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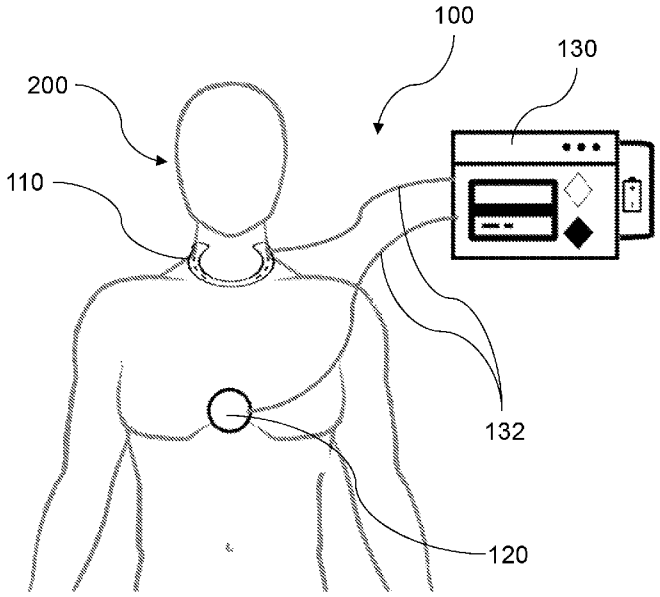

Figure 1

(57) Abstract: The present disclosure generally relates to a system (100) and method (300) for diaphragm stimulation during cardiopulmonary resuscitation of a patient (200). The system (100) comprises electrodes (112) for transmitting electrical pulses to the patient 200 to electrically stimulate the phrenic nerve and diaphragm, and sensors for measuring compressions of the chest during CPR. The system (100) further has a control device (130) for detecting decompression phases from the chest compressions, and controlling the electrodes (112) to transmit the electrical pulses in response to detection of the decompression phases, thereby synchronizing stimulation of the diaphragm with the decompression phases.

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SYSTEM AND METHOD FOR DIAPHRAGM STIMULATION DURING CPR

Cross Reference to Related Application(s)

The present disclosure claims the benefit of Singapore Patent Application No. 10202260648X filed on 30 December 2022, which is incorporated in its entirety by reference herein.

Technical Field

The present disclosure generally relates to diaphragm simulation. More particularly, the present disclosure describes various embodiments of a system and a method for diaphragm simulation during cardiopulmonary resuscitation (CPR).

Background

Cardiac arrest is a life-threatening condition where the heart suddenly stops beating and it can occur in people of all ages. Cardiac arrests can be classified into out-of-hospital cardiac arrests (OHCA) or in-hospital cardiac arrests (IHCA) depending on the location of the patient at the point of arrest. More than 356,000 people have an OHCA in the United States annually, and despite increased efforts to improve bystander CPR rates, survival to hospital discharge remains low at about 10%. IHCA numbers are also high at about 300,000 annually, albeit with a slightly higher survival rate of about 20%.

In addition, according to statistics from the American Heart Association (AHA), there was a 119% increase in OHCAs during the COVID-19 pandemic. One reason for the poor outcomes is due to limitation of traditional CPR which only provides up to 20% of the usual blood flow and oxygen to the brain. Therefore, in order to address or alleviate at least one of the aforementioned problems and/or disadvantages, there is a need to improve blood flow during CPR.

Summary

According to a first aspect of the present disclosure, there is system for diaphragm stimulation during cardiopulmonary resuscitation of a patient. The system comprises:

an electrode device comprising a set of electrodes applicable to a skin surface of the patient, the electrodes configured for transmitting electrical pulses to the patient to electrically stimulate a phrenic nerve of the patient and thereby stimulate a diaphragm of the patient;

a sensor device comprising a set of sensors applicable to the skin surface of the patient, the sensors configured for measuring compressions of a chest of the patient during cardiopulmonary resuscitation; and

a control device configured for:

detecting decompression phases from the chest compressions measured by the sensors; and

controlling the electrodes to transmit the electrical pulses in response to detection of the decompression phases, thereby synchronizing stimulation of the diaphragm with the decompression phases.

According to a second aspect of the present disclosure, there is a method for diaphragm stimulation during cardiopulmonary resuscitation of a patient. The method comprises:

measuring, using a set of sensors applied to a skin surface of the patient, compressions of a chest of the patient during cardiopulmonary resuscitation;

detecting, using a control device, decompression phases from the chest compressions measured by the sensors;

controlling, using the control device, a set of electrodes applied to the skin surface of the patient to transmit electrical pulses in response to detection of the decompression phases;

transmitting, using the electrodes, the electrical pulses to the patient to electrically stimulate a phrenic nerve of the patient and thereby stimulate a diaphragm of the patient; and

synchronizing, using the control device, stimulation of the diaphragm with the decompression phases.

A system and method for diaphragm stimulation during cardiopulmonary resuscitation according to the present disclosure are thus disclosed herein. Various features, aspects, and advantages of the present disclosure will become more apparent from the following detailed description of the embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

Brief Description of the Drawings

Figure 1 is an illustration of a system for diaphragm stimulation during cardiopulmonary resuscitation.

Figures 2A to 2D are various illustrations of an electrode device of the system for diaphragm stimulation during cardiopulmonary resuscitation.

Figures 3A to 3D are various illustrations of a sensor device of the system for diaphragm stimulation during cardiopulmonary resuscitation.

Figure 4 is a flowchart illustration of a method for diaphragm stimulation during cardiopulmonary resuscitation.

Figure 5 is another flowchart illustration of the method for diaphragm stimulation during cardiopulmonary resuscitation.

Detailed Description

For purposes of brevity and clarity, descriptions of embodiments of the present disclosure are directed to a system and method for diaphragm stimulation during cardiopulmonary resuscitation, in accordance with the drawings. While aspects of the present disclosure will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and equivalents to the embodiments described herein,

which are included within the scope of the present disclosure as defined by the appended claims. Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that the present disclosure may be practiced without specific details, and/or with multiple details arising from combinations of aspects of particular embodiments. In a number of instances, well-known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the embodiments of the present disclosure.

In embodiments of the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith.

References to “an embodiment / example”, “another embodiment / example”, “some embodiments / examples”, “some other embodiments / examples”, and so on, indicate that the embodiment(s) / example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore, repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does not necessarily refer to the same embodiment / example.

The terms “comprising”, “including”, “having”, and the like do not exclude the presence of other features / elements / steps than those listed in an embodiment. Recitation of certain features / elements / steps in mutually different embodiments does not indicate that a combination of these features / elements / steps cannot be used in an embodiment.

As used herein, the terms “a” and “an” are defined as one or more than one. The use of “/” in a figure or associated text is understood to mean “and/or” unless otherwise

indicated. The term "set" is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least one (e.g. a set as defined herein can correspond to a unit, singlet, or single-element set, or a multiple-element set), in accordance with known mathematical definitions. The recitation of a particular numerical value or value range herein is understood to include or be a recitation of an approximate numerical value or value range.

In representative or exemplary embodiments of the present disclosure, there is a system 100 for diaphragm stimulation during cardiopulmonary resuscitation or CPR of a patient 200. The system 100 includes an electrode device 110, a sensor device 120, and a control device 130.

The electrode device 110 and sensor device 120 are non-invasive devices that can be attached to the skin surface of the patient 200 without hurting the patient 200. For example, the electrode device 110 can attached and aligned to the phrenic nerve or diaphragm, such as on the neck of the patient 200. The electrical pulses transmitted by the electrodes 112 stimulate the phrenic nerve and diaphragm.

The electrode device 110 includes a set of electrodes 112 applicable to a skin surface of the patient 200. The electrodes 112 are configured for transmitting electrical pulses to the patient 200 to electrically stimulate the phrenic nerve of the patient 200 and thereby stimulate the diaphragm of the patient 200. Notably, the phrenic nerve is a bilateral nerve that extends from the neck through the thorax to the diaphragm. In some embodiments, the electrodes 112 are individually placed on the skin surface of the patient 200. In some embodiments as shown in Figure 2A, the electrode device 110 includes a substrate 114 attachable to the skin surface of the patient 200, wherein the electrodes 112 are arranged on the substrate 114. The electrodes 112 may be arranged as a single electrode, such as an electrode strip, or an array of multiple electrodes on the substrate 114.

In one embodiment as shown in Figure 2B, the electrode device 110 includes a substrate 114 in the form of a snap band that can be changed between an open state and a closed state. In the closed state, the snap band can be attached at least partially

around the neck of the patient 200. In one embodiment as shown in Figure 2C, the electrode device 110 includes a substrate 114 in the form of a pliable band that can be attached at least partially around the neck of the patient 200. In one embodiment as shown in Figure 2D, the electrode device 110 includes a substrate 114 in the form of an adhesive patch that can be attached to the torso of the patient 200 and aligned to the diaphragm.

The sensor device 120 includes a set of sensors applicable to the skin surface of the patient 200. The sensors are configured for measuring compressions of a chest of the patient 200 during cardiopulmonary resuscitation. The sensors may include one or more of an accelerometer sensor, a pressure sensor, and a strain sensor. Multiple sensors devices 120 or multiple sensors may be arranged in multiple positions and directions to improve measurements of the chest compressions by increasing the sensitivity and reducing false measurements. For example, the sensors can be positioned at the thorax, sternal, or abdominal region to detect movements in these regions that result from the chest compressions. Each chest compression has a compression phase (when the chest is compressed and contracts) and a decompression phase (when the chest expands and decompresses, reverting to its initial uncompressed state).

In some embodiments, the sensor device 120 includes a substrate 122 attachable to the skin surface of the patient 200, wherein the sensors are arranged on the substrate 122. In one embodiment as shown in Figure 3A, the sensor device 120 includes a substrate 122 in the form of an adhesive patch that can be attached to the sternum of the patient 200, and an array of one or more accelerometer sensors 124 is arranged on the adhesive substrate 122. In one embodiment as shown in Figure 3B, the sensor device 120 includes a substrate 122 in the form of an adhesive patch that can be attached to the sternal notch of the patient 200, and an array of one or more strain sensors 126 is arranged on the adhesive substrate 122. In one embodiment as shown in Figure 3C, the sensor device 120 includes a substrate 122 comprising a pliable material and is attachable to the epigastrium of the patient 200, and an array of one or more accelerometers 124 is arranged on the pliable substrate 122.

In some embodiments as shown in Figure 3D, the sensor device 120 includes an adjustable clamp 140 that can be clamped to the chest of the patient 200. The sensor device 120 further includes one or more accelerometers 124 and/or one or more pressure sensors 128 attached to the clamp 140. For example, when the clamp 140 is in use, an accelerometer 124 is positioned at the side of the chest while a pressure sensor 128 is positioned at the front or back of the chest.

As shown in Figure 1, the electrode device 110 and sensor device 120 are connected to the control device 130 via respective cables 132. The system 100 is configured for sensor input from the sensor device 120 and concomitant electrical stimulation output from the electrode device 110. Specifically, the control device 130 is configured for detecting decompression phases from the chest compressions measured by the sensors, and for controlling the electrodes 112 to transmit the electrical pulses in response to detection of the decompression phases. The electrical pulses simulate the phrenic nerve and diaphragm of the patient in response to the decompression phases, thereby synchronizing stimulation of the diaphragm with the decompression phases.

In various embodiments of the present disclosure as shown in Figure 4, there is a method 300 for diaphragm stimulation during cardiopulmonary resuscitation of the patient 200. The method 300 includes a step 310 of measuring, using the set of sensors applied to the skin surface of the patient 200, compressions of the chest of the patient 200 during cardiopulmonary resuscitation. The method 300 includes a step 320 of detecting, using the control device 130, decompression phases from the chest compressions measured by the sensors.

For example, during a decompression phase, the sensors measure an upward movement of the chest or thorax region resulting from the chest expanding back to its initial uncompressed state. The input signal from this upward movement is sent from the sensor device 120 to the control device 130.

The method 300 includes a step 330 of controlling, using the control device 130, the set of electrodes 112 applied to the skin surface of the patient 200 to transmit the

electrical pulses in response to detection of the decompression phases. The method 300 includes a step 340 of transmitting, using the electrodes 112, the electrical pulses to the patient 200 to electrically stimulate the phrenic nerve of the patient 200 and thereby stimulate the diaphragm of the patient 200.

For example, the control device 130 receives the input signal from the sensor device 120 in response to the sensors measuring the chest upward movement in the decompression phase. The control device 130 then sends an output signal to the electrode device 110 that cause the electrodes 112 to generate the electrical pulses.

The control device 130 includes a multichannel stimulator configured to enable the electrode device 110 to deliver monophasic electrical pulses to the patient 200 via the electrodes 112 on the skin surface. The electrical pulses include one or more of a pulse duration of a predefined range, a pulse amplitude of a predefined range, and a pulse frequency of a predefined range. For example, the pulse duration ranges from 1 μs to 400 μs, and has a resolution range of 10 μs to 25 μs. For example, the pulse amplitude ranges from 1 mA to 200 mA, and has a resolution range of 1 mA to 5 mA. For example, the pulse frequency ranges from 1 Hz to 30 Hz, and has a resolution range of 1 Hz.

The method 300 includes a step 350 of synchronizing, using the control device 130, stimulation of the diaphragm with the decompression phases. The method 300 is thus able to achieve accurate timing for stimulation of the phrenic nerve and diaphragm, including the initiation, strength, duration, and frequency of the stimulation. Electrically stimulating the diaphragm contracts the diaphragm repetitively while avoiding muscle fatigue. Further, synchronizing the diaphragm contractions with the decompression phases of the CPR chest compressions increases venous return which is the rate of blood flow back to the heart. This results in increased cardiac output and increased brain oxygenation due to higher blood flow to the brain, in turn improving both cardiovascular and neurological outcomes.

In some situations, the electrode device 110 is placed on the neck and the electrical pulses may concurrently stimulate the vagus nerve of the patient 200. Stimulating the

vagus nerve may sometimes exhibit beneficial cardiac arrest outcomes for the patient 200 during cardiopulmonary resuscitation, such as via cardioprotective and neuroprotective mechanisms, including cardiovascular, cerebrovascular, and inflammatory mechanisms.

In some embodiments, the electrodes 112 transmit the electrical pulses with a predefined pulse duration, a predefined pulse amplitude, and a predefined pulse frequency. In some embodiments, the control device 130 is configured for adjusting one or more of the pulse duration, pulse amplitude, and pulse frequency of the electrical pulses based on the chest compressions. For example, the control device 130 adjust the pulse duration, pulse amplitude, and/or pulse frequency based on the magnitude and/or frequency of the chest compressions, which may be measured by the sensor device 120. This allows for complete and optimal stimulation of the phrenic nerve and for maximal contraction of the diaphragm contractions in sync with the decompression phases during cardiopulmonary resuscitation.

In some embodiments, the electrical pulses are transmitted during selected decompression phases, and the electrical pulses are not transmitted during the other decompression phases. For example, the control device 130 is configured for detecting every nth instance of the decompression phases, where n is a positive integer. Further, the control device 130 is configured for controlling the electrodes to transmit the electrical pulses in response to detection of every nth instance of the decompression phases, wherein the electrical pulses are not transmitted during the other decompression phases.

Figure 5 shows a method 400 for diaphragm stimulation during cardiopulmonary resuscitation, wherein the electrical pulses are transmitted only during the selected decompression phases. For example. n equals to 3 and the electrical pulses are transmitted only during every 3rd decompression phase.

In a step 410, the sensors measure every 3rd decompression phase based on every 3rd upward movement of the chest. In a step 420, the control device 130 receives the input signal from the sensor device 110, which is preferably completed in 50 ms or

less. In a step 430, the control device 130 sends the output signal to the electrode device 110, which is preferably completed in 50 ms or less. In a step 440, the electrodes 112 are triggered and starts to transmit the electrical pulses, such as within 50 ms or less after the electrode device 110 receives the output signal.

In a step 450, the electrodes 112 transmit the electrical pulses to the patient 200. Preferably, the electrical pulses have a pulse duration of 1 μs to 400 μs, a pulse amplitude ranges of 1 mA to 200 mA, and a pulse frequency of 1 Hz to 30 Hz. In a step 460, the electrical pulses stimulate the phrenic nerve and diaphragm, causing the diaphragm to contract in sync with the decompression phase. In a step 470, the electrodes 112 stop transmitting the electrical pulses, thus stopping stimulation of the diaphragm. The steps repeat for the next 3rd decompression phases, thus periodically stimulating the diaphragm in sync with every 3rd decompression phase.

It will be appreciated that the method 400 will be applicable for synchronizing stimulation of the diaphragm with every nth instance of the decompression phases, wherein the nth instance can be the 1st, 2nd, 3rd, or higher orders.

In some embodiments, the control device 130 is configured for performing a CPR mode and a non-CPR mode. In the CPR mode, the control device 130 performs various steps of the method 300 or 400 to synchronize the diaphragm contractions with the chest compressions during CPR. The control device 130 then switches to the non-CPR mode upon the return of spontaneous circulation (ROSC). ROSC is the restart of a sustained heart rhythm after a cardiac arrest.

For example, the control device 130 is configured for detecting ROSC in the patient 200. For example, the control device 130 may be connected to another sensor configured to measure arterial pulse palpation which is an indicator of ROSC. The control device 130 is further configured for desynchronizing the electrical pulses from the decompression phases in response to detection of the return of spontaneous circulation. The control device 130 is further configured for controlling the electrodes 112 to transmit the electrical pulses at a lower pulse amplitude and/or a lower pulse frequency after desynchronizing the electrical pulses from the decompression phases.

The phrenic nerve and diaphragm are stimulated at a lower amplitude / frequency to improve apnoeic oxygenation in the patient 200, particularly if the patient 200 has no definite airway. In the non-CPR mode, the diaphragm stimulation is timed to an optimal frequency instead of synchronicity with the decompression phases.

In some embodiments, the control device 130 is configured for communicating information to guide usage of a manual resuscitator to ventilate the patient 200 during CPR. The use of a manual resuscitator to ventilate a patient 200 is referred to as "bagging" the patient 200 and is necessary when the patient 200 has respiratory failure or respiratory arrest. The manual resuscitator force feeds air or oxygen into the lungs in order to inflate them under pressure, thus providing positive-pressure ventilation.

For example, the control device 130 includes a display screen and audio devices to generate visual and audio information. For example, the information may include a timing and a duration of using the manual resuscitator. The information can help clinicians who are bagging the patient 200 to achieve an optimal rate of bagging that augments cardiac output and brain oxygenation.

In the foregoing detailed description, embodiments of the present disclosure in relation to a system and method for diaphragm stimulation during cardiopulmonary resuscitation are described with reference to the provided figures. The description of the various embodiments herein is not intended to call out or be limited only to specific or particular representations of the present disclosure, but merely to illustrate non-limiting examples of the present disclosure. The present disclosure serves to address at least one of the mentioned problems and issues associated with the prior art. Although only some embodiments of the present disclosure are disclosed herein, it will be apparent to a person having ordinary skill in the art in view of this disclosure that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present disclosure. Therefore, the scope of the disclosure as well as the scope of the following claims is not limited to embodiments described herein.

Claims

1. A system for diaphragm stimulation during cardiopulmonary resuscitation of a patient, the system comprising:

an electrode device comprising a set of electrodes applicable to a skin surface of the patient, the electrodes configured for transmitting electrical pulses to the patient to electrically stimulate a phrenic nerve of the patient and thereby stimulate a diaphragm of the patient;

a sensor device comprising a set of sensors applicable to the skin surface of the patient, the sensors configured for measuring compressions of a chest of the patient during cardiopulmonary resuscitation; and

a control device configured for:

detecting decompression phases from the chest compressions measured by the sensors; and

controlling the electrodes to transmit the electrical pulses in response to detection of the decompression phases, thereby synchronizing stimulation of the diaphragm with the decompression phases.

2. The system according to claim 1, wherein the sensors comprise one or more of an accelerometer sensor, a pressure sensor, and a strain sensor.

3. The system according to claim 1 or 2, wherein the electrical pulses comprise:

a pulse duration of 1 μs to 400 μs;

a pulse amplitude of 1 mA to 200 mA; and/or

a pulse frequency of 1 Hz to 30 Hz.

4. The system according to claim 3, wherein the control device is configured for adjusting one or more of the pulse duration, pulse amplitude, and pulse frequency of the electrical pulses based on the chest compressions.

5. The system according to any one of claims 1 to 4, wherein the control device is configured for detecting every nth instance of the decompression phases, where n is a positive integer.

6. The system according to claim 5, wherein the control device is configured for controlling the electrodes to transmit the electrical pulses in response to detection of every nth instance of the decompression phases, wherein the electrical pulses are not transmitted during the other decompression phases.

7. The system according to claim 6, wherein the electrical pulses are transmitted during every 3rd decompression phase.

8. The system according to any one of claims 1 to 7, wherein the control device is configured for detecting return of spontaneous circulation in the patient.

9. The system according to claim 8, wherein the control device is configured for desynchronizing the electrical pulses from the decompression phases in response to detection of the return of spontaneous circulation.

10. The system according to claim 9, wherein the control device is configured for controlling the electrodes to transmit the electrical pulses at a lower pulse amplitude and/or a lower pulse frequency after desynchronizing the electrical pulses from the decompression phases.

11. The system according to any one of claims 1 to 10, wherein the control device is configured for communicating information to guide usage of a manual resuscitator to ventilate the patient during cardiopulmonary resuscitation.

12. A method for diaphragm stimulation during cardiopulmonary resuscitation of a patient, the method comprising:

measuring, using a set of sensors applied to a skin surface of the patient, compressions of a chest of the patient during cardiopulmonary resuscitation;

detecting, using a control device, decompression phases from the chest compressions measured by the sensors;

controlling, using the control device, a set of electrodes applied to the skin surface of the patient to transmit electrical pulses in response to detection of the decompression phases;

transmitting, using the electrodes, the electrical pulses to the patient to electrically stimulate a phrenic nerve of the patient and thereby stimulate a diaphragm of the patient; and

synchronizing, using the control device, stimulation of the diaphragm with the decompression phases.

13. The method according to claim 12, comprising adjusting, using the control device, one or more of a pulse duration, a pulse amplitude, and a pulse frequency of the electrical pulses based on the chest compressions.

14. The method according to claim 12 or 13, comprising detecting, using the control device, every nth instance of the decompression phases, where n is a positive integer.

15. The method according to claim 14, comprising controlling, using the control device, the electrodes to transmit the electrical pulses in response to detection of every nth instance of the decompression phases, wherein the electrical pulses are not transmitted during the other decompression phases.

16. The method according to claim 15, comprising transmitting, using the electrodes, the electrical pulses during every 3rd decompression phase.

17. The method according to any one of claims 12 to 16, comprising detecting, using the control device, return of spontaneous circulation in the patient.

18. The method according to claim 17, comprising desynchronizing, using the control device, the electrical pulses from the decompression phases in response to detection of the return of spontaneous circulation.

19. The method according to claim 18, comprising controlling, using the control device, the electrodes to transmit the electrical pulses at a lower pulse amplitude and/or a lower pulse frequency after desynchronizing the electrical pulses from the decompression phases.

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20. The method according to any one of claims 12 to 19, comprising communicating, using the control device, information to guide usage of a manual resuscitator to ventilate the patient during cardiopulmonary resuscitation.

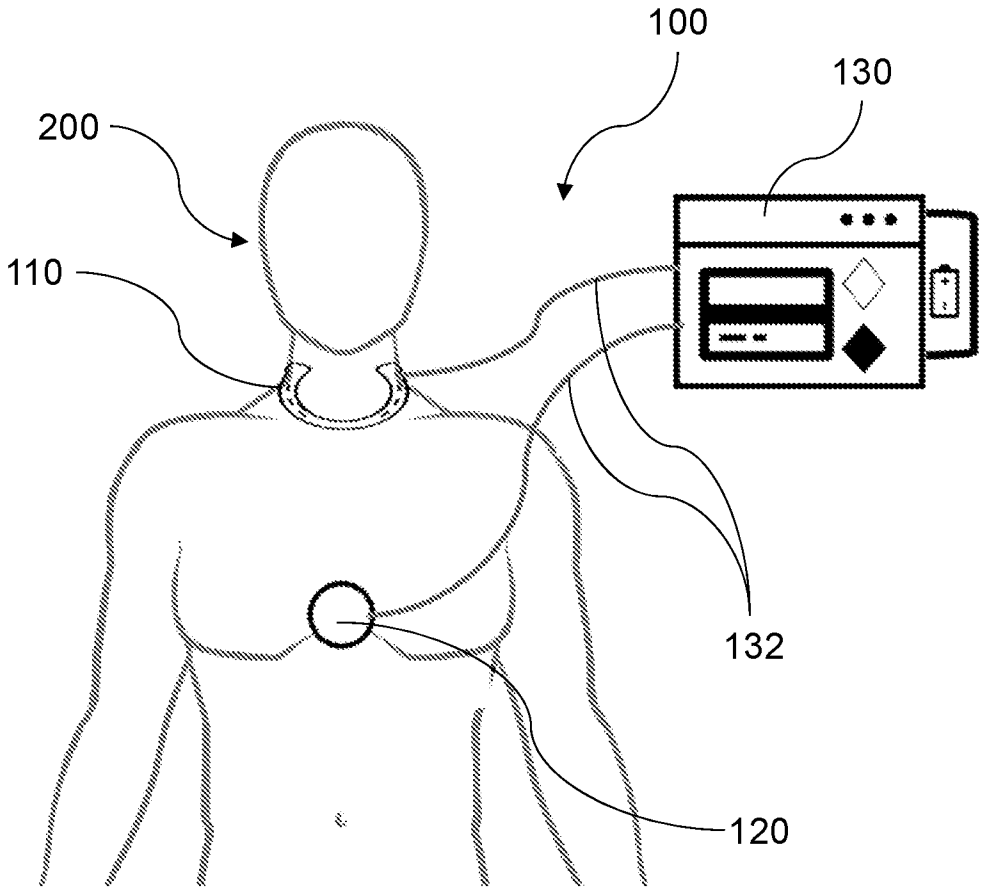

Figure 1

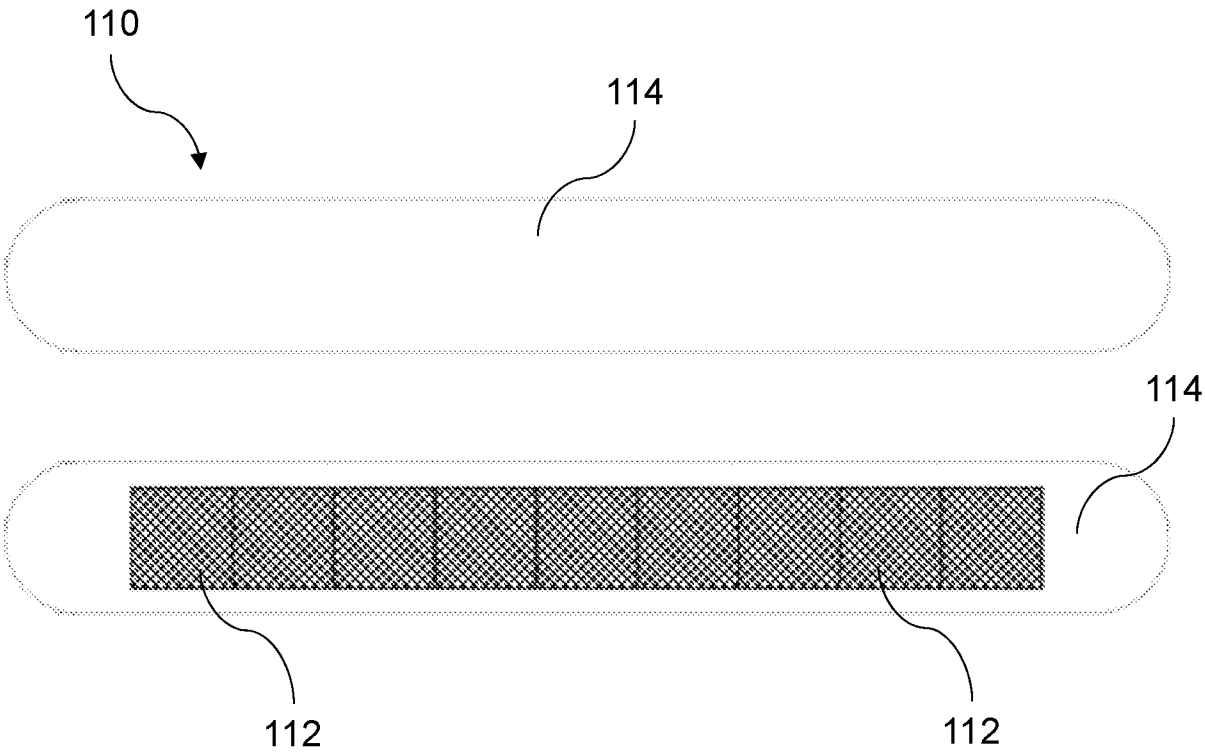

Figure 2A

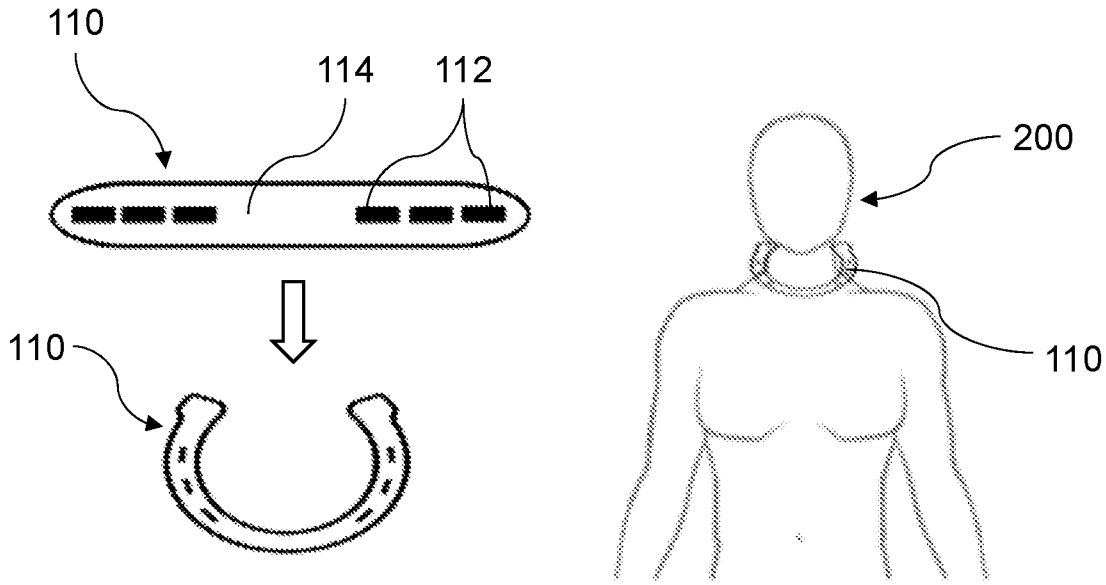

Figure 2B

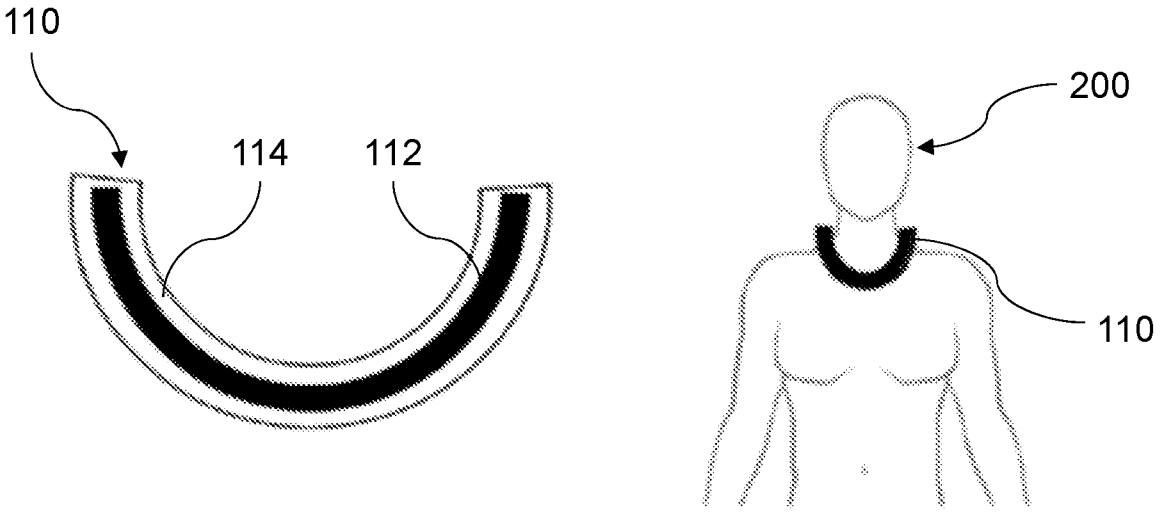

Figure 2C

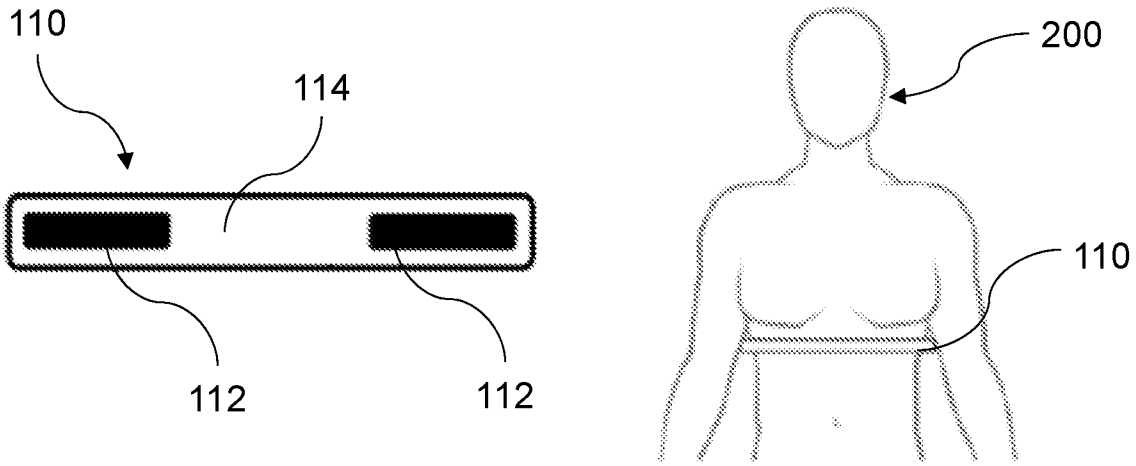

Figure 2D

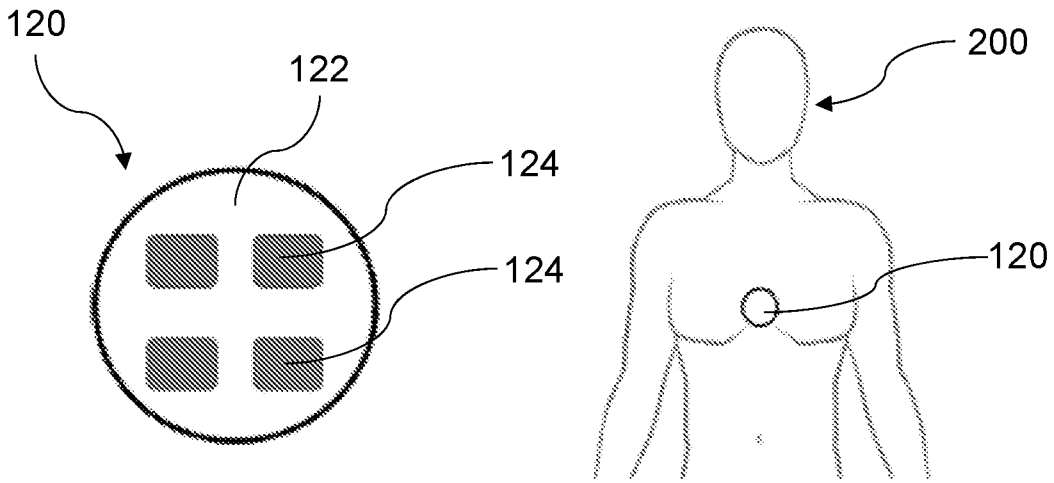

Figure 3A

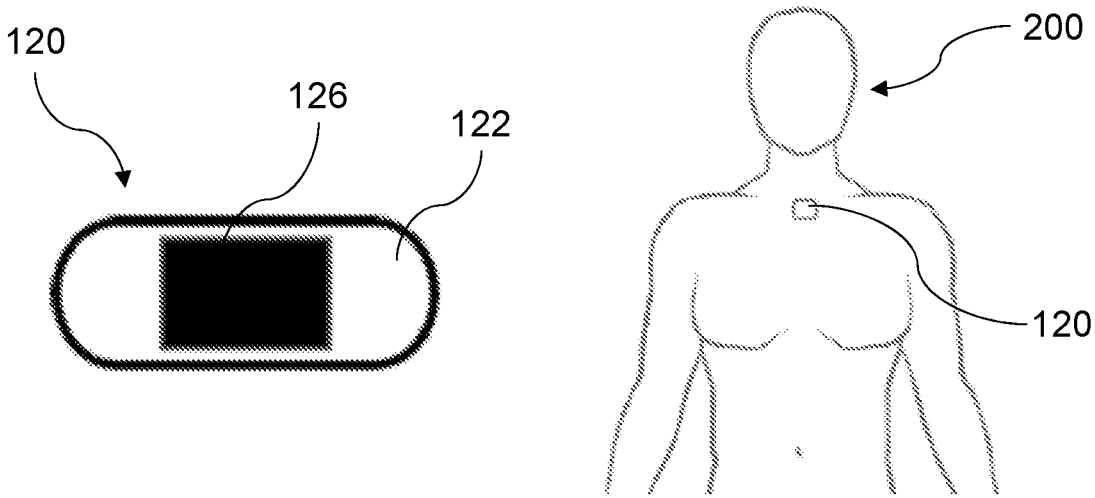

Figure 3B

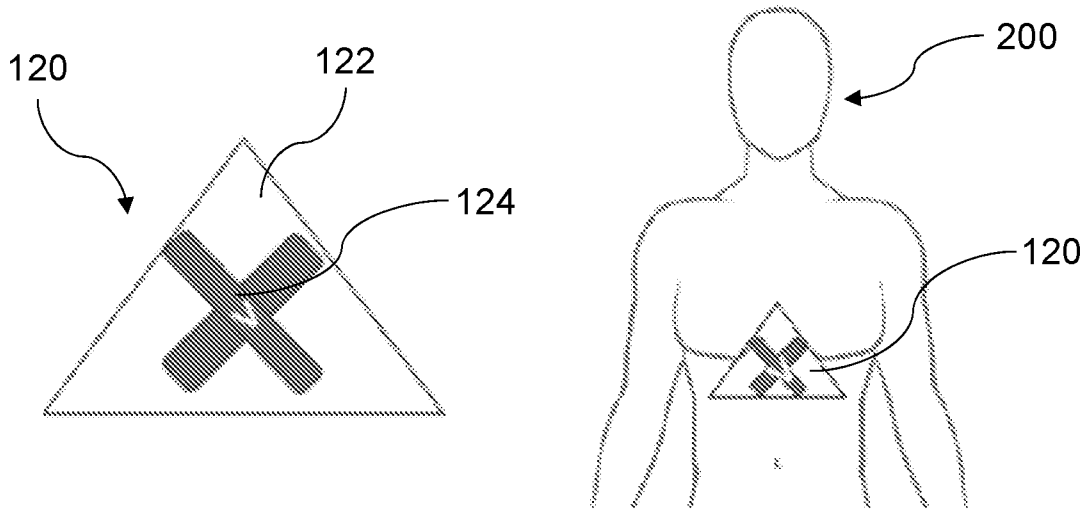

Figure 3C

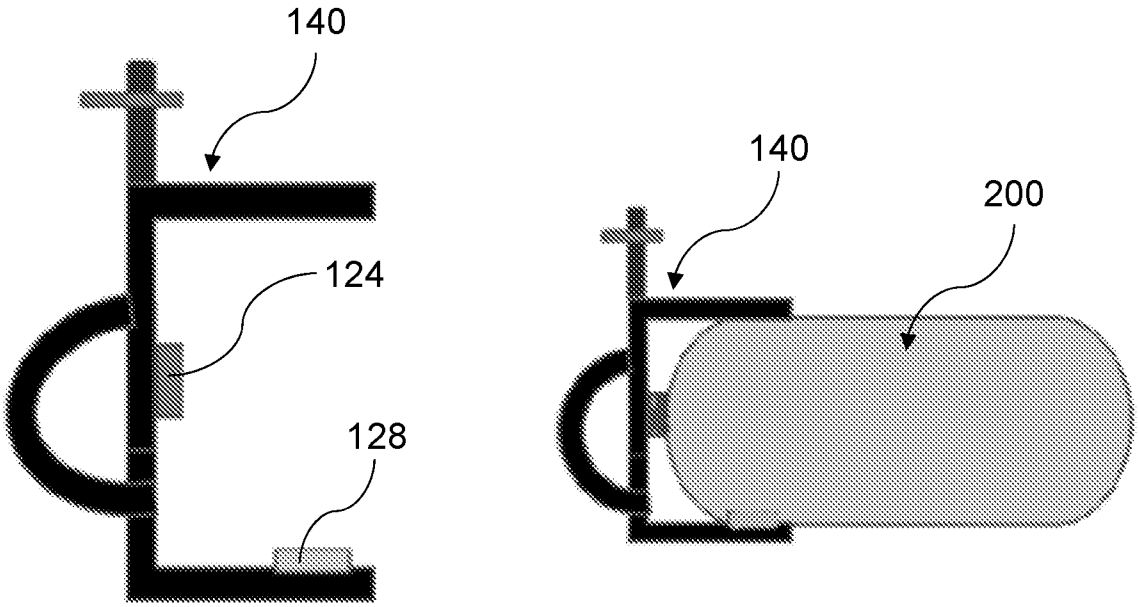

Figure 3D

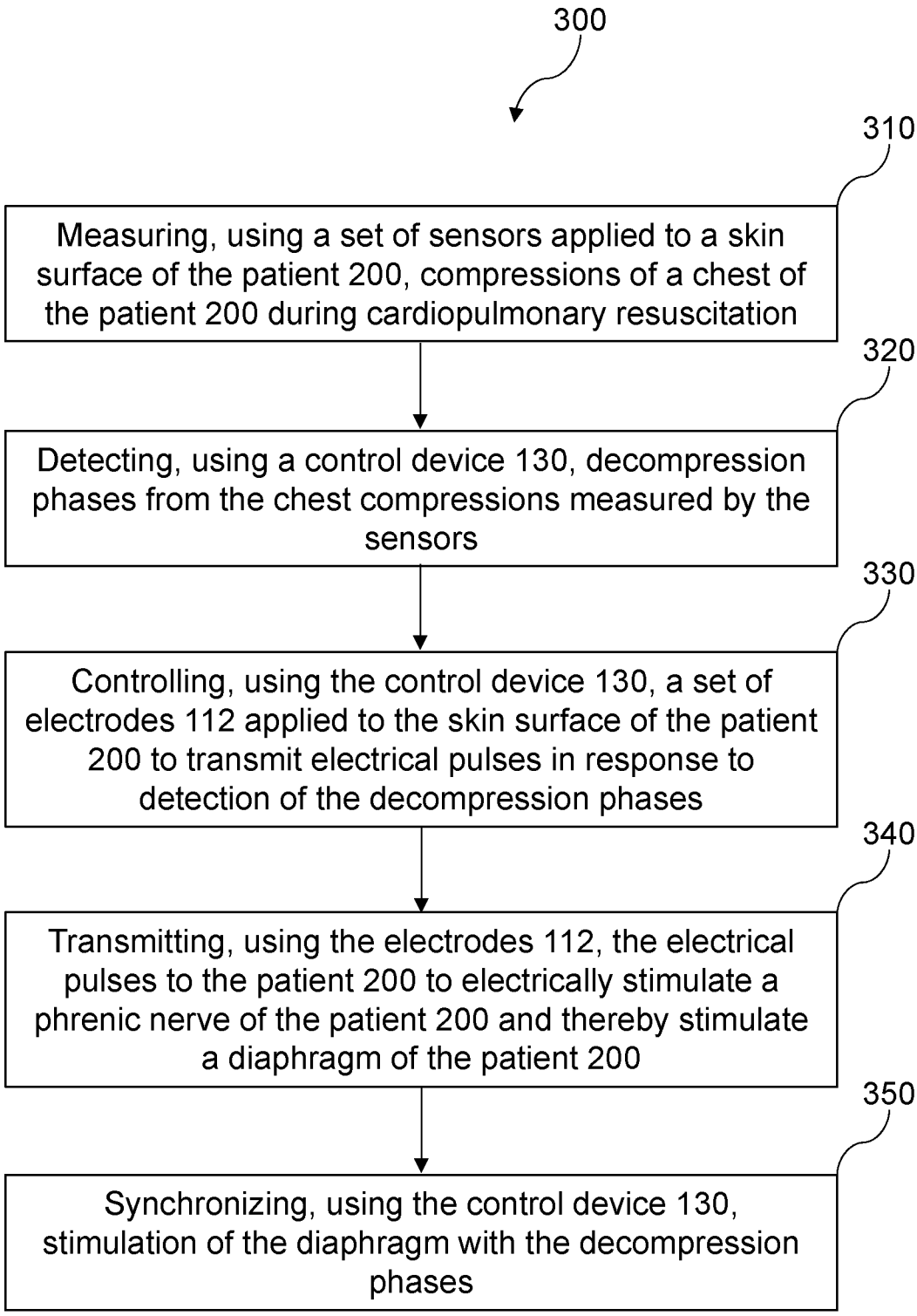
300
310
Measuring, using a set of sensors applied to a skin surface of the patient 200, compressions of a chest of the patient 200 during cardiopulmonary resuscitation
320
Detecting, using a control device 130, decompression phases from the chest compressions measured by the sensors
330
Controlling, using the control device 130, a set of electrodes 112 applied to the skin surface of the patient 200 to transmit electrical pulses in response to detection of the decompression phases
340
Transmitting, using the electrodes 112, the electrical pulses to the patient 200 to electrically stimulate a phrenic nerve of the patient 200 and thereby stimulate a diaphragm of the patient 200
350
Synchronizing, using the control device 130, stimulation of the diaphragm with the decompression phases

Figure 4

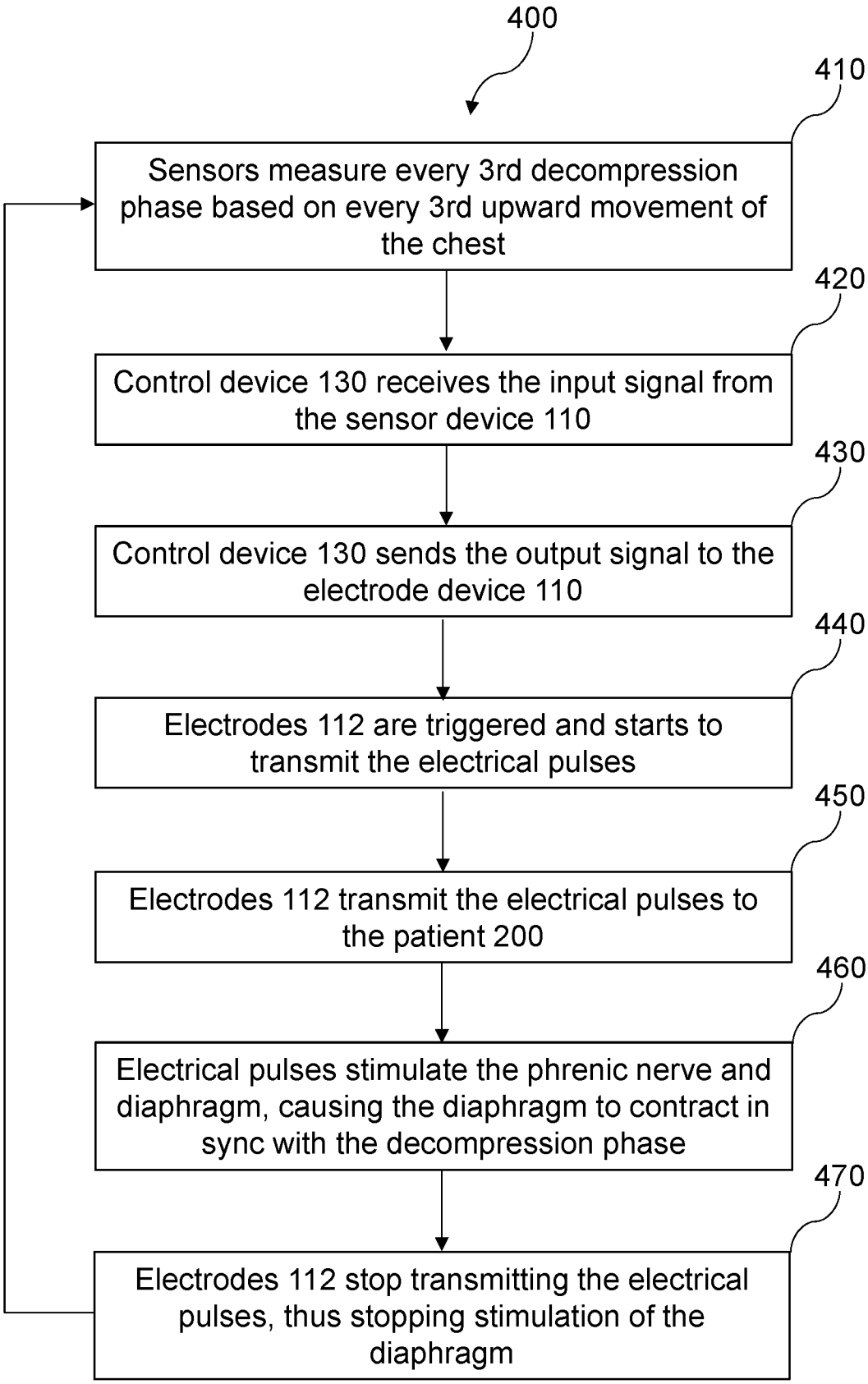
400
410
Sensors measure every 3rd decompression phase based on every 3rd upward movement of the chest
420
Control device 130 receives the input signal from the sensor device 110
430
Control device 130 sends the output signal to the electrode device 110
440
Electrodes 112 are triggered and starts to transmit the electrical pulses
450
Electrodes 112 transmit the electrical pulses to the patient 200
460
Electrical pulses stimulate the phrenic nerve and diaphragm, causing the diaphragm to contract in sync with the decompression phase
470
Electrodes 112 stop transmitting the electrical pulses, thus stopping stimulation of the diaphragm

Figure 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2023/050832

A. CLASSIFICATION OF SUBJECT MATTER

A61H 31/00 (2006.01) ***A61N 1/18 (2006.01)***

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

FAMPAT: cardiopulmonary resuscitation, cpr, diaphragm stimulation, phrenic nerve, chest, electrical pulse, decompression, compression and related terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002/0188332 A1 (LURIE K. G. ET AL.) 12 December 2002 Paragraphs [0026], [0028], [0089], [0094]-[0097], [0099], [0100], [0103], [0104], [0112], [0119], [0136], [0137], [0145], Figures 1-3, 8A	1-20
X	US 6312399 B1 (LURIE K. G. ET AL.) 6 November 2001 Column 9, lines 12-65, column 10, lines 34-44, column 11, lines 1-5, column 11, lines 54-56, column 11 line 66- column 12, line 19, column 14, lines 20-35, column 15, lines 51-60, Figures 1-3, 8A	1-20
X	US 2009/0177127 A1 (SHERMAN D. R. & BYSTROM S. R.) 9 July 2009 Paragraphs [0012], [0018]-[0019], [0022], [0024], [0026], [0027], [0028], [0036], [0038], Figures 1-3, claims 1 and 3,	1-20

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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26/03/2024 *(day/month/year)*	26/03/2024 *(day/month/year)*

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2023/050832

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/0324110 A1 (BYSTROM S. R. & SHERMAN D. R.) 30 October 2014 Whole document	-

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SG2023/050832

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

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