially the same. Column 1, line C shows the pulse course of an ICP pulse in the pathological pressure range above 20 mmHg. The pulse course is flattened and shows only slightly formed peaks. In contrast to the present invention, the above-mentioned publication states that the peaks of the pulse course of the intracranial pressure are not any clinically relevant factor and are not suitable for determining a condition of a patient.

The pulse course of a concentration of oxygenated haemoglobin, deoxygenated haemoglobin and an overall haemoglobin concentration was determined by means of a measuring device according to Figure 3 through NIRS measurement. The pulse course of the concentration of Hb_{oxy} under normal conditions is shown in column 2, line A. Peak $P1_{2A}$ shows an amplitude of the choroid plexus, and peak $P2_{2A}$ an amplitude of an arterial component of the pulse. The arterial component clearly rises with increasing intracranial pressure, as can be seen in column 2, line B, from the elevation of the peak $P2_{2B}$. The pulse course of the concentration of Hb_{deoxy} under normal conditions is shown in column 3, line A. Peak $P1_{3A}$ shows again the amplitude of the choroid plexus. The arterial component of the pulse is hardly visible, whereas the venous component strongly influences the pulse course with a peak $P3_{3A}$. With elevated pressure the venous component dominates the pulse course with peak $P3_{3B}$, as can be seen in column 3, line B. The pulse course of the overall haemoglobin concentration in the normal pressure range has clearly pronounced peaks $P1_{4A}$, $P2_{4A}$ and $P3_{4A}$, see column 4, line A. With elevated pressure the venous component disappears and the arterial component is more pronounced with peak $P2_{4B}$. In the pathological pressure range above 20 mmHg the pulse course shows no individual peaks anymore; instead the pulse is identified by a pulse over the width of a single peak value.

Measurements have shown that the course of the pulsatility of the body parameter, such as the concentration here, determined through absorption measurement by means of the measuring device, is reproducible and can be clearly related to the values of the intracranial pressure. Basically, one body parameter is sufficient for this purpose, such as e.g. oxygenated haemoglobin. The use of a plurality of body parameters, e.g. Hb_{oxy} , Hb_{deoxy} and Hb_{tot} , can increase the measurement precision however. The transformation

algorithm of the measurement system comprises for this purpose a comparison algorithm, with which the measured pulsatility course can be assigned a specific pressure value. For this purpose reference curves for the course of the intracranial pressure can be made use of. Above and beyond this, the pulsatility of the individual concentrations can
5 be assigned to an intracranial pressure by means of the pressure-volume curve of Figure 1. Also a combination with a comparison with the peaks of the intracranial pressure is possible in order to determine the existing pressure.

Advantageous with the invention is that the determination of body parameters can be used that are able to be detected in a simple way and which are by themselves helpful
10 for the monitoring of a patient. It is not necessary to use an additional measuring unit for the determination of the pressure.

Shown schematically in Figure 3 is a measurement system 1 for measuring at least one body parameter according to the invention. The measurement system comprises at least one measuring device 4, a light-emitting optical unit 3 and an evaluation unit 2. The
15 measuring device is designed as non-invasive patch, which is provided on a body organ, such as e.g. a cranium or on a muscle, over an optical measurement volume in the bodily tissue. Further provided are light guides 5 between optical unit 3, measuring device 4 and evaluation unit 2 for transmission of light waves. Light waves emitted from the optical unit 3 are thereby radiated by means of the measuring device 4 into the optical
20 measurement volume in the brain, and measurement waves received by the measuring device 4 from the brain are transmitted to the evaluation unit 2. The optical unit 3 provides a multiplicity of light waves of different wavelength to the at least one measuring device 4. Preferably at least one wavelength thereby lies in the range of the water absorption and each further wavelength is selected according to the absorption of one of
25 the body parameters to be determined.

According to the invention, at least four light waves of differing wavelength are provided, wherein the weighting of the different absorptions of the wavelengths in the optical measurement volume preferably lies within an order of magnitude. For measurement of each constituent in the bodily tissue, a wavelength corresponding to the
30 absorption of this constituent is preferably provided. Preferably provided are a wavelength corresponding to the absorption for measuring a concentration of bodily tissue, a further wavelength corresponding to the absorption for measuring a concentration of deoxygenated blood and, if desired, still another wavelength

corresponding to the absorption for measuring a concentration of oxygenated blood. The light waves and the measurement waves for all parameters to be measured can be conducted simultaneously by the measuring device.

5 In the corresponding wavelengths, which react to changes in the blood concentration, the system can measure the pulsatility of the measurement value. With unchanging conditions the amplitude of the pulsatility averaged over a multiplicity of pulse waves should remain approximately the same. If the amplitude changes, this indicates a change in the pressure in the bodily tissue. A rise or respectively a drop in the pressure is clearly determined from the measured values, by means of a corresponding correlation in the evaluation unit. An increase or decrease in the tissue water
10 concentration is detected from the determination of the concentration of the constituents in the bodily tissue. An increase or decrease of an oedema can thereby be diagnosed. The haemodynamics, the concentration of the tissue components, the magnitude of the oedema and of the pressure are preferably determined at the same time using the measurement system.
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An example for implementation of the measuring system according to the invention is the examination of the brain and the determination of the intracranial pressure, or respectively its change, as explained in the preceding. The measurement system and the method are also suitable for examination of muscle tissue in order to determine the
20 pressure in a muscle compartment or respectively its change.

Patentkrav

1. Målesystem til bestemmelse af mindst en trykparameter i et legemsvæv i en hjerne eller en muskel omfattende:

- mindst et måleapparat til anbringelse på legemet,
 - 5 - en optisk enhed til udsendelse og detektering af mindst fire lysbølger med forskellige bølgelængder, idet mindst en af lysbølgernes bølgelængder ligger i absorptionsområdet for en af legemsvævetts bestanddele,
 - mindst en lysleder mellem den optiske enhed og det mindst ene måleapparat til transmission af lysbølgerne med forskellig bølgelængde og
 - 10 - en bedømmelsesenhed til bedømmelse af målebølgesignaler, der modtages og transmitteres af måleapparatet,
 - idet af den optiske enhed udsendte lysbølger med forskellige bølgelængder kan indstråles i et optisk målerumfang i legemsvævet ved hjælp af det mindst ene måleapparat, og de fra det optiske målerumfang af
 - 15 måleapparatet modtagne målebølgesignaler kan transmitteres til bedømmelsesenheden,
- hvor
- bedømmelsesenheden er konfigureret til at bearbejde de modtagne målebølgesignaler på grundlag af absorptionen af de udsendte lysbølger
 - 20 - for at bestemme en pulsilitet af en i målerumfanget målt koncentrationsparameter, og idet
 - bedømmelsesenheden omfatter en transformationsalgoritme, der er konfigureret til ud fra koncentrationsparameterens pulsilitet at bestemme en trykparameter i legemsvævet ved en sammenligningsoperation af
 - 25 forandringen eller forløbet af en amplitude af pulsiliteten med en reference-tryk-volumenkurve.

2. Målesystem ifølge krav 1, **kendetegnet ved, at** mindst en af bestanddelenes koncentrationsværdier er en koncentration af oxygeniseret hæmoglobin,

30 desoxygeneret hæmoglobin og/eller er en totalhæmoglobinkoncentration.

3. Målesystem ifølge krav 1 eller 2, **kendetegnet ved, at** trykparameteren er en parameter for det intrakranielle tryk i hjernen.

4. Målesystem ifølge krav 1 eller 2, **kendetegnet ved, at** trykparameteren er et kompartmentalt tryk i musklen.

5. Målesystem ifølge et af de foregående krav, **kendetegnet ved, at** en af de udsendte lysbølgers bølgelængder ligger i hydrogenabsorptionens område, og en anden af bølgelængderne er valgt i absorptionsområdet for en af bestanddelene i legemsvævet.

6. Målesystem ifølge et af de foregående krav, **kendetegnet ved, at** mindst fire lysbølger med forskellige bølgelængder kan udsendes af den optiske lysenhed til bestemmelse af fire bestanddele i legemsvævet, idet et produkt af bestanddelens absorptionskoefficient og koncentrationsværdi for de fire bestanddele i legemsvævet ligger inden for en størrelsesorden.

7. Målesystem ifølge et af de foregående krav, **kendetegnet ved, at** der til forskellige bestanddele i legemsvævet er tilvejebragt en bølgelængde svarende til absorptionen af en af bestanddelene til måling af en koncentration af denne bestanddel, fortrinsvis er der tilvejebragt en bølgelængde svarende til absorptionen til måling af en koncentration af legemsvævet og/eller en bølgelængde svarende til absorptionen til måling af en koncentration af blod.

8. Målesystem ifølge et af de foregående krav, **kendetegnet ved, at** flere udsendte lysbølger og flere modtagne målebølgesignaler ledes i måleapparatet samtidig.

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9. Målesystem ifølge et af de foregående krav, **kendetegnet ved, at** det mindst ene måleapparat er et ikke-invasivt måleapparat.

10. Målesystem ifølge et af de foregående krav, **kendetegnet ved, at** der i bedømmelsesenheden er implementeret en numerisk fremgangsmåde, som ved hjælp af et lineært ligningssystem bestemmer et vævsvandvolumen, koncentrationen af blod og/eller en vævsvandkoncentration og koncentrationen af oxygenet hæmoglobin, desoxygeneret hæmoglobin og/eller en totalhæmoglobinkoncentration.

35

11. Målesystem ifølge et af de foregående krav,
kendetegnet ved, at der er tilvejebragt en mærkningsindretning til indføring af et farvestof i en blodstrøm i legemsvævet, og målesystemet har en modus til bestemmelse af en farvestofkoncentration i blodstrømmen.

5

12. Fremgangsmåde til måling af mindst en parameter i et legemsvæv ved hjælp af et målesystem ifølge et af kravene 1 til 11 omfattende følgende fremgangsmådetrin:

- anbringelse af mindst et måleapparat på legemet,
- 10 - udsendelse og detektering af mindst fire lysbølger med forskellige bølgelængder, idet mindst en af lysbølgernes bølgelængder ligger i absorptionsområdet for en af legemsvævetts bestanddele,
- transmission af de fra legemsvævet modtagne målebølgesignaler til en bedømmelsesenhed og bearbejdning af disse,
- 15 - bestemmelse af en pulsilitet af målebølgesignalerne på grundlag af ændringer i koncentrationens værdier af bestanddele i legemsvævet,
- bestemmelse af en trykparameter i legemsvævet ved hjælp af en transformationsalgoritme under anvendelse af en sammenligningsoperation af forandringen eller forløbet af en amplitude af pulsiliteten med en
- 20 reference-tryk-volumenkurve.

13. Fremgangsmåde til måling af mindst en parameter i et legemsvæv ved hjælp af et målesystem ifølge krav 12, idet hæmodynamikken og koncentrationen af bestanddele i hjernen eller i en muskel bestemmes samtidig ved en numerisk

25 fremgangsmåde ud fra målebølgesignalerne for flere lysbølger med forskellig bølgelængde.

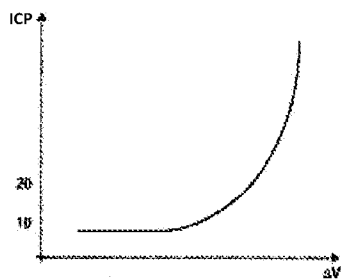


Fig. 1

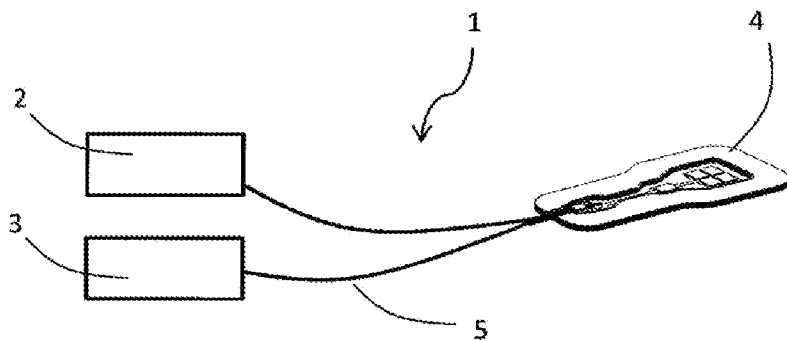


Fig. 3

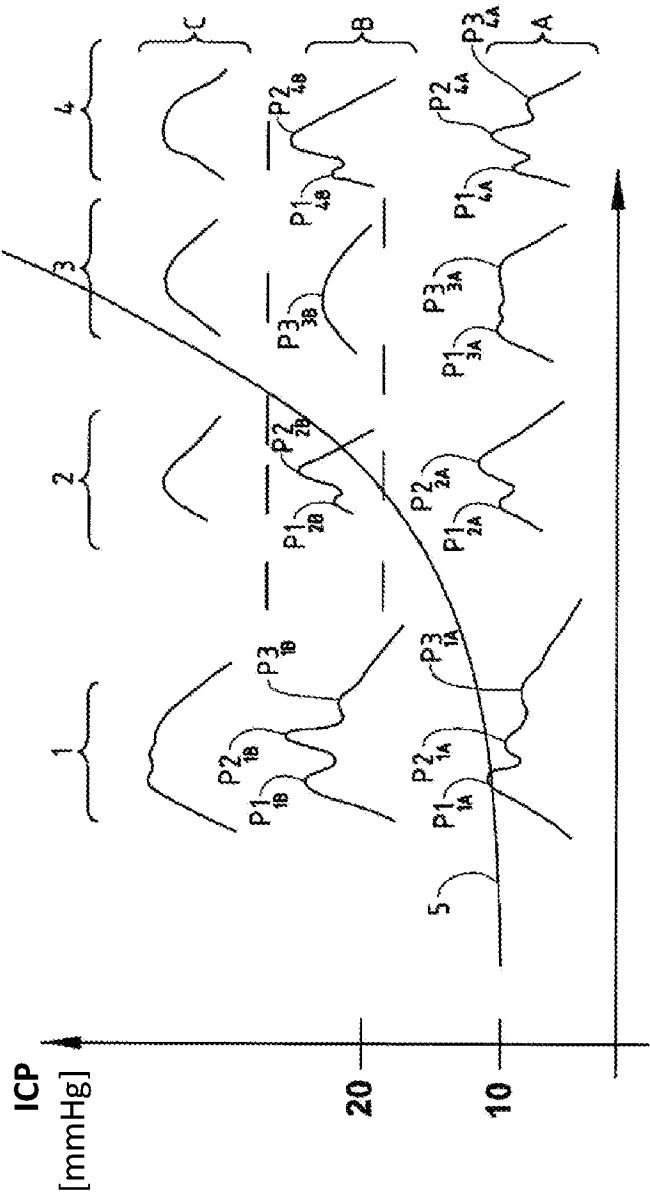


Fig. 2