(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 375 359 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
19.09.2018 Bulletin 2018/38

(21) Application number: **17161116.3**

(22) Date of filing: **15.03.2017**

(51) Int Cl.:
A61B 5/021 (2006.01)
A61B 5/022 (2006.01)
A61B 5/00 (2006.01)
A61B 7/04 (2006.01)
A61B 5/0402 (2006.01)

(84) Designated Contracting States:
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
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(71) Applicant: **Nokia Technologies Oy**
02610 Espoo (FI)

(72) Inventors:
- **MERLOT, Antoine**
  75005 Paris (FR)
- **CAMPO, David**
  92100 Boulogne Billancourt (FR)
- **VISSAC, Virginie**
  92100 Boulogne Billancourt (FR)
- **BALTI, Haïkel**
  94400 Vitry sur Seine (FR)

(74) Representative: **Cabinet Plasseraud**
66, rue de la Chaussée d'Antin
75440 Paris Cedex 09 (FR)

(54) METHOD FOR ANALYSING CARDIOVASCULAR PARAMETERS OF AN INDIVIDUAL

(57) A method to collect cardiovascular data relating to an individual user (U), in a system comprising an acoustic sensor (4) configured to be coupled to the chest of the user, an arm band (2) having an inflatable bladder (53) configured to be placed around at a predefined position around a upper limb of the user, for example the left arm (BG), a pneumatic unit with at least a pump (7) and a pressure sensor (61), configured to inflate and deflate the inflatable bladder, an arterial blood path (P) being defined from the heart to the left arm (BG) of the user, the method comprising a set of steps named PTT procedure :

/A1/- acquiring acoustic signals at the acoustic sensor,

/A2/- acquiring pressure signals at the pressure sensor, image of pressure occurring at the brachial artery,

/SO/ - inflate the bladder at a predetermined pressure (PT1)

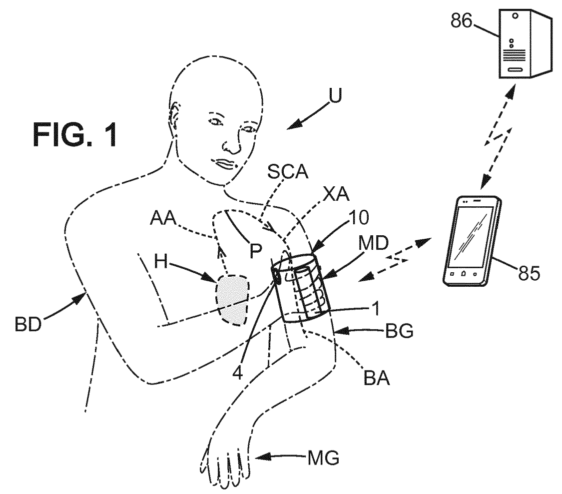
/S1/- determining aortic valve closing instant T1(k) from acoustic signals,

/S2/- determining subsequently, from pressure signals, a characteristic point (M2) of the pressure signal curve occurring at instant T2(k),

/S3/- calculate a time difference, defined as $\Delta T(k) = T2(k) - T1(k)$

Repeating, for each heartbeat, steps S1 to S3 until a stop criterion (SC) is met.

FIG. 1



EP 3 375 359 A1

Printed by Jouve, 75001 PARIS (FR)

Description

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to methods for analysing cardiovascular parameters of an individual and devices used to carry out such methods.

[0002] More particularly, it relates to a method designed to assess parameters of the type "pulse transit time", these parameters being determined from acoustic signals and/or electrical signals emitted by the heart of such individual, and from responsive signals sensed at a blood circulation sensor, which may be a blood pressure sensor or other type of sensor. Likewise for one instance this kind of method, there may be used an inflatable bladder comprised in a blood pressure cuff.

BACKGROUND OF THE DISCLOSURE

[0003] There is known devices that combine arterial pressure sensing means and electrocardiogram sensing means, of the type for example disclosed in document US20160235325, in which some attempts have been done to assess pulse transit time from ECG signal. However, such method shows inaccuracy shortcomings since ECG signal fails to accurately reflect the mechanical activity of the heart. Furthermore, acquiring pressure waves at the wrist is not fully adequate to accurately detect some trouble located in the arterial network close to the heart.

[0004] Therefore, the inventors have identified a need to enhance functionalities provided by such methods and improve their accuracy.

SUMMARY OF THE DISCLOSURE

[0005] According to one aspect of the present disclosure, there is disclosed a method to collect cardiovascular data relating to an individual user (U), in a system comprising an acoustic sensor (4) configured to be coupled to the chest of the user, a blood sensor configured to be placed at a predefined position at the user's body, an arterial blood path (P) being defined from the heart to said predefined position, the method comprising a set of steps named PTT procedure:

/A1/- acquiring acoustic signals at the acoustic sensor,
/A2/- acquiring of blood circulation signals at the blood sensor, image of instantaneous blood circulation parameters prevailing at the predefined position,
/S1/- determining aortic valve closing instant T1(k) from acoustic signals,
/S2/- determining subsequently, from blood circulation signals, a characteristic point (M2) occurring at instant T2(k),
/S3/- calculate a time difference, defined as $\Delta T(k) = T2(k) - T1(k)$
/Sloop/ repeating, for each heartbeat, steps /S1/ to /S3/ until a stop criterion (SC) is met.

[0006] Thereby, the electronic controller acquires acoustic signals, sensed by the acoustic sensor, in timely conjunction with blood circulation parameters at the predefined position, to determine therefrom for example a Pulse Transit Time (PTT) from the aortic valve to the artery location of interest.

The term "predefined position" should be understood as a predefined location at an artery vessel where the heart pulses reflect. The artery location of interest is not necessarily at the vicinity of the skin, it can be located in depth into a user's limb.

It should be understood that the so-called predefined position can be located at the left arm, but it could also be somewhere else on the left arm, e.g. on the forearm, on the wrist, somewhere else on the right arm of the user, including the wrist; it is not excluded to implement the proposed method with pressure signals taken on a lower limb of the user. Of course, calculation parameters to be used are to be adapted in particular to the length of the arterial blood path (P) for each case.

The inventors have found that acoustic signals provide a good time marker for start time in order to perform calculation of Pulse Transit Time (PTT). Particularly, the closure of the aortic valve produces a sufficient noise to be properly captured.

The term "blood circulation parameters" can designate the blood local pressure, the blood local speed, or even an image of both pressure and speed, prevailing at the predefined position.

[0007] In one implementation, the system may comprise means for exerting pressure around a limb of the user, at the predefined position, and the blood sensor may be a pressure sensor, wherein blood fluid circulation parameters signals are pressure signals,
and wherein the method comprises, prior to step /S1/ :

/S0/ - exert a predetermined pressure (PT1)

And at step /S2/ the characteristic point (M2) is determined from a pressure signal curve. With pressure signals, the method works well even though the artery vessel is deep below the *skin.*

In one implementation, the means for exerting pressure is a band (2) having an inflatable bladder (53) configured to be placed at the predefined position, a pneumatic unit with at least a pump (7), the pressure sensor being configured to be fluidly connected to the inflatable bladder.

While aortic valve closure can be taken as a first time marker and, further, the corresponding reflection/response in the pressure signal at bladder can be taken as a relevant second time marker.

[0008] In one implementation, the predefined position is at the left arm (BG) of the user, the band (2) is an arm band and is configured to be placed around the left arm of the user.

It should be noted that, in the case of the left arm, the blood path at interest for assessing the Pulse Transit Time (PTT) is rather short namely less than 40 cm and concentrates on the main arterial network starting from the heart, which enables to detect potential problems affecting aorta or other portion of the main arterial network leading from the heart to the arm, (under this perspective the arm can be a better location than the wrist or a leg). Thereby, the electronic controller acquires pressure wave signals to determine therefrom for example a Pulse Transit Time (PTT) from the aortic valve to the brachial artery.

[0009] According to one particular option, there is disclosed a method to collect cardiovascular data relating to an individual user (U), in a system comprising an acoustic sensor (4) configured to be coupled to the chest of the user, an arm band (2) having an inflatable bladder (53) configured to be placed at a predefined position around a limb of the user, for example at the left arm (BG), a pneumatic unit with at least a pump (7) and a pressure sensor (61), configured to inflate and deflate the inflatable bladder, an arterial blood path (P) being defined from the heart to the predefined position, for example the left arm (BG) of the user, the method comprising a set of steps named PTT procedure :

A1- acquiring acoustic signals at the acoustic sensor,
A2- acquiring pressure signals at the pressure sensor, image of pressure prevailing at the brachial artery,
/S0/ - inflate the bladder at a predetermined pressure (PT1)
/S1/- determining aortic valve closing instant T1(k) from acoustic signals,
/S2/- determining subsequently, from pressure signals, a characteristic point (M2) of the pressure signal curve occurring at instant T2(k),
/S3/- calculate a time difference, defined as $\Delta T(k) = T2(k) - T1(k)$
/Sloop/ repeating, for each heartbeat, steps S1 to S3 until a stop criterion (SC) is met.

The arterial blood path of interest is therefore mainly focused on the central arterial distribution network; this improves the detection of potential problems affecting aorta or other portion of the main arterial network leading from the heart to the left arm.

The blood path at interest for assessing the Pulse Transit Time (PTT) is rather short namely less than 40 cm and concentrates on the main arterial network starting from the heart, which enables to detect potential problems affecting aorta or other portion of the main arterial network leading from the heart to the left arm.

[0010] According to one particular option, the characteristic point (M2) of the pressure signal curve is defined as a succession of a maximum apex (M1) and a minimum apex (M2), said instant T2(k) being defined as the instant when said minimum apex occurs.

Faithfull and relevant time marker corresponding to arrival at the arm of the effect of the closure of aortic valve is thus determined.

[0011] According to one particular option, the system comprises a set of contact electrodes (3) for electrocardiographic sensing, configured to be brought in contact with the skin of the user U, the method comprising the steps:

/A3/- acquiring ECG signals at the contact electrodes,
/S10/ - determining a characteristic QRS signal from ECG signals as a synchronization signal (TO) reflecting heartbeat.

This helps to synchronize the analysis of acoustic and blood circulation signals.

[0012] According to one particular option, the aortic valve closing instant T1(k) is defined as a second significant sound (B2) of the heartbeat.

Faithfull/relevant time marker corresponding to the closure of aortic valve is thus determined.

[0013] According to one particular option, wherein at step /S1/, the aortic valve closing instant T1(k) is determined as follows :

/S11/- identifying a first significant sound (B1) of the heartbeat, reflecting mitral valve closing, just following QRS signal at instant T0,
/S12/- identifying a second significant sound (B2) of the heartbeat, reflecting aortic valve closing, and record said second significant sound (B2) as instant T1(k).

This provides a simple and reliable method to determine instant T1(k).

[0014] According to one particular option, a significant sound is defined whenever a instantaneous power of the acoustic signals exceeds a predetermined threshold (BS).

Noises can thus be disregarded.

[0015] According to one particular option, the method comprises, before the PTT procedure, a preliminary set of steps named Blood Pressure procedure comprising the steps :

/Ph1/- start inflating the bladder,
/Ph2/- stop inflating the bladder (when no more pressure wave is identified),
/Ph3/- start deflating the bladder,

meanwhile are performed the following steps :

/PhS/ - determining Systolic Blood pressure (PTS), during inflating phase and/or deflating phase
/PhD/ - determining Diastolic Blood pressure (PTD), during inflating phase and/or deflating phase

This provides a blood pressure reference prior to carry out PTT procedure; abortion of PTT can be decided if BP procedure is incorrect.

[0016] According to one particular option, prior to steps /S1/ to /S3/, the predetermined pressure **PT1**, providing pressurization for PTT procedure, is calculated with reference to the diastolic pressure (PTD) determined at step PhD.

PT1 is therefore user dependent.

According to one particular option, the predetermined pressure **PT1** can be defined as a function of **PTD,** for example with a value below PTD, this difference defined by a predefined offset; in other words, PT1 can be equal to PTD - PTof, with PTof for example equal to 10 mmHg (10 Torr).

According to one particular option, the stop criterion SC is met after N heartbeats for which steps S1 to S3 were carried out properly, N being comprised between 4 and 10.

PTT procedure can be short. Time duration can be defined by user or according to a quality index criteria. Respiration/Breathing or other disturbances can be compensated for. According to one particular option, at steps /A1/ and/or /A2/, acoustic signals and/or pressure signals are digitalized are further filtered with a band pass filter having a passing band range of [0,5Hz - 1kHz].

Continuous components and noises can thus be eliminated.

[0017] According to one particular option, during PTT procedure, pump is not energized and a bleeder valve comprised in the pneumatic unit is not energized.

No noise from the device itself : no disturbance on acoustic signals.

According to one particular option, the method may further comprise :

> /S41/ - calculate an average value **ΔTav** of **ΔT(k)**, for **k=j to j+N** (with N being the number of heartbeats with effective PTT measurement),
>
> /S42/- calculate a Pulse Wave Velocity (PWV) defined as **PWV(k) = length(P) / ΔTav,**
>
> /S5/- assess therefrom an arterial stiffness (AS) of the user.

This provides a reliable rating averaged over several cycles.

According to one particular option, the **height** (UH) of the user is taken into account at step /S42/, namely **length(P) = F1 (UH)**

This provides a personal index, which is relevant whatever the length of the blood path (which depends on the height of the user at first order).

According to one particular option, age (UA), gender (UG), and weight (UW), of the user is additionally taken into account at step /S42/, namely **length(P) = F2 (UH,UA,UG,UW).**

A cardiovascular index can be refined to faithfully reflect the arterial stiffness, irrespective of user profile particulars.

According to one particular option, subsequent evaluations of Pulse Wave Velocity are recorded for a particular user to form a history curve, and a deviation in said curve is notified to said particular user.

The change in user habits can be detected by this means; said change can relate to food intake, physical exercise, initial phase of a disease etc.

[0018] The present disclosure is also directed to a system, device or apparatus configured to carry out the above-mentioned methods and functionalities.

[0019] The present disclosure is also directed to computer readable medium encoded with instructions that, when executed by a computer, cause performance of a method as described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Other features and advantages of the disclosure appear from the following detailed description of one of its embodiments, given by way of non-limiting example, and with reference to the accompanying drawings, in which:

- Figure 1 illustrates a general overview of a device according to the present disclosure in a use configuration,
- Figure 2 shows a diagrammatic sectional view of the device in place on the left arm of the user, and adjacent to the chest, for the generically defined embodiment,
- Figure 3 illustrates a mechanical configuration of the device in an open configuration, according to a first embodiment,
- Figure 4 shows a diagrammatic sectional view of the device in place on the left arm of the user, according to the embodiment shown in Figure 3,
- Figure 5 shows another diagrammatic sectional view of the device in place on the left arm of the user, according to a second embodiment,
- Figure 6 illustrates a buckle configured to be used in co-operation with the arm band, according to the second embodiment
- Figure 7 shows an exemplary block diagram of the device,
- Figure 8 shows a timing chart illustrating the method, at the heartbeat timescale,
- Figure 9 shows a timing chart illustrating the method at a larger timescale,
- Figure 10 illustrates the mechanical configuration of the device of the first embodiment in a stowed configuration.
- Figure 11 illustrates a general perspective view of the device of the first embodiment,
- Figure 12 illustrates a general overview of the disclosed method,
- Figure 13 shows steps of the method regarding pressure signals handling,
- Figure 14 shows steps of the method regarding pulse

transit time handling,

- Figure 15 shows a detailed sectional view of the armband.

DETAILLED DESCRIPTION OF THE DISCLOSURE

[0021] In the figures, the same references denote identical or similar elements. For clarity purposes, some parts are represented intentionally not at scale with regard to other parts. Also, some parts of timing charts can be represented intentionally not at scale.

[0022] Figure 1 shows an individual (also 'user') **U** in a configuration where he/she is using a device **10** according to the present disclosure. The device (otherwise called "apparatus") **10** looks like a known brachial blood pressure sensing device (commonly named Blood Pressure Monitor i.e. in short "BP Monitor"), but the device exhibits extended functionalities as will be apparent below, so that the device can be called 'upgraded BP Monitor.

[0023] The user **U** in question has, among other organs and limbs in his/her anatomy : a left arm **BG,** a right arm **BD,** a heart **H,** a left hand **MG** a right hand **MD.**

[0024] Further the user in question has an aortic artery ('aortic arch') denoted **AA,** a subclavian artery **SCA,** an axillary artery **XA,** a brachial artery **BA,** belonging generally to the cardiovascular system of the user. Therefore a blood path of interest noted **P** is defined as the fluid conduit from the heart **H** to a reference point at the brachial artery **BA.**

[0025] Besides the left arm brachial artery as reference point, it should be understood that the proposed method would properly work with another predefined position where a band can be secured around a limb, either a lower limb or an upper limb.

[0026] The device **10** has a wireless communication capability to exchange data with a mobile entity like a smartphone **85** (more generally a mobile device belonging to the user U like a tablet, a laptop....). Such smartphone **85** may in turn exchange data with a remote entity like an Internet server **86** (more generally any resource available somewhere in Internet, not excluding a so-called "cloud" resource).

[0027] The device **10** has either a small display or no display at all, since the user interface capability provided by the smartphone **85** is fully relevant to support displays relating to the use and extended functionalities of the device.

[0028] The device **10** is intended to be used at a home environment, for healthy people as well as people suffering from some disease. It may be used in a medical environment but is particularly suitable to be used by non-medical personnel, i.e. the user under measurement him/herself.

[0029] In the shown example, the device **10** comprises an armband **2** wrapped around the left arm **BG,** a control unit assembly **1,** and an acoustic sensor denoted **4.**

[0030] The rest of the time the device is stowed, notably in a folded configuration as will be seen later.

[0031] As illustrated on Figure 1, the device comprises an armband wrapped around the arm i.e. the part of the upper limb comprised between the shoulder and the elbow. However it is not excluded to use the device elsewhere, at the forearm for example.

[0032] As illustrated on Figure 1, the device is installed on the left arm of the user. However it is not excluded to use the device elsewhere, at the right arm for example.

[0033] As illustrated on Figure 2, the left arm of the user includes a bone named humerus denoted **81,** muscles (not specially shown), and the abovementioned brachial artery denoted **82.** The humerus extends along an axis denoted **Z.** The armband band **2,** when wrapped around the arm BG, has a general cylindrical shape with a reference axis substantially coinciding with arm axis **Z.**

[0034] The armband has an internal wall denoted **26** intended to contact the arm's skin and to press against the arm. The armband has an external wall denoted **27** on the opposite side of the band with regard to the internal wall **26.**

[0035] In use configuration, the acoustic sensor **4** is located against the chest, i.e. against the left side of chest. Sound waves **4H** emitted by the heart are sensed by a sensitive portion **41** of the acoustic sensor **4,** the sensitive portion 41 bearing on the left-side chest, i.e. adjacent to the chest. Handling of electrical signals transduced from acoustic waves **4H** will be detailed later. It should be noted that acoustic waves 4H can be sensed by the sensitive portion **41** without trouble through a light clothing, an underwear or the like.

[0036] According to one particular option, the device is further equipped with an ECG function, i.e. ElectroCardioGraphic function.

[0037] For this purpose there are provided three contact electrodes **31, 32, 33,** the three of them integrated in the device, without the need to have linking wires like in most prior art devices.

[0038] The first electrode **31** is arranged on the internal wall **26** of the band and has a sensitive face oriented toward the skin of the arm. The first electrode **33** is also arranged on the internal wall **26** and has also a sensitive face oriented toward the skin of the arm.

[0039] Each of the electrodes is formed as a thin pad of a surface comprised between 5 cm^2 and 10 cm^2; for example, the shape of the thin pad is somewhat arched to follow the standard curvature of the skin of the arm.

[0040] In a particular option, first and third contact electrodes **31, 33** are disposed at distance from each other. Alternatively, first and third contact electrodes **31, 33** can be arranged differently, for example one above the other or one aside the other.

[0041] Whenever the armband is pressurized, first and third contact electrodes **31, 33** are firmly pressed against the skin of the arm, thereby ensuring a fairly good contact with a small electrical contact resistance. It should be noted that no gel is required at the contact electrode contrary to conventional habits. Contact electrodes are to be placed against the bare skin; however, thanks to the pressure, it is not excluded to have a light underwear cloth between the skin and the electrodes.

[0042] The contact electrodes can be made of stainless steel, silver, or other coated materials (coated with silver, chromium, gold, titanium or platinum), not excluding materials coated by physical vapor deposition technique (known as PVD techniques).

[0043] It is to be noted that two electrodes might be sufficient, therefore the third electrode **33** is considered optional.

[0044] Regarding the second electrode **32,** it is arranged around the external surface of the control unit assembly as best seen at figure 11. A conductive material forms a coating of at least a part of the control unit housing. A metallic coating material (silver, titanium, chromium), are deposited by physical vapor deposition technique (known as PVD techniques).

[0045] The second electrode covers the lower third of the cylinder, for example all around the accessible circumference by the fingers of the user (see Fig 1). Therefore, it is easy for the user to grab/seize the second electrode with a good electrical contact.

[0046] The above mentioned control unit assembly **1** has, in the shown example, an overall cylindrical shape with an axis denoted **Z1** (cf Figures 2,4,11). The control unit assembly **1** is fixed to the arm band **2.** For example, it is fixed to the first portion **21** as explained below.

[0047] As seen on Figures, the general arrangement is as follows: the control unit assembly **1** extends from the external wall 27 of the band with regard to the main axis **Z** along a direction denoted **X.** In use configuration, when the chest of the user is nearly vertical, **X** is substantially horizontal and in a front-rear direction.

[0048] In the illustrated case of a cylinder, the diameter of the control unit assembly **1,** denoted **D1,** is less than 40 mm, for example about 35 mm or even about 30 mm.

[0049] The acoustic sensor **4** has a center **44,** which is referred to to define the transversal axis **Y,** extends from the external wall 27 of the band with regard to the main axis **Z** and passing through the center **44** of the acoustic head. In use configuration, when the chest of the user is nearly vertical, **Y** is substantially horizontal and in a left-right direction.

[0050] Angular distance between axis X and Y is denoted by angle α. In use configuration, the angle α is comprised between 90° and 140°, for example between 110° and 130°. As shown at Figure 1, in use configuration, the right hand can conveniently seized the control unit assembly **1** and the acoustic sensor is naturally placed against the chest of the user **U.**

[0051] Regarding the acoustic sensor **4,** according to one preferred option, it is formed as a piezoelectric transducer, which can provide a very thin configuration; this piezoelectric transducer requires very little space projecting from the external wall **27** of the arm band; this piezoelectric transducer requires no electronic supply, no local electronic adaptation circuit.

[0052] Since the user naturally squeezes the acoustic sensor against the chest, the acoustic sensor can properly work through a thin cloth like a T-shirt, a shirt, even two layers of such cloth.

[0053] According to an alternative option, the acoustic sensor can be formed as a microphone.

[0054] In Figure 2, a generic view of the armband is represented; this type of band can be a ring adaptable in diameter/circumference. This kind of band can be inserted from the hand without opening the ring, and slid up to the shown position on the arm. There may be provided restriction means to decrease the play and lock the current position, before pneumatic inflation.

[0055] An inflatable bladder **53** is provided. Such a compliant inflatable bladder is known per se in blood pressure sensing apparatuses, and therefore not described in details here. At rest, the bladder is arranged within the thickness of the band, as an internal layer.

[0056] There may be provided an armature **25,** otherwise called *cuff holder,* for structural support of at least a part of the band. The armature can be an arcuate plastic part, made from a plastic material with good or high mechanical properties (polypropylene, ABS, PVC, or the like), having a part-of-a-cylinder shape, or generally an arcuate shape.

[0057] According to one particular aspect, both the bladder **53** and the armature **25** extend circumferentially along the major part of the active portion of the armband **2;** such that in use, the bladder is surrounding practically all the circumference of the arm of the user. Therefore, a homogeneous pressure is applied all around the arm which is beneficial for the accuracy of the measurement and the quality of the contact of the ECG electrodes **31,33.**

[0058] As visible on Figure 7, the control unit assembly **1** comprises a battery **17,** an electronic controller **6** and a pneumatic unit **5.** We note that no external wired connection is needed.

[0059] The pneumatic unit **5** comprises at least a pump **7** driven by an electric motor **57,** a release valve **56** also called "bleeder valve" **56,** and a pressure sensor **61.**

[0060] The pneumatic unit **5** may optionally comprise a check valve **58.** The release valve 56 may be an On/off valve or a progressive valve.

[0061] The control unit assembly **1** comprises an On/Off switch **16;** the user may start a measurement, after having installed the armband, by actuating the switch **16,** pressing or touching according to various possible types of switches.

[0062] Further the control unit assembly **1** may further comprise a wireless interface **68** such as for example a wireless coupler (WiFi, Bluetooth™, BLE or the like), and a display **67** already mentioned. The display **67** can be a LED display and or a dot matrix display; on this display, blood pressure results can be displayed directly without use of the smartphone application.

[0063] There is provided a pneumatic hose **59** to fluidly connect the output of the pump to the bladder. It can be a one-way pneumatic connection or a two-ways pneumatic connection (59,59'). According to one variant, there is provided a specific sense line **59'** decoupled from the pressurization line 59.

[0064] The pressure sensor 61 is in fluid connection with the inflatable bladder 53 through the specific line 59', or through the common single 59 where applicable.

[0065] A first overview of the functionality of the device is given here, whereas it would be described later in more detail with the help of Figures 9 and 12.

[0066] A blood pressure measuring cycle is carried out first, and optionally, thereafter a pulse transit time PTT measuring cycle is carried out. In the same timeframe or separately, individual ECG signal analysis and/or phonocardiogram signal analysis can also be performed.

[0067] For the blood pressure measuring cycle, the electronic controller 6 is configured to first inflate the inflatable bladder 53 until the blood flow is greatly reduced by the pressure exerted on the arm. During inflation, the analysis of the evolution of pressure signals allows to infer the systolic pressure and the diastolic pressure. The controller is configured to then progressively deflate the bladder **53.** The progressive reinstatement of the blood pressure waves is also analyzed by the electronic controller **6** to infer the systolic pressure and the diastolic pressure, in confirmation or replacement of values deduced during the inflation phase.

[0068] Regarding the pulse transit time PTT, the electronic controller **6** determines a first characteristic instant and a second characteristic instant, and the resulting time difference is used to calculate a pulse wave velocity to finally issue an index representative of the arterial stiffness to the user.

[0069] Now are described in detail embodiments and variants of the device structure.

[0070] According to the first embodiment, illustrated at Figures 3, 4, 10 and 11, the band **2** comprises a first portion **21** and a second portion **22.** The first portion **21** can be considered as the main portion since the control unit assembly **1** and the acoustic sensor **4** are affixed to this first portion **21,** and furthermore this first portion houses the inflatable bladder **53,** and optionally, the structural elastic armature **25** already mentioned.

[0071] The first portion **21** has a developed length denoted **L1**. The second portion **22** has a developed length denoted **L2.** The band has a height **H.** Likewise, the armband **2** is made from a generally rectangular shape with a width corresponding to dimension **H** and a length corresponding to added dimensions **L1 + L2.**

[0072] For installing the arm band **2** around the arm prior to inflating, the user starts for example from a stowed configuration depicted in figure 10, the user unrolls the second portion **22** (see Fig 3) to make it possible to install the first portion around his/her left arm BG. Thanks to the elasticity of the first portion, the first portion **21** can be opened so as to facilitate the insertion of the arm into the internal space encompassed by the first portion. The user has to move away a little bit his/her arm from the chest to do that.

[0073] It should be noted that this configuration allows installing the band/cuff without inserting it along the forearm from the hand side.

[0074] Further operation involves the closing of the band 2 around the arm, and securing this configuration prior to inflation.

[0075] A hook pad **29** is arranged at the external wall of the first portion **21** and a corresponding loop pad **28** is arranged at the internal wall of the second portion **22.** Of course the reverse configuration loop/hook is also possible.

[0076] Hook pad **29** and loop pad **28** may have a general rectangular shape. Regarding the dimensions, the hook pad **29** can extend along all the height **H** over a length of 5cm to 10cm; the loop pad **28** is longer, it also can extend along all the height **H** but over a length of 10cm to 20cm.

[0077] After the user has placed the first portion **21** around the arm on the side of the chest as described before, he/she pulls the second portion **22** toward the rear direction and then sticks the second portion 22 onto the first portion 21 by securing the loop pad **28** on the hook pad **29.** The remaining unused end 22e of the second portion is left free.

[0078] Alternatively, according to a variant illustrated at figure 11, where a special cutout 24 is provided, the remaining unused end **22e** of the second portion can be folded around back into the front direction.

[0079] Fig 4 shows the device ready for inflation, the user presses the device onto his/her chest to guarantee acoustic adaptation, namely proper collection of acoustic waves.

[0080] It should be noted that the length of the second portion together with the length of the hook pad and the length of the loop pad allows the device to be adjusted to a large variety of arm circumference and diameter **D2.**

[0081] At Figures 5 and 6, a second embodiment of the armband is represented, which also allows to instal the band/cuff without inserting it from the hand. Again, the band **2** comprises a first portion **21** and a second portion **22.**

[0082] In this embodiment, the device also comprises a buckle **9,** also named 'return buckle' as seen on Fig 6. The buckle can be manufactured as a bent metallic wire, shaped as a rectangular loop. The buckle can also be made from plastic material with good or high mechanical properties. Two long sides **9a, 9b** are connected at their respective ends by two small sides, thereby forming a rectangle with a length/height **H** and a width denoted **L9.**

[0083] The buckle is fastened to one circumferential end **21a** of the first portion 21, at complete opposite from the other end **22e** of the band 2.

[0084] For the assembly of the buckle on to the end **21a**, it can be provide a seam in the band end, done after insertion of the loop buckle. Alternatively, the loop formed by the buckle may have an openable slit **9s**, with self locking retaining means (hook and the like).

[0085] For installing the arm band **2** around the arm prior to inflating, the user places the first portion **21** around the arm on the side of the chest and passes the second portion **22** into the buckle **9** toward the rear and then pulls the end of the second portion **22** toward the front direction, until the arm wraps without substantial play the arm. Then the user sticks the returning portion **22c** against the base **22b** of the second portion to attach the attachment means, which results in the configuration shown at figure 5.

[0086] According to an aspect which is common to above embodiments, at least in part of the band, as shown at Figure 15, the band **2** comprises an internal layer **36** and an external layer **37** with an interval **2G** available between the two layers. In the gap **2G,** there may be provided the bladder **53,** the armature **25,** rivets **30** for fastening the contact electrode 31 and a connection wire **39.** Other wires may be present, for connecting the acoustic sensor to the electronic controller **6,** and the third electrode.

[0087] There may be a single layer portion (i.e. without gap or interval), notably in the distal end of the second portion 22.

[0088] The band **2** is for example made of strong fabric, woven or non-woven or synthetic material.

[0089] Generally speaking, the band **2** comprises attachment means, for fixing the size of the armband prior to inflating. The attaching means may comprise one or more couple(s) of loop and hook pads.

[0090] Therefore, a 'continuous' unquantized adjustment of encompassed circumference is made available, for any size of arm.

[0091] It should be noted that in the present specification, arm circumference **CIRC** or diameter D2 are indifferently used, since we know that **CIRC = π x D2.**

[0092] According to other possible solutions, there may be provided attaching means including a releasable ratchet system, or a teeth system.

[0093] Regarding dimensions, the following preferences can be noted.

[0094] For a baseline device intended to encompass arms having a perimeter/circumference comprised between 20cm and 42 cm, which represents most of the users :

L1 is for example comprised between 20 cm and 32 cm.

L2 is for example comprised between 15 cm and 25 cm.

H is for example comprised between 12 cm and 16 cm.

[0095] For an XXL device (special large dimension variant) intended to encompass arms having a perimeter comprised between 40cm and 62 cm :

L1 is for example comprised between 40 cm and 45 cm.

L2 is for example comprised between 20 cm and 25 cm.

H is for example comprised between 14 cm and 18 cm.

[0096] This XXL variant can have a frusto-conical configuration, smaller diameter at the elbow oriented end.

[0097] When the device is unused, as illustrated at figure 10, it can be rolled up, whereby its size is less than 10cm x 10cm x H.

[0098] In the variant illustrated at figure 11, the second portion 22 of the armband can exhibit a smaller height for its most distal area; this option is delineated by the dotted line **24;** in this case, when the free end **22e** of the second portion is wrapped around the first portion at the location of the acoustic sensor, the acoustic sensor 4 is still uncovered by the second portion. Therefore, even though the user installs the device by wrapping it all around, this won't prevent the device from working regarding the acoustic acquisition against the user's chest.

The device works as follows, as illustrated at figures 8, 9, 12, 13 and 14.

[0099] During a measurement, the patient's heart generates electrical impulses that pass through the body at high speed. Also simultaneously the patient's heart generates acoustic waves that pass through the body with a certain sonic speed.

[0100] These impulses/waves accompany each heartbeat, and the heartbeat generates a pressure wave in artery network that propagates through the patient's vasculature at a significantly slower speed. The blood path **P** of interest has a certain length, let's say 30 cm to 40 cm according to the physical characteristic of the individual under measurement. As will be seen in more detail later, this length depends at first order on user's height denoted **UH.**

[0101] Immediately after the heartbeat ventricular contraction, the pressure wave leaves the heart and aorta, passes through the subclavian artery, to the brachial artery along the path **P.**

[0102] The ECG electrodes measure electrical signals which pass to an amplifier/filter circuit within the control unit assembly. For example, a filtering circuit is provided before the signal is digitized and entered into the microcontroller.

[0103] Within the controller, the signals are processed with an analog-to-digital converter to form the ECG digitized waveform and then recorded together with the time of occurrence, namely instant **T0**. ECG waveform is named "QRS waveform" or "QRS complex" as sample shown at Figure 8.

[0104] The acoustic waves are also band-pass filtered and amplified, for example after upfront digitalization. A bandpass filter with cutting frequencies [0,5 Hz - 1kHz] is applied, either in the analog font end before digitization or applied to the digitized acoustic signal.

[0105] "QRS waveform" **91** is the top curve shown on timechart at Figure 8. This waveform is known per se thus not described in details here. Instant **T0** corresponds in the illustrative embodiment to R apex, but another marker can be taken alternately.

[0106] Aortic valve open/close state is also shown just beneath, signal denoted **92.**

[0107] Mitral valve open/close state is also shown just beneath, signal denoted **93.**

[0108] Just before aortic valve opening, the mitral valve closes; this produces a particular sound which is reflected in the first significant sound named **B1** as shown on curve **95.**

[0109] Further, after closing mitral valve and opening aortic valve, the ventricular volume decreases as blood is ejected to the aorta. At the same time ventricular pressure **94** exhibits a rounded apex. Aortic pressure curve is shown and denoted **97.**

[0110] Sound phonocardiogram corresponds to curve denoted **95** electrically reflects waves received at the acoustic sensor **4.**

[0111] This curve **95** exhibits two characteristics sounds; the first sound denoted **B1** corresponds to the closing of the mitral valve, the second sound denoted **B2** corresponds to the closing of the aortic valve.

[0112] A *"significant sound"*, in the sense of the present disclosure, is defined whenever a instantaneous power of the acoustic signals exceeds a predetermined threshold (BS), cf Fig 8.

[0113] It should be noted that sounds **B1** and **B2** exceeds **BS** threshold.

[0114] Pressure wave at pressure sensor **61** in fluid communication with bladder **53** is shown at curve **96.**

[0115] This curve **96** exhibits three characteristics apexes. The first apex denoted **M1** is a maximum apex; the second apex denoted **M2** is a minimum local apex; the third apex denoted **M3** is a maximum local apex.

[0116] Besides **M0** is the minimum value, just before the rise which is a consequence/response of the arrival of the pressure pulse at the arm.

[0117] The second apex denoted **M2** is a marker corresponding to arrival of the effect of the closure of aortic valve at the brachial artery within the arm band.

[0118] There may be defined a reference point in the arm, so that the ideal position for the device can be notified to the user, for example distance from the elbow internal fold, or another criterion.

[0119] Generally speaking, for the purpose of PTT, **T1** is defined as the instant of the maximum instantaneous signal power of the second sound **B2** reflecting when aortic valve closes.

[0120] Generally speaking, **T2** is defined as the instant when second apex denoted **M2** occurs.

Blood Pressure procedure

[0121] This procedure is known in the art, and thus it is not described in details here. Basically, it comprises the following phases:

- **/Ph1/-** start inflating the bladder, inflation phase is denoted **71** at Fig 9, *'INFLATE'* at Fig 12,
- **/PhD/ -** determining Diastolic Blood pressure (PTD) during inflating phase
- **/PhS/ -** determining Systolic Blood pressure (PTS), during inflating phase
- **/Ph2/-** stop inflating the bladder **72** (when hardly no more pressure wave is identified),
- **/Ph3/-** start deflating the bladder, deflation phase is denoted **73** *'DEFLATE'* at Fig 12,
- **/PhS/ -** determining Systolic Blood pressure (PTSa), during deflating phase
- **/PhD/ -** determining Diastolic Blood pressure (PTDa) during deflating phase

[0122] More precisely, the shape of the pressure waves are analyzed by the electronic controller. During inflation **71,** as shown at Fig 9, the shape of the pressure waves evolves, and a predefined criteria on the waveform makes the decision to record a first diastolic blood pressure **PTD,** and another set of predefined criteria on the waveform makes the decision to record a systolic blood pressure **PTS.**

[0123] In a similar manner, during deflation phase, the shape of the pressure waves are analyzed by the electronic controller. During deflation **73** the shape of the pressure waves evolves, and a predefined criteria on the waveform makes the decision to record another systolic blood pressure **PTSa,** and another set of predefined criteria on the waveform makes the decision to record another diastolic blood pressure **PTDa.**

[0124] It should be noted that pressure curved is shown after rectifying at figure 8, whereas it is shown before rectifying at figure 9.

[0125] The second systolic blood pressure noted **PTSa** can be regarded as a confirmation of the first systolic blood pressure noted **PTS.** According to one example, an outputted systolic blood pressure can be an average of the value PTS and PTSa.

[0126] Similarly, the second diastolic blood pressure noted **PTDa** can be regarded as a confirmation of the first diastolic blood pressure noted **PTD.** According to one example, an outputted diastolic blood pressure can be an average of the value PTD and PTDa.

PTT Procedure

[0127] This procedure is adapted to determine as accurately as possible the pulse transit time PTT.

[0128] It comprises the following phases:

- /S0/ - inflate **75** the bladder at a predetermined pressure denoted **PT1**, the inflation bringing the pressure from the lowest value **74** to this predefined level **PT1**, detailed below
- /S1/- determining the above-mentioned aortic valve

closing instant **T1**(k) from acoustic signals,

/S2/- determining subsequently, from pressure signals, a characteristic point (M2) of the pressure signal curve occurring at instant **T2**(k),

/S3/- calculate a time difference, defined as Δ**T(k)** = **T2(k) - T1(k)**

[0129] The predetermined pressure **PT1** can be defined as a function of **PTD,** for example with a value below the diastolic pressure **PTD;** this value may be defined by a predefined offset **PTof**; in other words, PT1 can be such **PT1 = PTD - PTof,** with **PTof** for example equal to 10 mmHg (10 Torr).

[0130] According to one option, said characteristic point **(M2)** is the above-mentioned local minimum apex, after first apex **M1**.

[0131] Further, steps **S1** to **S3** are repeated until a stop criterion **SC** is met. This stop criterion **SC** can be defined according to different possibilities. One consists in predefined duration. Another one consists in counting the number **N** of heartbeat cycle ; for example **N** is chosen between 4 and 20, for example between 6 and 12.

[0132] Overall duration for BP procedure is denoted **TMBP** and duration for pulse transit time procedure is denoted **TMPTT.** For example **TMBP** is less than 10 seconds. For example **TMPTT** is less than 12 seconds. According to a user configuration, selectively chosen by user through the smartphone or locally by a double press on the switch **16,** the user can choose to carry out only the blood pressure **or BP** procedure plus **PTT** procedure.

[0133] During PTT procedure, pump 7 is not energized and a bleeder valve comprised in the pneumatic unit is not energized. Therefore, no intrinsic parasitic noise disturbs the phonocardiogram analysis and therefore the PTT procedure and related calculation is not disturbed by endogenous noise.

[0134] The electronic controller **6** computes therefrom a time difference, defined as

Δ**T(k) = T2(k) - T1(k)** for the heartbeat arbitrarily numbered **k.**

PWV is the wave velocity along path P.

PWV is defined as **PWV = length(P) /** Δ**T(k)**

[0135] In practice, we prefer to rely on a successive series of **N** measurements; in this condition, the method may comprise the following:

/S41/ - calculate an average value Δ**Tav** of Δ**T(k)**, for **k=j to j+N**

/S42/- calculate a Pulse Wave Velocity (PWV) defined as **PWV(k) = length(P) /** Δ**Tav,**

[0136] The number N of effective PTT measurement can be chosen between 4 and 20.

[0137] The average value can be computed as follows

$$\Delta \mathrm{Tav} = \frac{1}{N} \sum_{k=j+1}^{k=j+N} \Delta \mathrm{T}(\mathrm{k}).$$

[0138] The **height** (UH) of the user is taken into account at step S42, namely **length(P)** = **F1 (UH)**

[0139] Also any combination of **age** (UA), **gender** (UG), and **weight** (UW), of the user may additionally be taken into account at step /S42/, namely **length(P) = F2 (UH,UA,UG,UW).**

[0140] Arterial stiffness **AS** can be defined as a function of **PWV.** AS can be expressed as a rating between 1 and 10 ; it can also be expressed as an equivalent age of the person. Arterial stiffness **AS** is referred to as step **/S5/.**

[0141] Fig 14 shows a summary of the above mentioned steps /S0/ to /S5/, with a repetition until stop criterion (SC) becomes true (in other words criterion is met).

[0142] An optional step referred to as step /S6/ consists in transmitting the resulting data and parameters to the smartphone 85 over the wireless link. Please note that alternatively this transmission can be continuous all along the process, ECG signal and/or phonocardiogram can be displayed in real time on the smartphone application. Transmission of resulting data and parameters can also be done by packets, for example one packet after blood pressure values are obtained (BP procedure) and another packet after PTT Procedure.

[0143] A plurality of subsequent evaluations of Pulse Wave Velocity are recorded for a particular user to form a history curve, and a deviation in said curve is notified to said particular user.

[0144] It should be noted that the disclosed device has complete power autonomy; According to a particular option, the device is formed as an integral unit, there is no external wire, not external hose, therefore style and practicality are enhanced.

Summary of Cardiovascular parameters/functions that can be monitored by the device :

[0145] As already mentioned, Diastolic blood pressure **PTD,** and systolic blood pressure **PTS** can be obtained from the blood pressure procedure, as a motion of blood pressure cuff.

[0146] Also, as described before, PTT procedure allows to determine the arterial stiffness.

[0147] Also, heart rate **HR** can be inferred from ECG signals 91, from phonocardiogram signals 95, or from oscillometric signals 96, by measuring the average time separation between two heartbeats and deducing therefrom the number of heartbeat and minute.

[0148] HR variability is also calculated, over at least three subsequent heartbeats.

[0149] Also, the device can perform ECG signal analysis, for detection of arrhythmia, as known per se. Some anomalies in ECG signal 91 can be identified and associated to a type of arrhythmia, such as arterial fibrillation.

[0150] Also, the device can perform a phonocardiogram analysis for detection of heart anomalies responsible for so-called heart murmurs. In particular, some anomalies in phonocardiogram signal 95 can be identified and associated to a valvulopathy, concerning any of the mitral, tricupside, aortic, or pulmonary valves.

[0151] ECG analysis and phonocardiogram analysis can be carried out simultaneously with the PTT procedure, or separately, namely before or after PTT procedure.

[0152] As illustrated at figure 12, ECG analysis can be performed all along and at any time. According to one option, though ECG analysis is suspended whenever the electric motor is energized to run the pump (this produce electromagnetic interference detriment as to ECG signals).

[0153] Regarding the phonocardiogram analysis, it is for example carried out when no intrinsic source of noise is present, for example during the constant pressure sequence for PTT determination.

[0154] As shown at figure 13, pressure signals are sensed by pressure sensor 61 and made available at the microcontroller **6.** According to one option the microcontroller 6 digitizes the signal and then applies a digital bandpass filter. For example a band range of [0,3Hz - 3kHz] or [0,5Hz - 1kHz] can be used.

[0155] The microcontroller **6** identifies wave pulses and determines values characteristics of said pulses, i.e. amplitude, time position, apexes, derivatives, Q-factor,...

System, application and remote patient monitoring

[0156] The user can follow his/her own metrics on a smartphone application.

[0157] The device can be used by more than one user, selection of relevant user can be done through the local display 67 or through the smartphone application. When actuated, directly on the device, the activation switch 16 can be used to scroll across several users names.

[0158] There is provided a Micro USB connection **69** for battery recharge and for up/downloading of data.

[0159] The smartphone application can display a history of measurement reports, which can include BP, PTT, ECG signals, phonocardiograms.

[0160] It should be noted that phonocardiogram can be replayed via the smartphone application and the loudspeaker/headphones coupled to the smartphone.

[0161] Smartphone application can issue time reminders for the user, so the user can measure cardiovascular parameters regularly with the integrated device **10.**

[0162] The integrated device **10** is configured to send an alert to the physician whenever some particular thresholds are exceeded or when particular events are detected, such as an episode of arrhythmia. Such thresholds regarding blood pressure can be defined either by the user him/herself or by the physician/doctor.

[0163] The user can add the contextual note(s), such as medicine intake or a life circumstance (just after wake-up, just before going to bed), to one or more measurement reports.

[0164] Measurement reports can be sent remotely to a server that can be accessed the physician/doctor, so that the physician can analyze the patient's data from a distant location.

[0165] The system allows remote analysis of ECG signals; the user can receive in return the diagnostic from the physician.

[0166] Although the drawings and the text above mainly focus on an example with an armband placed around the left arm, it should be understood that the predefined position where pressure signals are captured could also be somewhere else on one limb of the user, for example at the forearm, at the wrist, somewhere else on the right arm of the user, including the wrist; it is not excluded to implement the proposed method on a lower limb of the user. Of course, parameters to be used are to be adapted in particular to the length of the arterial blood path P.

[0167] Also, it is important to note that the acoustic sensor can be placed somewhere else other than the left side chest of the user, the acoustic sensor may be provided with an extension cord to electrically couple the acoustic sensor to the control unit.

[0168] Additionally, there may be provided a control unit implemented differently, not necessarily adjacent to the armband.

[0169] According to another embodiment, instead of an inflatable bladder, the system may include pressure exerting means that are different from compressed air. For example, it can be two bladders filled with water with a ballasting system. As per another example, it can be a mechanically collar with controllable restraint. Although, solutions like a set of piezoelectric actuators, or a collar with temperature dependent memory alloys are not excluded.

[0170] According to still another embodiment, instead of a pressure sensor, at least one blood circulation parameter like the instantaneous local speed can be sensed by a Doppler effect sensor placed adjacent to a surface blood vessel.

Claims

1. A method to collect cardiovascular data relating to an individual user (U), in a system comprising an acoustic sensor (4) configured to be coupled to the chest of the user, a blood sensor configured to be placed at a predefined position *at the user's body,* an arterial blood path (P) being defined from the heart to the predefined position, the method comprising a set of steps named PTT procedure :

    /A1/- acquiring acoustic signals at the acoustic sensor,
    /A2/- acquiring of blood circulation signals at the blood sensor, image of instantaneous blood circulation parameters prevailing at the predefined position,
    /S1/- determining aortic valve closing instant T1(k) from acoustic signals,
    /S2/- determining subsequently, from blood cir-

culation signals, a characteristic point (M2) occurring at instant T2(k),

/S3/- calculate a time difference, defined as $\Delta T(k) = T2(k) - T1(k)$

/Sloop/- repeating, for each heartbeat, steps /S1/ to /S3/ until a stop criterion (SC) is met.

2. The method according to claim 1, wherein the system comprises means for exerting pressure around a limb of the user, at the predefined position, and the blood sensor may be a pressure sensor, wherein blood fluid circulation parameters signals are pressure signals,
and wherein the method comprises, prior to step /S1/ :

/S0/ - exert a predetermined pressure (PT1)

And at step /S2/ the characteristic point (M2) is determined from a pressure signal curve.

3. The method according to claim 2, wherein the means for exerting pressure is a band (2) having an inflatable bladder (53) configured to be placed at the predefined position, a pneumatic unit with at least a pump (7), the pressure sensor being configured to be fluidly connected to the inflatable bladder.

4. The method according to claim 3, wherein, the predefined position *is* at the left arm (BG) of the user, the band (2) is an arm band and is configured to be placed around the left arm of the user.

5. The method according to claim 2, wherein the characteristic point (M2) of the pressure signal curve is defined as a succession of a maximum apex (M1) and a minimum apex (M2), said instant T2(k) being defined as the instant when said minimum apex occurs.

6. The method according to any of the claims 1 to 5, wherein the system comprises a set of contact electrodes (3) for electrocardiographic sensing, configured to be brought in contact with the skin of the user U, the method comprising the steps:

/A3/- acquiring ECG signals at the contact electrodes,

/S10/ - determining a characteristic QRS signal from ECG signals as a synchronization signal (TO) reflecting heartbeat.

7. The method according to any of the claims 1 to 6, wherein the aortic valve closing instant **T1(k)** is defined as a second significant sound (B2) of the heartbeat.

8. The method according to claim 7, wherein at step /S1/, the aortic valve closing instant **T1(k)** is determined as follows :

/S11/- identifying a first significant sound (B1) of the heartbeat, reflecting mitral valve closing, just following QRS signal at T0,

/S12/- identifying a second significant sound (B2) of the heartbeat, reflecting aortic valve closing, and record said second significant sound (B2) as instant T1(k).

9. The method according to any of the claims 1 to 8, wherein the method comprises, before the PTT procedure, a preliminary set of steps named **Blood Pressure procedure** comprising the steps :

/Ph1/- start inflating the bladder,

/Ph2/- stop inflating the bladder (when no more pressure wave is identified),

/Ph3/- start deflating the bladder,

meanwhile are performed the following steps :

/PhS/ - determining Systolic Blood pressure (PTS), during inflating phase and/or deflating phase

/PhD/ - determining Diastolic Blood pressure (PTD), during inflating phase and/or deflating phase

10. The method according to claim 9, wherein prior to steps /S1/ to /S3/, the predetermined pressure **PT1**, providing pressurization for PTT procedure, is calculated with reference to the diastolic pressure (PTD) determined at step /PhD/.

11. The method according to any of the claims 1 to 10, wherein during PTT procedure, pump is not energized and a bleeder valve comprised in the pneumatic unit is not energized.

12. The method according to any of the claims 1 to 11, further comprising :

/S41/ - calculate an average value **ΔTav** of **ΔT(k)**, for **k=j to j+N**

/S42/- calculate a Pulse Wave Velocity (PWV) defined as **PWV(k) = length(P) / ΔTav,**

/S5/- assess therefrom an arterial stiffness (AS) of the user.

13. The method according to claim 12, wherein the **height** (UH) of the user is taken into account at step /S42/, namely **length(P) = F1 (UH).**

14. The method according to claim 12, wherein subsequent evaluations of Pulse Wave Velocity are recorded for a particular user (U) to form a history curve, and a deviation in said curve is notified to said particular user.

15. A system comprising an acoustic sensor (4) configured to be coupled to the chest of the user, a blood sensor configured to be placed at a predefined position *at the user's body,* an arterial blood path (P) being defined from the heart to the predefined position,
characterized in that the system is configured to carry out the method comprising a set of steps named PTT procedure:

/A1/- acquiring acoustic signals at the acoustic sensor,
/A2/- acquiring of blood circulation signals at the blood sensor, image of instantaneous blood circulation parameters prevailing at the predefined position,
/S1/- determining aortic valve closing instant T1(k) from acoustic signals,
/S2/- determining subsequently, from blood circulation signals, a characteristic point (M2) occurring at instant T2(k),
/S3/- calculate a time difference, defined as $\Delta \mathbf{T(k)} = \mathbf{T2(k) - T1(k)}$
/Sloop/- repeating, for each heartbeat, steps /S1/ to /S3/ until a stop criterion (SC) is met.

16. A computer readable medium encoded with instructions that, when executed by a computer, cause performance of a method in a system comprising an acoustic sensor (4) configured to be coupled to the chest of the user, a blood sensor configured to be placed at a predefined position *at the user's body,* an arterial blood path (P) being defined from the heart to the predefined position, the method comprising a set of steps named PTT procedure:

/A1/- acquiring acoustic signals at the acoustic sensor,
/A2/- acquiring of blood circulation signals at the blood sensor, image of instantaneous blood circulation parameters prevailing at the predefined position,
/S1/- determining aortic valve closing instant T1(k) from acoustic signals,
/S2/- determining subsequently, from blood circulation signals, a characteristic point (M2) occurring at instant T2(k),
/S3/- calculate a time difference, defined as $\Delta \mathbf{T(k)} = \mathbf{T2(k) - T1(k)}$
/Sloop/- repeating, for each heartbeat, steps /S1/ to /S3/ until a stop criterion (SC) is met.

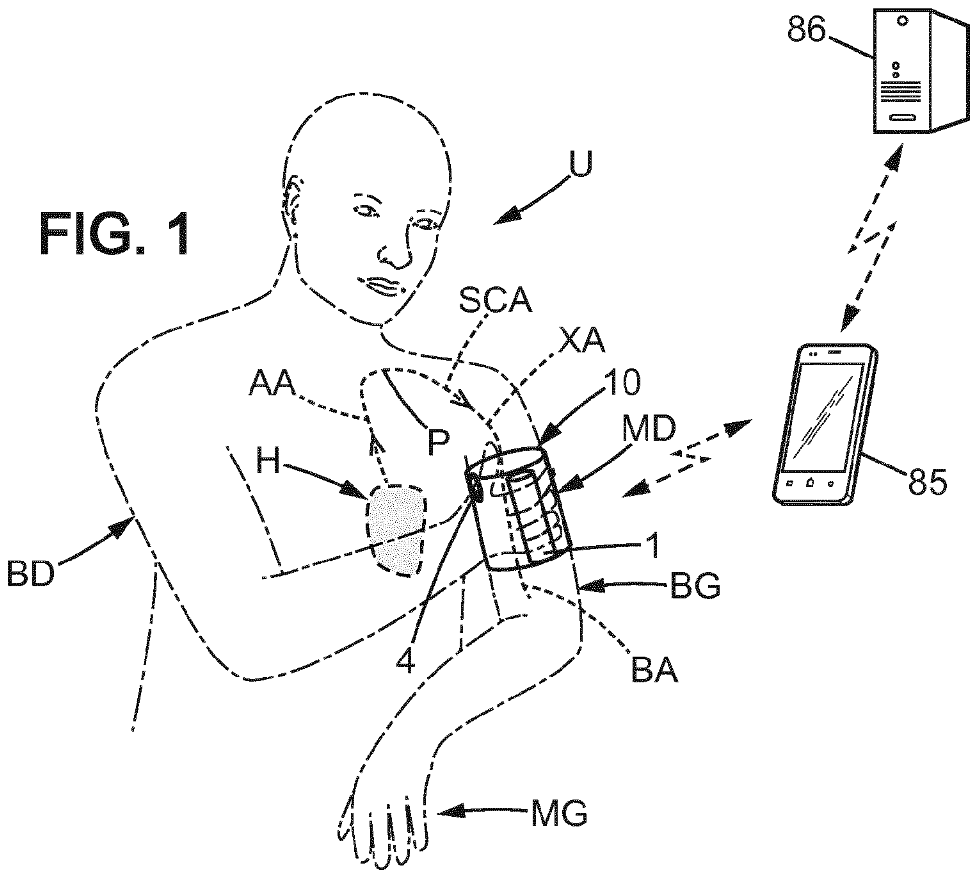

86
U
SCA
XA
AA
10
MD
H
P
85
1
BG
BD
4
BA
MG

FIG. 1

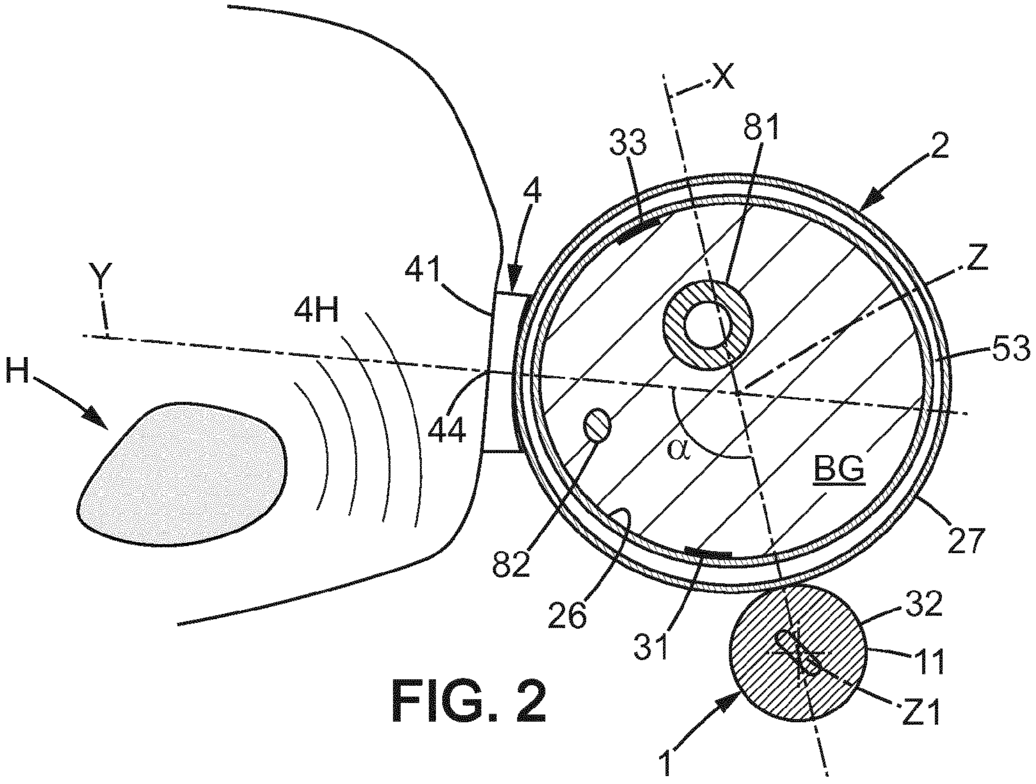

X
33
81
2
4
41
Y
4H
Z
H
53
44
α
BG
27
82
26
31
32
11
Z1
1

FIG. 2

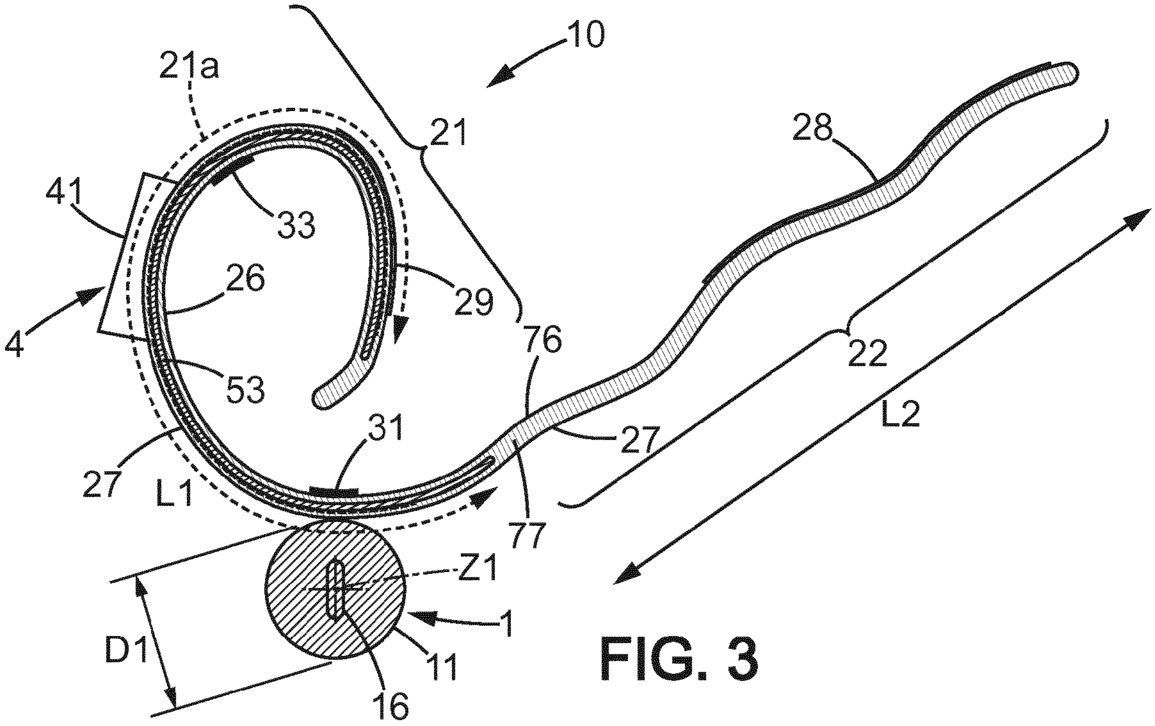

10
21a
21
28
41
33
26
29
4
76
22
53
31
27
L2
27
L1
77
Z1
D1
1
11
16

FIG. 3

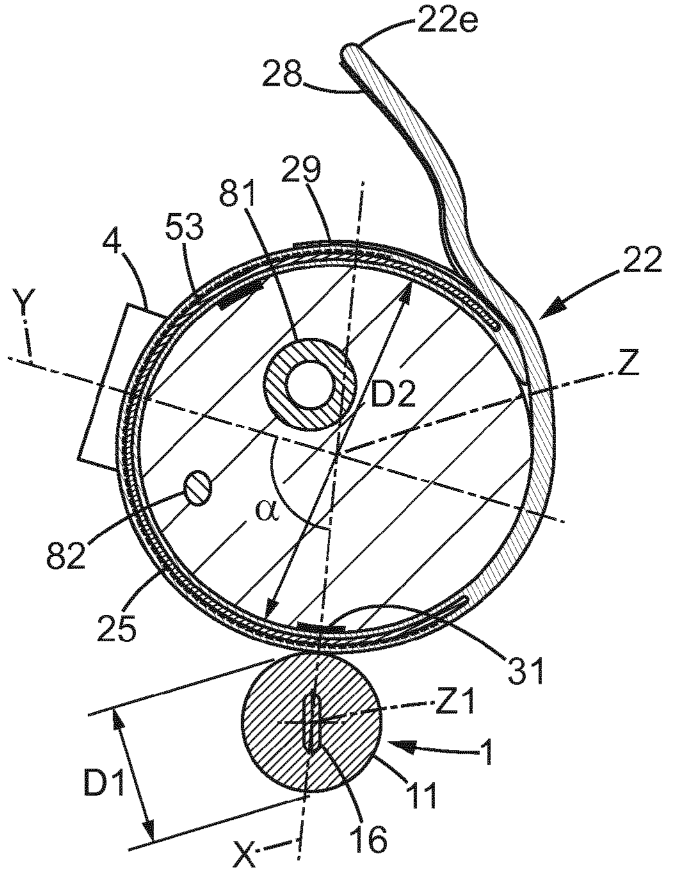

22e
28
29
81
53
22
4
Y
Z
D2
α
82
25
31
Z1
D1
1
11
16
X

FIG. 4

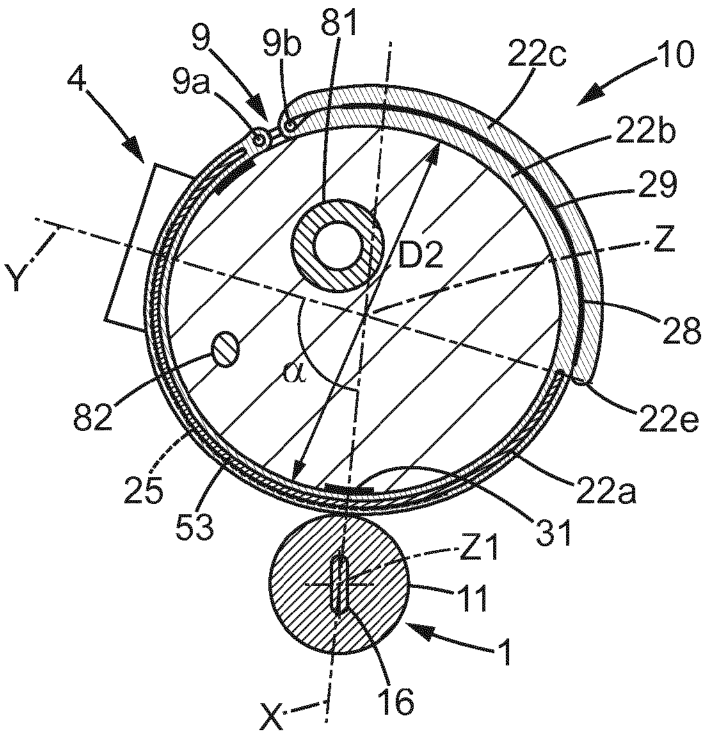


FIG. 5

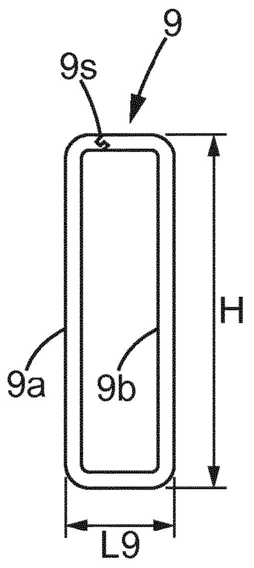


FIG. 6

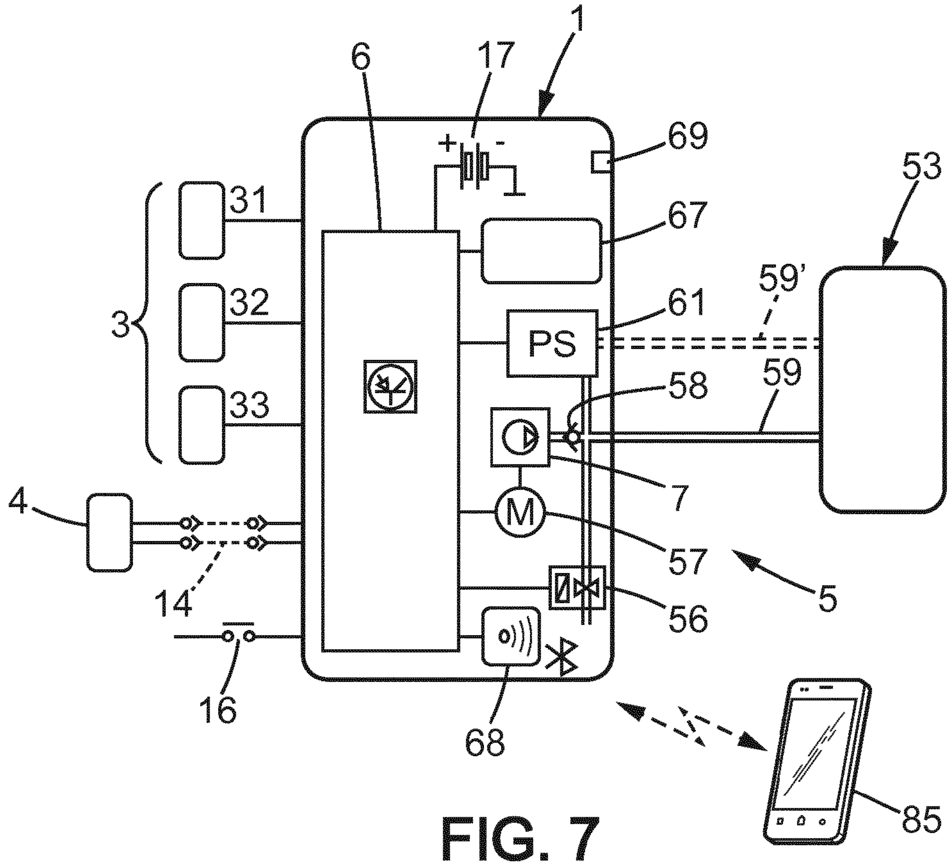


FIG. 7

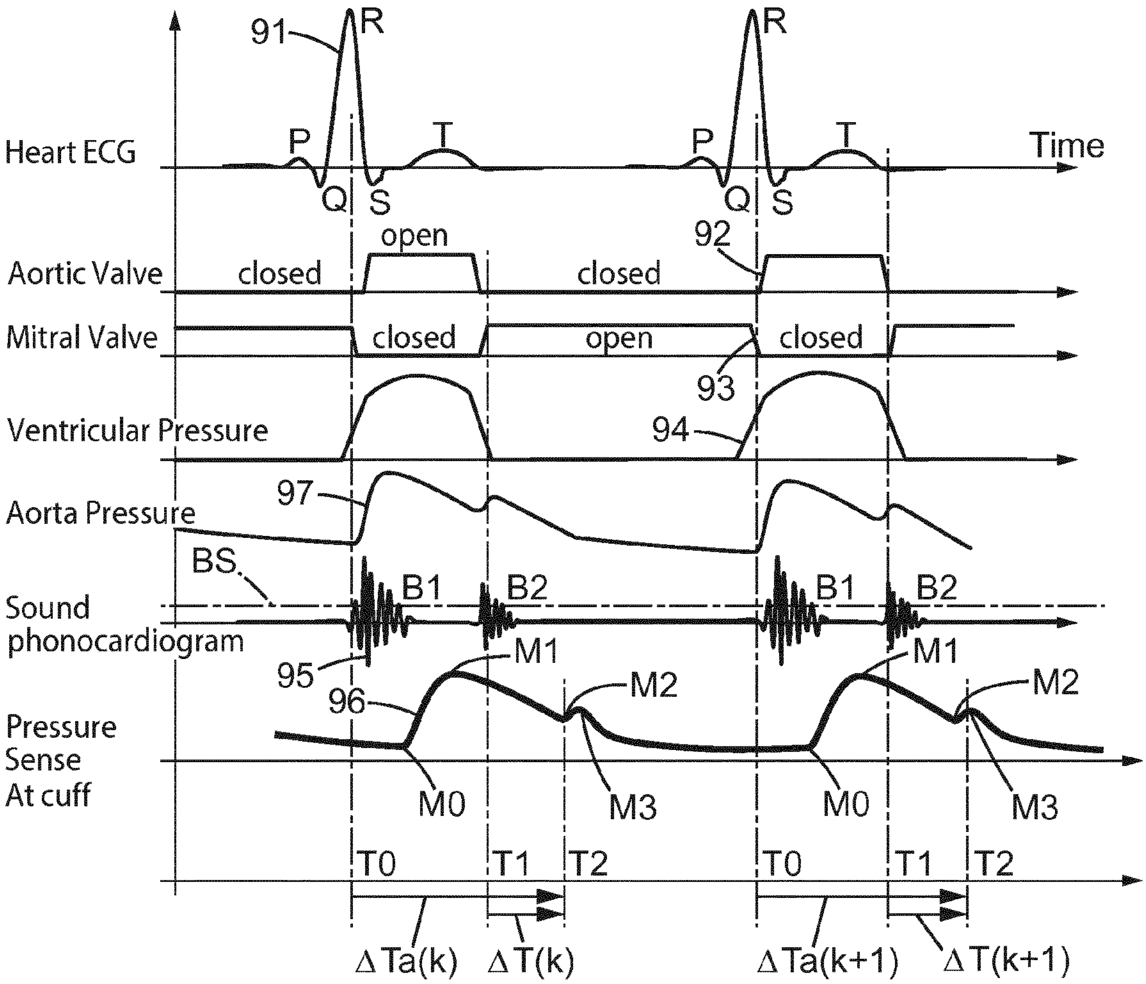

Heart ECG
91
R
P
T
Q
S
Time
Aortic Valve
closed
open
closed
92
Mitral Valve
closed
open
closed
93
Ventricular Pressure
94
Aorta Pressure
97
BS
Sound phonocardiogram
B1
B2
95
96
M1
M2
Pressure Sense At cuff
M0
M3
T0
T1
T2
ΔTa(k)
ΔT(k)
ΔTa(k+1)
ΔT(k+1)

FIG. 8

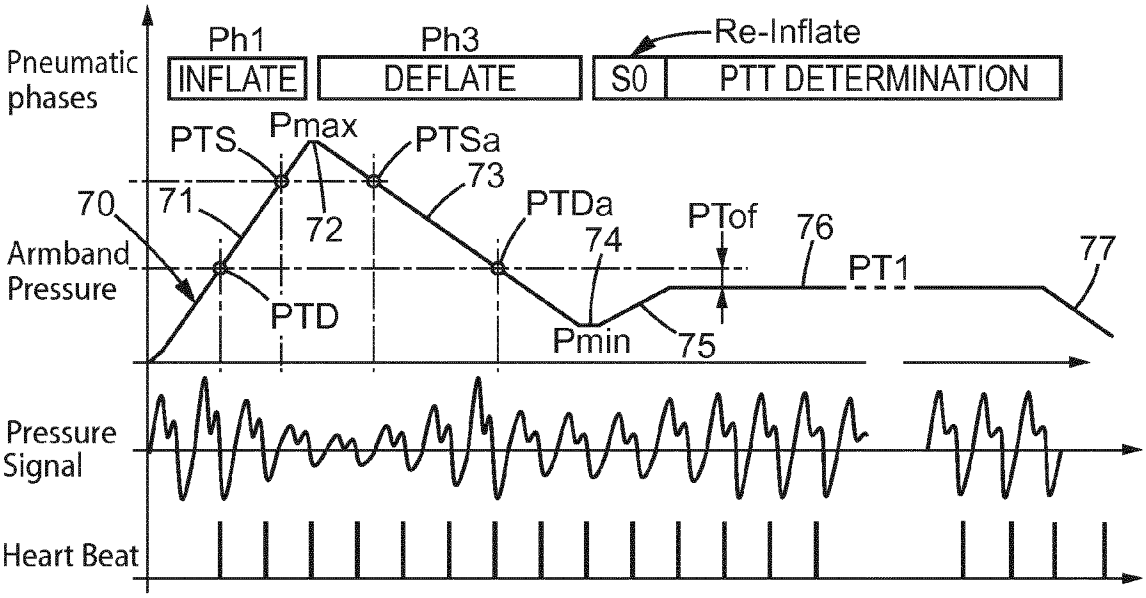

Pneumatic phases
Ph1
INFLATE
Ph3
DEFLATE
Re-Inflate
S0
PTT DETERMINATION
Armband Pressure
70
71
PTS
Pmax
72
PTSa
73
PTDa
74
PTD
Pmin
75
PTof
76
PT1
77
Pressure Signal
Heart Beat

FIG. 9

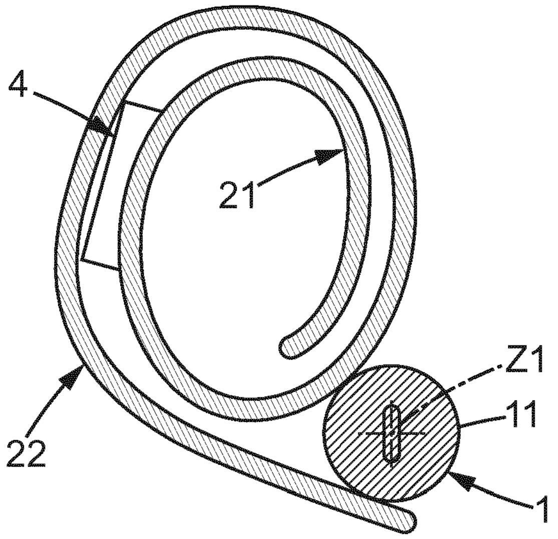


FIG. 10

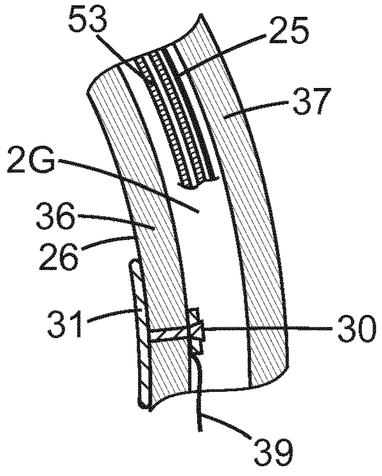


FIG. 15

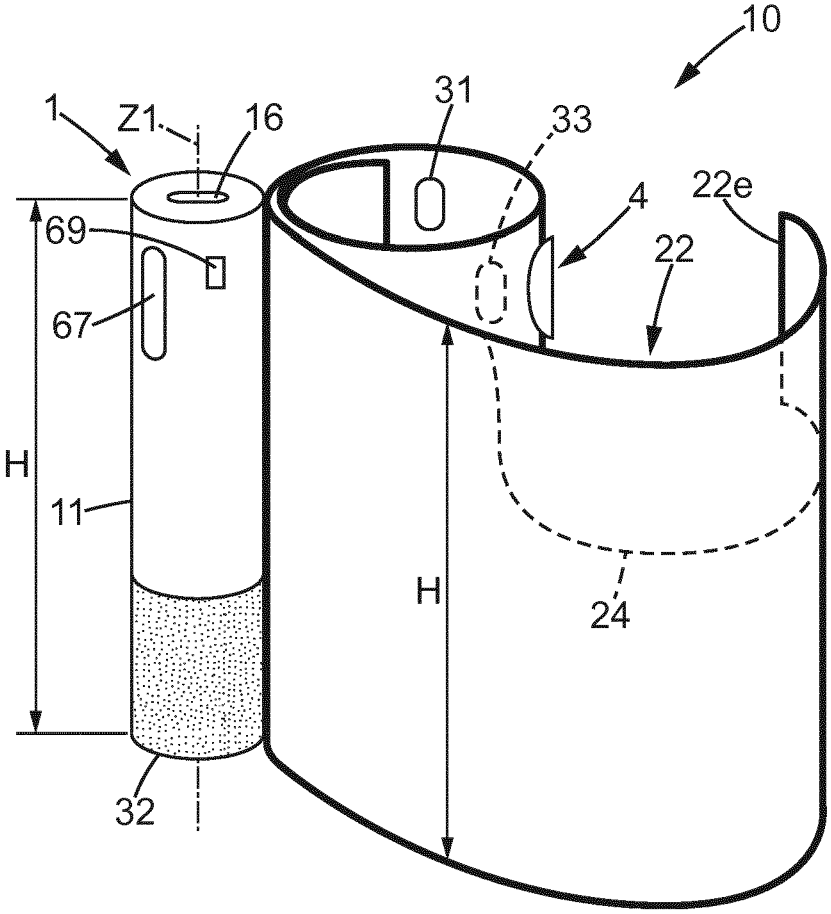


FIG. 11

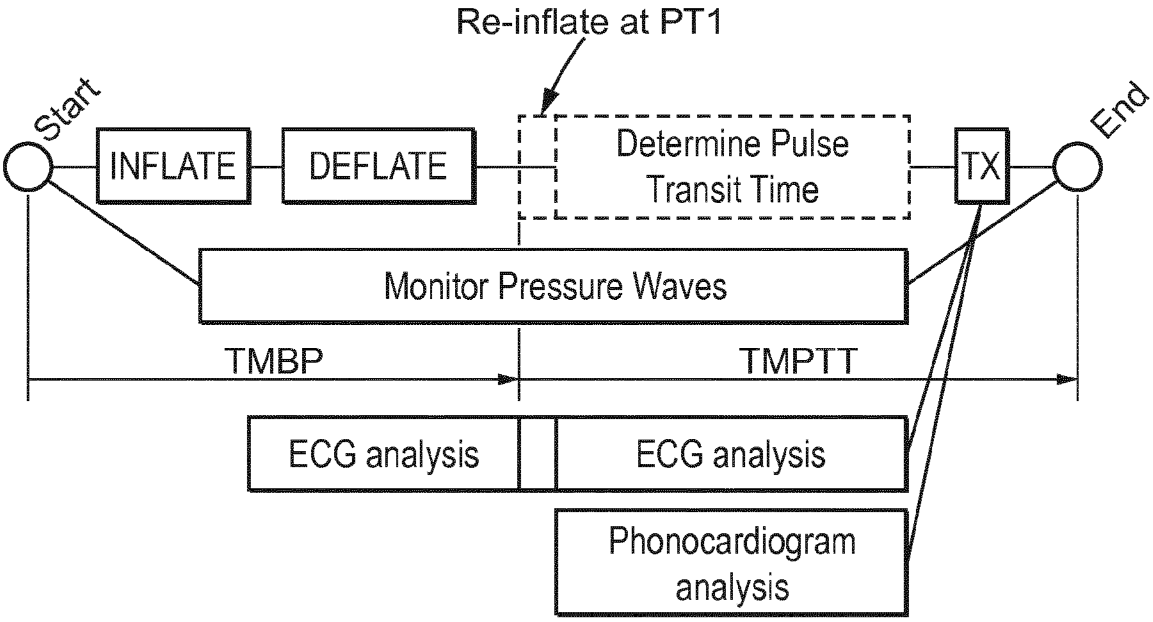


FIG. 12

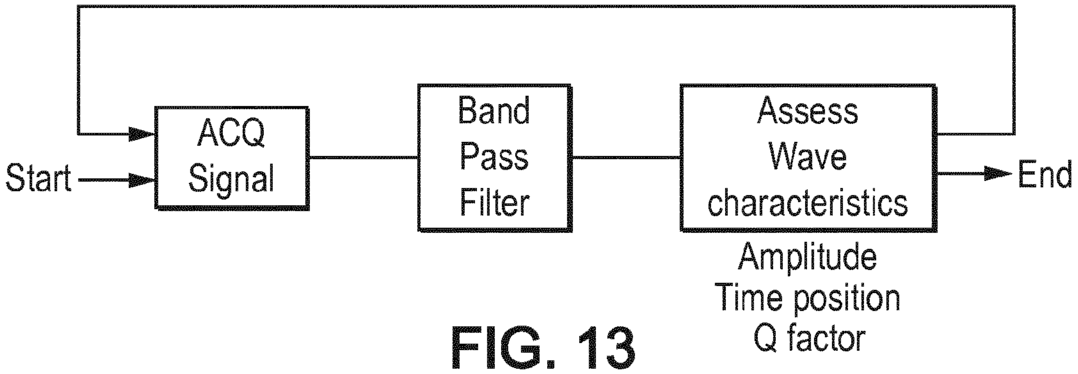


FIG. 13

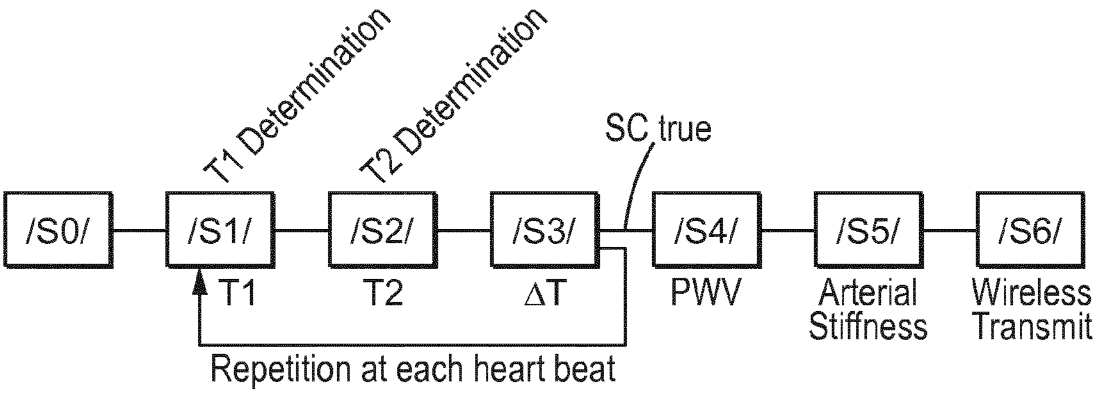


FIG. 14

Europäisches
Patentamt
European
Patent Office
Office européen
des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 16 1116

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2003/220577 A1 (BARTELS KEITH A [US] ET AL) 27 November 2003 (2003-11-27) * abstract * * paragraphs [0007], [0046], [0049], [0053], [0054], [0057] * * figures 5, 7 * -----	1-16	INV. A61B5/021 A61B7/04 A61B5/022 ADD. A61B5/0402 A61B5/00
X	US 2016/287172 A1 (MORRIS DANIEL [US] ET AL) 6 October 2016 (2016-10-06) * paragraphs [0071] - [0074] * -----	1,15,16	
X	US 2015/374244 A1 (YOO HOI JUN [KR] ET AL) 31 December 2015 (2015-12-31) * paragraphs [0014] - [0027] * * paragraphs [0072] - [0077] * -----	1,15,16	

TECHNICAL FIELDS SEARCHED (IPC)
A61B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	14 September 2017	Kowalczyk, Szczepan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 16 1116

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

14-09-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003220577 A1	27-11-2003	AU 2003222638 A1	03-11-2003
		AU 2003225066 A1	03-11-2003
		JP 2005523066 A	04-08-2005
		JP 2006505300 A	16-02-2006
		US 2003220577 A1	27-11-2003
		US 2003220584 A1	27-11-2003
		WO 03088838 A1	30-10-2003
		WO 03088841 A2	30-10-2003
US 2016287172 A1	06-10-2016	TW 201639521 A	16-11-2016
		US 2016287172 A1	06-10-2016
		WO 2016161228 A1	06-10-2016
US 2015374244 A1	31-12-2015	CN 105163652 A	16-12-2015
		DE 112014000736 T5	22-10-2015
		KR 101408845 B1	20-06-2014
		US 2015374244 A1	31-12-2015
		WO 2014123345 A1	14-08-2014

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 20160235325 A **[0003]**

专利名称(译)	分析个体心血管参数的方法		
公开(公告)号	EP3375359A1	公开(公告)日	2018-09-19
申请号	EP2017161116	申请日	2017-03-15
[标]申请(专利权)人(译)	诺基亚技术有限公司		
申请(专利权)人(译)	NOKIA TECHNOLOGIES OY		
当前申请(专利权)人(译)	NOKIA TECHNOLOGIES OY		
[标]发明人	MERLOT ANTOINE CAMPO DAVID VISSAC VIRGINIE BALTI HAIKEL		
发明人	MERLOT, ANTOINE CAMPO, DAVID VISSAC, VIRGINIE BALTI, HAÏKEL		
IPC分类号	A61B5/021 A61B7/04 A61B5/022 A61B5/0402 A61B5/00		
CPC分类号	A61B5/02125 A61B5/02233 A61B5/0402 A61B5/6823 A61B7/04 A61B5/02141 A61B5/6824		
代理机构(译)	柜PLASSERAUD		
外部链接	Espacenet		

摘要(译)

一种收集与个体用户（U）有关的心血管数据的方法，该系统包括配置成耦合到用户胸部的声学传感器（4），具有可充气囊（53）的臂带（2）围绕使用者的上肢围绕预定位置放置，例如左臂（BG），具有至少一个泵（7）和压力传感器（61）的气动单元，其被配置为对该臂进行充气和放气。可膨胀的膀胱，从用户的心脏到左臂（BG）限定的动脉血液路径（P），该方法包括称为PTT过程的一组步骤：/ A1 / - 在声学传感器处获取声学信号，/ A2 / - 在压力传感器处获取压力信号，在肱动脉处发生压力的图像，/ SO / - 以预定压力（PT1）/ S1 / - 使膀胱膨胀，从声学信号确定主动脉瓣闭合时刻T1（k），/ S2 / - 随后根据压力信号确定特征点（M2）在时刻T2（k）发生的压力信号曲线，/ S3 / - 计算时间差，定义为ΔT（k）= T2（k）-T1（k）对于每个心跳，重复步骤S1至S3直到满足停止标准（SC）。

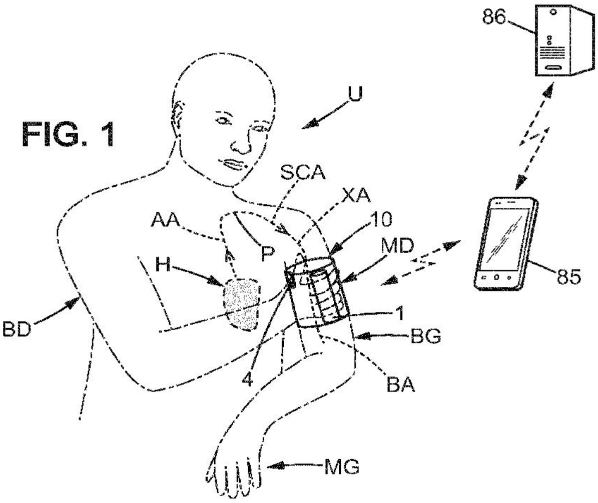


FIG. 1