



(43) International Publication Date
22 May 2014 (22.05.2014)

- (51) **International Patent Classification:**
A61H 31/00 (2006.01) *A62B 33/00* (2006.01)
- (21) **International Application Number:**
PCT/US2013/069849
- (22) **International Filing Date:**
13 November 2013 (13.11.2013)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
13/677,209 14 November 2012 (14.11.2012) US
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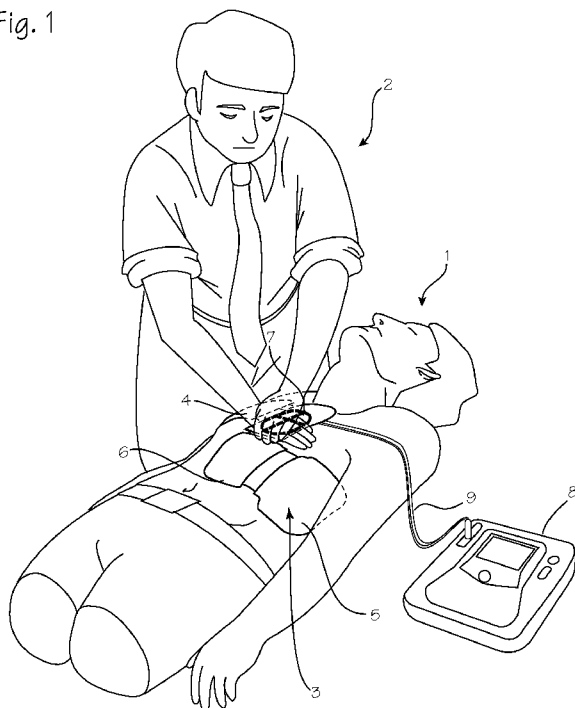
(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

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(54) Title: CHEST COMPRESSION MONITOR WITH ROTATIONAL SENSING OF COMPRESSIONS FOR DISCRIMINATION OF CPR MOVEMENT FROM NON-CPR MOVEMENT

Fig. 1



(57) Abstract: A chest compression monitor for measuring the depth of chest compressions achieved during CPR. A sensor of the chest compression monitor is disposed within its housing such that compression of the housing due to CPR compressions, and its resultant deformation, is detected by the sensor and used by the control system as the starting point for calculating chest compression depth based on an acceleration signal indicative of the downward displacement of the chest.



Published:

— *with international search report (Art. 21(3))*

Chest Compression Monitor with Rotational Sensing of
Compressions for Discrimination of CPR Movement from Non-CPR
Movement

Field of the Inventions

[0001] The inventions described below relate the field of cardiopulmonary resuscitation (CPR).

Background of the Inventions

[0002] Chest compression monitoring during the course of CPR is now possible with the Real CPR Help® and CPR-D-padz technology marketed by ZOLL Medical Corporation. This technology is described in U.S. Patents 6,390,996, 7,108,665, and 7,429,250, and includes the use of an accelerometer to measure accelerations of the chest and calculating the depth of each compression from the acceleration signal. The technology is used in ZOLL's Real CPR Help® compression depth monitoring system to provide real-time rate and depth CPR feedback for manual CPR providers. Commercially, it is implemented in ZOLL's electrode pads, such as the CPR-D•padz® electrode pads. It is also implemented for training use in the PocketCPR® chest compression monitor and PocketCPR® iPhone app.

[0003] U.S. Patent 6,390,996 to Halperin, as well as U.S. Patent 7,122,014 to Palazzolo, described chest compression monitors capable of determining chest compression depth accurately during repeated rapid chest compressions required by CPR. The devices of Halperin and Palazzolo were adapted to be placed between the CPR provider's hand and the patient's sternum during CPR. In both cases, the CPR chest compression monitor is held in fixed relationship to the chest during use, and the chest compression module is operable to determine the

depth of each chest compression based on acceleration data from accelerometers in the chest compression module, without input from other sources, especially without input of data from other sensors fixed in space or remote from the compression module. The disclosures of patents 6,390,996, 7,108,665, and 7,429,250 to Halperin, and patent 7,122,014 to Palazzolo are hereby incorporated by reference.

[0004] Various other chest compression monitors have required or suggested the use of additional inputs to detect the initiation of a compression. Myklebust et al., System for Measuring and Using Parameters During Chest Compression in a Life-Saving Situation or a Practice Situation and Also Application Thereof, U.S. Patent 6,306,107 (Oct. 23, 2001) describes a device which uses a pressure pad containing an accelerometer and requires a force activated switch to determine the start of each compression in order to determine the depth of depressions. However, Myklebust does not provide a means to measure compression depth using an accelerometer alone, nor does Myklebust account for some kinds of error in the measured value of chest compression depth (such as drift). Our own prior patent, Palazzolo, et al., Method of Determining Depth of Compressions During CPR, U.S. Patent 7,122,014 (Oct. 17, 2006) after describing methods of determining compression depth with such additional inputs, also describes the use of switches to detect the start of compressions that may be beneficial in discriminating between acceleration due to chest compressions and external acceleration of the patient.

Summary

[0005] The devices and methods described below for improved accuracy of a chest compression monitor to be used to aid in the proper application of CPR. This is accomplished by detecting the starting point of chest compressions by detecting deformation of a compression monitor, or a component

of the compression monitor, that is associated with the beginning of a compression stroke. For example, the accelerometers used in the compression monitor can be used to detect the beginning of a compression stroke by allowing the accelerometers within the chest compression monitor to rotate within the chest compression monitor in response to applied compressive forces. This is accomplished by modifying a chest compression monitor described in U.S. Patent 6,390,996 to Halperin. Halperin discloses a hand-held CPR chest compression monitor that accurately measures the rate and depth of chest compressions during the administration of CPR. The CPR compression monitor is adapted to be secured in fixed relation to a cardiac arrest victim's chest, with a housing, including accelerometers, a processor, and output means such as a display and speaker. The system provides for measuring and prompting chest compressions to facilitate the effective administration of CPR. The device provides prompts to the rescuer to encourage correct compressions. A signaling mechanism provides signals corresponding to chest compression depth and frequency of compressions achieved by a rescuer, and provides prompts to help the CPR provider provide compressions within desired frequency range and maintain the chest displacement within a desired distance range.

[0006] The chest compression monitor comprises accelerometers for determining an amount of CPR induced motion of the chest in relation to the spine. A control system within an associated AED, or within a housing which houses the accelerometer, converts an output signal produced by the motion detector into a distance value. The control system compares the distance value to a desired range of distance values, and operates a signaling mechanism for signaling directions regarding chest compression depth and frequency in accordance with whether the value falls within the desired range of distance values. The chest compression monitor can

also be operated to provide a signal corresponding to the distance value to an associated chest compression device.

[0007] To assist in determining the starting point of a chest compression, the accelerometer and its mounting board are disposed within the accelerometer such that they naturally rotate or twist while moving downwardly and upwardly during chest compressions, but do not typically rotate or twist when moving downwardly or upwardly due to external accelerations that may be caused, for example, by transporting the patient in a vehicle. The control system is programmed to integrate the acceleration signal to determine the depth of numerous repeated compressions, using the signal corresponding to rotation to determine the starting point of each compression, while ignoring acceleration signals indicative of downward motion that are not accompanied by acceleration signals indicative of rotation.

[0008] Other sensors which detect the deformation of other components of the chest compression monitor may also be used to detect the start and end of a compression. For example, in conjunction with a housing that may deflect, bend or twist during compressions, strain gauges, piezo-resistive elements, impedance sensors embedded in the housing may be used to detect flexion of the housing which occurs only due to the action of chest compression, and will not be effected by ambient motion.

[0009] In addition to detecting the start of each compression to enhance the compression depth calculations, the system may also be used to detect the end of compressions, including the rapidity and completeness of release of compressive forces after a compression. When used in conjunction with manual CPR compressions, the device can provide prompts to a rescuer, indicating that the rescuer is removing the downward forced on the patient too slowly, and

prompting the rescuer to quickly and completely release the chest and remove any compressive force after each compression stroke.

Brief Description of the Drawings

[0010] Figure 1 illustrates the use of a chest compression monitor in use on a patient, with a rescuer providing manual chest compressions.

[0011] Figure 2 is a top view of the electrode assembly Figure 1.

[0012] Figure 3 illustrates the chest compression monitor as implemented in ZOLL Medical's Real CPR Help® chest compression monitor.

[0013] Figure 4 illustrates the chest compression monitor of Figure 3 modified to discriminate between acceleration due to compressions and acceleration due to environmental movement of the patient.

[0014] Figures 5 and 6 illustrate the flexion of the housing top portion and rotation of the accelerometer assembly.

[0015] Figure 7 illustrates the chest compression monitor with both a rotating accelerometer assembly and a fixed, non-rotating accelerometer.

[0016] Figures 8 and 9 illustrate the orientation of the device on a patient, such that natural tilting of the sternum and/or rib cage during compression is distinguishable from rotation of the rotatable accelerometer assembly caused by compression applied by the rescuer.

[0017] Figures 10 and 11 illustrate chest compression devices with additional means for detecting deformation of the housing caused by compression forces.

[0018] Figure 12 illustrates a means for indirectly detecting deformation of the housing as an indicator of the start of a compression.

[0019] Figure 13 illustrates the use of a chest compression monitor in use on a patient, with a chest compression device installed on the patient.

[0020] Figure 14 illustrates the chest compression monitor, with a rotatable accelerometer, adapted for use with a chest compression device as illustrated in Figure 13.

Detailed Description of the Inventions

[0021] Figure 1 illustrates the use of a chest compression monitor in use on a patient 1, with a rescuer 2 providing manual chest compressions. As part of the resuscitation effort, the rescuer has applied an ECG electrode assembly 3 on the patient's chest. This assembly includes a sternum electrode 4, an apex electrode 5, and sternal bridge 6. A chest compression monitor 7 is disposed within the sternal bridge, sandwiched between layers of foam that comprise the bridge. The bridge, along with the cross-hair indicia, serves as a template for proper placement of the chest compression monitor over the sternum of the victim which, together with the configuration of the bridge, ensures that the sternal and apex electrodes are properly placed (for patients of a wide variety of sizes). The electrode assembly is connected to a defibrillator 8 (through cable 9) which is fitted with a control system or systems capable of controlling (and programmed to control) ECG and defibrillating functions and capable of controlling (and programmed to control) the compression monitor functions of interpreting acceleration

signals from the compression monitor, determining the depth of compressions from those acceleration signals, and generating and providing feedback to the rescuer. The feedback may be both audio feedback provided through an annunciator or visual feedback provided on a display. These compression monitor functions can also be accomplished by a control system built into the compression monitor itself, as described in Halperin and as practiced by our PocketCPR® device. The feedback can include prompts to compress more deeply, prompts to compress at a faster or slower rate, and prompts to quickly and completely release the chest of the patient after each compression.

[0022] Figure 2 is a top view of the electrode assembly of Figure 1, which includes the chest compression monitor 7. In this view, the location of the sternal electrode 4 and apex electrode 5, and the chest compression monitor 7 within the bridge 6 are more clearly shown. The chest compression monitor is disposed within the electrode locating bridge shown in Figures 1, sandwiched between layers of foam, so that, when applied to the patient, the CPR chest compression monitor is disposed over the sternal notch of the patient. This chest compression monitor and its housing are referred to as a puck in the developing art.

[0023] Figure 3 illustrates the chest compression monitor 7 as implemented in ZOLL Medical's Real CPR Help® chest compression monitor and CPR stat padz or CPR-D-padz®. The puck includes a housing 12 with a housing bottom portion 13 and housing top portion 14. The housing bottom portion has a slightly convex bottom surface 15 (which opposes the chest, or anterior surface of the patient's thorax), to conform to the patient's sternal notch. The housing top portion has a slightly concave top surface 16 (superficial, relative to the patient) which facilitates hand placement over the puck during use. The accelerometer assembly 17 that measures acceleration

of the puck is disposed in its packaging and on a mounting board 18. Typically accelerometer assembly is a multi-axis accelerometer assembly, with two or three distinct accelerometers arranged orthogonally to each other, capable of detecting acceleration on two or three orthogonal axes. Preferably, the axes are aligned in the compression monitor to coincide with the compression axis 19 (typically, the vertical axis which corresponds to the anterior/posterior axis of the patient when supine) and one or two axes orthogonal to the compression axis (typically two horizontal axes). With this arrangement, chest compression depth can be measured, as described in the Halperin patent. The accelerometer assembly may also comprise separate accelerometers, with two or three accelerometers rotatably mounted to the housing. Alternately, as described below in relation to Figure 7, the device may employ a first, fixed accelerometer disposed within the housing and a second, rotatable accelerometer disposed within the housing.

[0024] The basic device of Figure 3 can be modified as shown in Figure 4, which illustrates the chest compression monitor of Figure 3 modified to discriminate between acceleration due to compressions and acceleration due to environmental movement of the patient. The housing 21 is modified such that the top surface 16 is slightly flexible, to a degree that it flexes downwardly when compressive force is applied to the top surface. In this device, the accelerometer mounting board 18 is inclined, relative to the compression axis, and rotatably fixed to the housing, for example at a pivot point 22, such that it can rotate relative to the housing. Because the accelerometer mounting board is tilted, compressive forces applied to the top surface will result in both downward movement of the puck and rotation of the mounting board, and rotation of the multi-axis (3-axis or 2-axis) accelerometer assembly, about the pivot point 22. (The

accelerometer mounting board can be fixed to the housing with a hinge or flex joint, or it may be floated in foam or gel within the housing, or merely fixed to the housing bottom portion and housing top portion. It is biased toward its original tilted position through its connection to the resilient portion of the housing, but may be biased with a spring.) The accelerometer assembly is disposed on the mounting board, and thus fixed to the housing, with a predetermined relationship between the accelerometer axes and the axes of the housing, which in turn is configured to be placed in a predetermined relationship to the anatomy of the patient. Preferably, one of the accelerometers will be disposed relative the mounting board and housing such that its axis of sensitivity is aligned with the compression axis. The device of Figure 4 may be incorporated into the electrode assembly as shown in Figures 1 and 2, or it can be used in a stand-alone chest compression monitor, similar to our PocketCPR® chest compression monitor and the puck disclosed in Halperin.

[0025] In this arrangement, compressions which force the accelerometer assembly downward will also rotate the accelerometer mounting board. The multi-axis accelerometer will sense the downward motion and the rotation. The rotation will indicate the start of a compression, and the control system will interpret the accelerometer data from the several accelerometers to calculate the downward displacement of the compression monitor, which corresponds to the depth of the CPR compression. Though the calculations will differ depending on the initial orientation of the accelerometers, the calculations are routine once the inventive concept is understood. By detecting the start of compressions with the accelerometer data, the device can more accurately calculate the compression depth, and ignore accelerations caused by

other forces acting on the patient and the compression depth monitor.

[0026] Figure 5 illustrates the flexion of the housing top portion and rotation of the accelerometer assembly. Figure 5 illustrates rotation of the accelerometer assembly as a result of the rescuer's compression effort. The rescuer is trained and/or prompted through instructions on the electrode assembly to place his/her hands 23 on the puck 21, such that the heel of the hand rests in the concavity of the housing top portion, and perform CPR compressions according to ACLS guidelines. During each compression, the rescuer will push downwardly on the housing, and force the housing top portion 14 to flex and deform to a more concave shape, and thus force the accelerometer assembly to rotate relative to housing, away from its original slightly tilted position to a more tilted position. This rotation will be sensed by the accelerometers of the accelerometer assembly, and the accelerometers will produce an acceleration signal corresponding to the rotation of the accelerometer assembly within the housing, and also the vertical and horizontal displacement of the housing. The accelerometer signal corresponding to the vertical displacement of the housing corresponds to the chest wall displacement, or compression depth, achieved by the manually applied compressions.

[0027] In the device illustrated in Figures 4 and 5, the accelerometers of the two or three axis accelerometer are the only sensors needed to determine the start of the compression, and thereafter calculate the depth of compression. The calculations may be made, and compression depth of numerous repeated compressions may be calculated, without reference to signals other than the accelerometers, or signals from sensors not located on, or disposed in fixed relationship to the housing, and without reference to a signal derived from a source external to the module (though such additional signals

may be used in conjunction with the accelerometers to determine the start of compressions and/or calculate depth of compression). The housing or module, which is adapted to seat on the patients chest with an upper surface adapted to accommodate and seat the rescuer's palm, is thus adapted to be held in fixed relationship to the patient's chest and move in conjunction with the anterior surface of the patient's chest and follow the movement of the chest of a patient undergoing compression. The accelerometers are fixed to the housing, and thus move in conjunction with the housing and the anterior surface of the patient's chest. The accelerometers output an acceleration signal indicative of the upward and downward acceleration of the chest, as well as the rotation of the accelerometer assembly within the housing. The associated control system is programmed to receive and process the acceleration signals to determine the depth of chest compression and produce a compression signal indicative of the depth of compression of the patient's chest. The control system is further programmed to determine the start of a compression based on accelerometer signals from the accelerometers which are indicative of rotation of the accelerometer assembly, without reference to a signal derived from a source external to the module, and without reference to a signal derived from a source which is not coupled to the patient's chest, and thereafter calculate downward displacement of the chest using the acceleration signal (though such additional signals may be used in conjunction with the accelerometers to determine the start of compressions and/or calculate depth of compression). The control system is further programmed to output a compression signal indicative of the calculated displacement, and, based on comparison of the calculated displacement with predetermined desired displacement and rate of compressions, provide prompts to the rescuer indicating the quality of compressions (for example,

indicating whether the displacement achieved is inadequate, adequate, or excessive).

[0028] The control system used in the device may be any suitable computer control system, and may be disposed within the housing, within an associated defibrillator, or within an associated chest compression device, or it may be a general purpose computer or a dedicated single purpose computer. The control system may comprise at least one processor and at least one memory including program code stored on the memory, where the computer program code is configured such that, with the at least one processor, when run on the processor, it causes the processor to perform the functions assigned to the control system throughout this specification. These functions include interpreting the accelerometer signals from the accelerometers, and/or signal produced by other sensors, to determine compression depth, and produce signals indicative of the calculated compression depth, and operate outputs such as audio speakers or displays to provide feedback to a rescuer, or use those signals as feedback for the control system of a chest compression device.

[0029] The device described above can also be used to determine whether a rescuer is substantially releasing the chest after each compression. Complete release of the compressive weight of the rescuer is necessary to ensure that the thorax of the patient can expand, due to its natural resilience, as quickly as possible and without the hindrance of the rescuer's weight. This is described in our U.S. Patent 7,220,235 to Freeman, incorporated herein by reference. As described in Freeman, an optimum compression cycle is characterized by very quick release of the compression force applied by the rescuer, between each application of downward force. That is, between compressions, it is desirable to completely and immediately remove the compression force of the rescuer's weight from the patient's chest, rather than slowly

remove the force and thereby restrict the resilient expansion of the patient's thorax. Release of the rescuer's weight and the attendant downward force will result in the resilient return housing upper surface 16 to its original, slightly concave shape, and thus result in return of the rotating accelerometer assembly to its original slightly tilted position. The immediacy of this return is thus indicative of the rapidity of the rescuer's release of compressive force. The control system used to measure chest displacement may thus be programmed to calculate the rapidity of the release of compressive forces and output a release signal indicative of the calculated release rate, and, based on comparison of the calculated release rate with predetermined desired release rate, and operate a speaker or display to provide prompts to the rescuer indicating whether the release achieved between compressions is inadequate or adequate. With this prompting, the rescuer can be prompted to avoid resting his or her weight on the patient between compressions. A compression cycle includes a compression stroke and a decompression release. Upon release, the rescuer should remove all of his/her weight from the patient's chest. During the compression stroke, the accelerometer assembly will be tilted relative to the housing (or other component will be deformed), but after the compression stroke, any remaining tilt indicates that accelerometer assembly is still impacted by the rescuer. Even though the entire device is moving upward, a restraint on upward movement by the rescuer's hand will result in some detectable tilt. Upon detection of overall upward movement with remaining tilt of the accelerometer assembly, which is indicative of incomplete release, the control system operates the display or speaker to prompt the rescuer to more completely release the chest after each compression. This determination and prompting can be used in combination with, or in lieu of, the determinations and prompting disclosed in U.S. Patent 7,220,235, such as the determination that the

rescuer does not reach the original starting point of compression (that is, the top of the compression cycle). Figure 6 illustrates the configuration of the housing top portion and accelerometer assembly when the rescuer fails to completely remove his/her weight or compressive force from the puck. The housing top portion 14 is only partially returned to its original position, limited in its return by a rescuer who has failed to completely release compressive force. In turn, the accelerometer assembly 17 is only partially rotated back to its original slightly tilted position. The accelerometer signals from the accelerometers are interpreted by the control system, and will indicate that the accelerometer assembly has not been rotated back to its original position.

[0030] Figure 7 illustrates the chest compression monitor with both a rotating accelerometer assembly similar to that of Figure 4 and a fixed, non-rotating accelerometer assembly 24 mounted on a second circuit board 25 which is also non-rotatably fixed to the housing (that is, it does not rotate relative to the housing). This additional accelerometer assembly is non-rotatably fixed to the housing 12, such that it produces accelerometer signals indicative of vertical movement, lateral movement, and also rotation of the housing. These additional accelerometer signals can be used as an adjunct to the accelerometer signals provided by the rotatable accelerometer assembly 17. The remainder of the compression monitor is similar to Figure 4, including the housing top portion 14, the housing bottom portion 13, the rotating accelerometer assembly 17. In this mode of use, the compression depth is determined using the accelerometer signal of the rotatable accelerometer assembly, and the start of compressions is determined by the detection of rotation of the rotatable accelerometer assembly, while the fixed accelerometer assembly detects rotations of the housing. The

control system is programmed to determine the chest compression depth based on the accelerometer signal of the rotatable accelerometer assembly, and the start of compressions as indicated by the detection of rotational acceleration signals received from the rotatable accelerometer assembly. The control system is further programmed to adjust the calculation of compression depth or the start of a compression based on acceleration signals received from the fixed accelerometer. For example, if acceleration signals from the fixed accelerometer indicate the housing has rotated in conjunction with the rotatable accelerometer assembly (that is, both assemblies indicate a similar rotation), the control system will determine that any change in depth of the housing is a result of spurious movement, and not the result of a CPR chest compression accomplished by the rescuer.

[0031] In a complementary mode of operation, the fixed accelerometer assembly 24 can be used as the primary acceleration sensor, as described by Halperin, U.S. Patent 6,390,996, while the rotatable accelerometer assembly 17 is used merely to detect the starting point for each compression. In this mode of operation, the control system is programmed to determine chest compression depth based on the acceleration signals from the fixed accelerometer, while determining the starting point for each compression from the accelerometer signal indicate of rotation received from the rotatable accelerometer assembly.

[0032] Figures 8 and 9 illustrate the orientation of the device on a patient, such that natural tilting of the sternum and/or rib cage during compression is distinguishable from rotation of the rotatable accelerometer assembly caused by compression applied by the rescuer. The accelerometer assembly provides a means for discriminating between inferior/superior tilting of the compression monitor and lateral tilting of the assembly. This is helpful to avoid

confusing inferior/posterior tilting of the xiphoid process with the tilt of the accelerometer assembly within the housing. The xiphoid process tends to compress differentially compared to the sternum, such that a compression monitor mounted on the chest, at the sternal notch, may tilt along the inferior/superior axis of the patient. The accelerometer assembly is mounted within the housing such that its hinge line is parallel to the inferior/superior axis, and the assembly rotates about this hinge line, back and forth across the lateral/medial axis of the device. Proper alignment of the accelerometer assembly on the body is ensured by the initial placement of the assembly on the electrode assembly, and proper application of the electrode assembly on the patient's body. As shown in Figure 8, the hinge line **26** is defined as the line about which the accelerometer assembly **17** rotates in response to CPR compressions and the resultant deformation of the housing top portion. The superior/inferior axis **27** of the patient is the head-to-toe axis of the patient. The anterior/posterior axis **28** extends from the front (anterior) of the patient to the back (posterior) of the patient. A lateral/medial axis, indicated by arrow **29**, extends from one side of the patient to the other. (The origins of the axes illustrated are arbitrarily placed relative to the patient.) The sternum of some patients tends to compress differentially. The inferior end of the sternum may be pressed deeper than the intermediate portions, so that the lower portion of the sternum and the xiphoid process "tilt" across a lateral/medial axis or plane of the patient, or rotate within an anterior/posterior plane of the patient (or the device), without tilting substantially about an inferior/superior axis of the patient (or the device). As shown in Figure 9, the lower portion of the sternum and the xiphoid process have, in response to compressions, tilted about lateral/medial axis **29** (and correspondingly tilted across the lateral/medial plane established by the patient and the device, but has not tilted

about the superior/inferior axis or twisted in a horizontal lateral/medial plane or about the anterior/posterior axis. That is, the device has not rocked back and forth across the chest, or rotated on the anterior surface of the chest wall. Thus, the hinge line about which the accelerometer assembly rotates is aligned with the superior/inferior axis of the patient, and perpendicular to an anterior/posterior axis and a lateral/medial axis (without necessarily being parallel to a superior/inferior axis: in practice the hinge line will lie in an anterior/posterior plane). This ensures that rotation of the accelerometer assembly is most likely due to deformation due to compression, rather than tilt of the device as it follows a sternum tilting about a lateral/medial axis. The desired alignment can be ensured by disposing the accelerometer assembly and circuit board within the housing, and providing indicia on the housing, to promote placement on the body of the patient such that the hinge line is substantially within an anterior/posterior plane of the patient's body. Referring to Figure 2, this is accomplished by placement of the housing within an electrode assembly, which must be placed on the patient's body to properly locate the sternum and apex electrodes. Highly trained rescuers, or even novice users, can properly place the electrodes given the indicia typically provided on the surface of the electrode assembly.

[0033] Figures 10 and 11 illustrate chest compression devices with additional means for detecting deformation of the housing caused by compression forces. The chest compression monitor illustrated in Figure 10 includes the housing 12, with a bottom portion and a top portion and an accelerometer assembly 17 and circuit board 18 (which may be fixed relative to the housing or rotatable relative to the housing). A strain gauge 30 is embedded in the housing top portion 14, which is slightly flexible, soft, or deformable, so that the

rescuer will deform the top portion, and thus the strain gauge, each time the rescuer pushes on the patient's chest. Deformation of the strain gauge will result in a change of resistance of elements within the strain gauge, which is communicated to the control system. The abrupt change of resistance incident to the start of a compression is interpreted by the control system as the start of the compression, and the control system is programmed to calculate the chest compression depth using the accelerometer signals from the accelerometer assembly, using the starting position as identified by resistance measurement from the strain gauge. The strain gauge, which detects deformation of the housing, may be disposed within any portion of the housing, which deforms during compressions, including the sidewall and the bottom portion, so long as those portions comprise a material that may deform slightly during compressions.

[0034] The chest compression monitor illustrated in Figure 11 includes the housing 12, with a bottom portion and a top portion and an accelerometer assembly 17 and circuit board 18 (which may be fixed relative to the housing or rotatable relative to the housing). A force sensitive resistor 31 is disposed within the housing, and as illustrated is disposed between the top portion 14 and the bottom portion, so that the rescuer will deform the top portion and thus impact the top portion upon the force sensitive resistor, each time the rescuer pushes on the patient's chest. Impingement of the top portion on the force sensitive resistor will result in a change of resistance of force sensitive resistor, which is communicated to the control system. The abrupt change of resistance incident to the start of a compression is interpreted by the control system as the start of the compression, and the control system is programmed to calculate the chest compression depth using the accelerometer signals from the accelerometer assembly, using the starting position

as identified by resistance measurement from the force sensitive resistor. As appears from Figures 10 and 11, the housing upper surface may comprise, at least in part, a piezo-resistor, a strain gauge (including a micro-strain gauge), a pressure sensitive touch screen, or any other sensor operable to detect deformation of the housing, or any other means for detecting a deformation of the housing. The means for detecting deformation of the housing can be disposed on, or be embedded in, the housing top portion, the housing bottom portion, and any part of the chest compression device subject to detectable stress and/or strain during compressions.

[0035] In addition to directly detecting deformation of the housing as an indication of the start of a compression as illustrated in Figures 10 and 11, deformation may be detected indirectly by detecting rotation of the accelerometer assembly or deflection of some other component which is rotated or deflected when the housing is deformed. Figure 12 illustrates a means for indirectly detecting deformation of the housing as an indicator of the start of a compression. Figure 12 includes the puck 12 with the housing bottom portion 13, housing top portion 14, the accelerometer assembly 17 and its mounting board 18 rotatably disposed between the housing bottom portion 13 and the housing top portion 14 so that compression of the housing top portion toward the bottom portion forces the accelerometer assembly to rotate about a pivot point such as point 22. A piezoelectric film 32 is fixed to both the housing (the bottom portion in Figure 12) and the accelerometer assembly or mounting board, and is folded along crease 33. Upon each application of compressive force, the accelerometer assembly rotates about the pivot 22, and bends the piezoelectric film 32. Deformation of the piezoelectric film creates a voltage spike within the film, which is detected by appropriate electronics and communicated to the control system. The control system interprets the

voltage spike incident to deflection of the film as the start of a compression. The piezoelectric film provides a means to detect rotation of the accelerometer assembly and mounting board. Other means for detecting rotation of the accelerometer assembly and mounting board may be used in place of the piezoelectric film, including a force transducer, force switch, relay switch positioned, a piezo-resistor, a strain gauge (including a micro-strain gauge), a pressure sensitive touch screen, or any other sensor operable to detect rotation of the accelerometer and/or mounting board disposed under the accelerometer assembly and mounting board, or, more generally, operably connected to the accelerometer and/or mounting board such that the sensor can detect compression induced motion of the accelerometer and/or mounting board. Additionally, the means for detecting rotation may be operably connected to any structure or component that moves within the puck in response to compressions. The electrode assembly may be rotationally fixed within the housing, as illustrated in Figure 7 (items 24 and 25 refer to a fixed accelerometer), and a rotating board or other component (with or without accelerometers) may be used to impinge upon or interact with the means for detecting rotation.

[0036] In use, the compression depth monitor is used by a CPR provider while providing CPR compressions to a patient. The CPR provider will place the chest compression monitor over the sternum of the patient, between his or her hands and the patient's chest, and perform compressions manually (or, as illustrated below, between a chest compression device and the patient's chest, and perform compressions with the chest compression device). The CPR provider may also install ECG/defibrillator electrodes on the patient, with the chest compression monitor integrated into an electrode assembly as shown in Figures 1 and 2. The CPR provider will operate the chest compression monitor, and its control system will

interpret the acceleration signals as described above to determine chest wall displacement, using the start of rotation, or deformation of the housing, as an indication that a compression has started, and will use the point at which the rotation or deformation is detected as the starting point for calculating compression depth. The control system will compare the calculated compression depth to a desired, predetermined compression depth (2 inches, under current ACLS guidelines), and operate a speaker or display to provide prompts to the user regarding the quality of compressions. The control system may also output a compression signal indicative of the calculated displacement. Likewise, if used to assess the quality of release of compressions based on the rate at which the sensors rotate back to their original position, or the housing rebounds to its original uncompressed shape, the control system will compare the calculated release rate to a desired, predetermined release rate, and operate a speaker or display to provide prompts to the user regarding the quality of release.

[0037] Figure 13 illustrates the use of a chest compression monitor in use on a patient, with a chest compression device 34 installed on the patient 1. The chest compression device is described in our U.S. Patents 7,410,470, and includes a compression belt 35 (shown in phantom) with load distributing panels 36 and pull straps 37 (one on each side of the patient) attached to a drive spool and a motor within the housing 38. As illustrated in this view, the ECG electrode assembly 3 is disposed on the patient's chest, under the load distributing band. This assembly includes the sternum electrode 4, the apex electrode 5, the sternal bridge 6 and the chest compression monitor 7 illustrated in Figure 1. The chest compression monitor and electrodes may be connected to a defibrillator directly, or through connection built into the housing. The chest compression monitor is disposed between

the patient and load distributing panels, above the sternum of the patient.

[0038] Figure 14 illustrates the chest compression monitor adapted for use with the chest compression device 34. This compression monitor includes the rotatable accelerometer, and the housing is adapted for use with a chest compression device as illustrated in Figure 13. The outer surface 43 of the housing top portion 14 is convex, though it may be flat, so that the belt of the chest compression device is certain to impinge upon the housing top portion and deform it, so as to cause the rotatable accelerometer assembly to rotate during each compression. In other respects, the compression monitor is similar to the device shown in Figure 4.

[0039] While the preferred embodiments of the devices and methods have been described in reference to the environment in which they were developed, they are merely illustrative of the principles of the inventions. The elements of the various embodiments may be incorporated into each of the other species to obtain the benefits of those elements in combination with such other species, and the various beneficial features may be employed in embodiments alone or in combination with each other. Other embodiments and configurations may be devised without departing from the spirit of the inventions and the scope of the appended claims.

We claim:

1. A chest compression monitor for facilitating the administration of cardiopulmonary resuscitation (CPR) by a CPR provider, said chest compression monitor comprising:

a housing adapted to be held in fixed relation to a CPR recipient's chest;

an accelerometer assembly disposed within the housing;

wherein the accelerometer assembly is rotatably fixed to the housing.

2. The chest compression monitor of claim 1, wherein:

a portion of the housing is resilient, and the accelerometer assembly is disposed relative to the housing such that deformation of the housing due to compression forces results in rotation of the accelerometer assembly.

3. The chest compression monitor of claim 2, wherein:

the accelerometer assembly is rotatably fixed along a first axis of the chest compression monitor; and

the housing is characterized by a top portion and a bottom portion, where the bottom portion is convex and the top portion is concave, and the top portion is flexible such that it deforms slightly in response to compressive forces applied by the CPR provider.

4. The chest compression monitor of claim 3, wherein:

the accelerometer assembly is rotatably fixed along a first axis of the chest compression monitor; and

the housing is characterized by a top portion and a bottom portion, where the bottom portion is convex and the top portion is concave, and the bottom portion is flexible such that it deforms slightly in response to compressive forces applied by the CPR provider.

5. The chest compression monitor of claim 2, wherein

the accelerometer assembly is rotatably fixed along an first axis of the chest compression monitor; and

the housing is characterized by a top portion and a bottom portion, where the bottom portion is convex along the first axis and the top portion is concave along a second axis parallel to the first axis, and the top portion is flexible such that it deforms slightly in response to compressive forces applied by the CPR provider, thereby forcing the accelerometer assembly to rotate about the first axis.

6. The chest compression monitor of claim 3, wherein:

the accelerometer assembly is rotatably fixed along a first axis of the chest compression monitor; and

the housing is characterized by a top portion and a bottom portion, where the bottom portion is convex along the first axis and the top portion is concave along a second axis parallel to the first axis, and the bottom portion is flexible such that it deforms slightly in response to compressive forces applied by the CPR provider, thereby forcing the accelerometer assembly to rotate about the first axis.

7. The chest compression monitor of claim 3, wherein the housing top portion is provided with indicia prompting a user to align the first axis of the device with a superior/inferior axis of the patient.

8. The chest compression monitor of claim 3, wherein:

the accelerometer assembly comprises three orthogonally disposed accelerometers operable to produce acceleration signals indicative of the displacement of the chest compression monitor and acceleration signals indicative of rotation of the accelerometer assembly; and further comprising

a control system programmed to receive and process the acceleration signals to determine the depth of chest compression and produce a compression signal indicative of the depth of compression of the patient's chest, to determine the start of a compression based on accelerometer signals from the accelerometers which are indicative of rotation of the accelerometer assembly, and thereafter calculate downward displacement of the chest using the acceleration signal, and, based on comparison of the calculated displacement with predetermined desired displacement and rate of compressions, provide prompts to the rescuer indicating the quality of compressions achieved by the rescuer.

9. The chest compression monitor of claim 3, wherein:

the accelerometer assembly comprises three orthogonally disposed accelerometers operable to produce acceleration signals indicative of the displacement of the chest compression monitor and acceleration signals indicative of rotation of the accelerometer assembly; and further comprising

a control system programmed to receive and process the acceleration signals to determine the depth of chest compression and produce a compression signal indicative of the depth of compression of the patient's chest, to determine the start of a compression based on

accelerometer signals from the accelerometers which are indicative of rotation of the accelerometer assembly, and thereafter calculate downward displacement of the chest using the acceleration signal, and further programmed to output a compression signal indicative of the calculated displacement.

10. The chest compression monitor of claim 9, wherein the control system is further programmed to process acceleration signals to calculate the release rate of compressive forces from the compression monitor, compare the calculated release rate with a predetermined desired release rate, and operate a speaker or display to provide prompts to the rescuer indicating the quality of the release rate.

11. A chest compression monitor for facilitating the administration of cardiopulmonary resuscitation (CPR) by a CPR provider by detecting compression depth of a chest of a patient undergoing CPR, said chest compression monitor comprising:

a housing adapted to be held in fixed relation to a CPR recipient's chest, between the hands of the CPR provider and the patient's chest, a portion of said housing being sufficiently flexible such that is deforms during CPR compressions provided by the CPR provider;

at least one accelerometer for detecting acceleration indicative of displacement of the chest of the patient;

a sensor operable to detect deformation of the housing and produce a signal indicative of deformation of the housing.

12. The chest compression monitor of claim 11, wherein:
- the accelerometer is operable to produce acceleration signals indicative of the displacement of the chest compression monitor; and further comprising
- a control system programmed to receive and process the acceleration signals to determine the depth of chest compression and produce a compression signal indicative of the depth of compression of the patient's chest, to determine the start of a compression based on signal indicative of deformation of the housing, and thereafter calculate downward displacement of the chest using the acceleration signal, and further programmed to output a compression signal indicative of the calculated displacement, and, based on comparison of the calculated displacement with predetermined desired displacement and rate of compressions, provide prompts to the rescuer indicating the quality of compressions achieved by the rescuer.
13. The chest compression monitor of claim 11, wherein:
- the sensor comprises a force sensitive resistor.
14. The chest compression monitor of claim 11, wherein:
- the sensor comprises a strain gauge.
15. The chest compression monitor of claim 11, wherein:
- the sensor comprises a piezo-resistor.
16. The chest compression monitor of claim 11, wherein:
- the sensor comprises a pressure sensitive touch screen.
17. The chest compression monitor of claim 11, wherein:
- the sensor comprises a piezoelectric film.

18. The chest compression monitor of claim 11, wherein the control system is further programmed to process sensor signals to calculate the release rate of compressive forces from the compression monitor, compare the calculated release rate with a predetermined desired release rate, and operate a speaker or display to provide prompts to the rescuer indicating the quality of the release rate.

19. A system for facilitating the administration of cardiopulmonary resuscitation (CPR), said system comprising:

- a housing adapted to be held in fixed relation to a CPR recipient's chest;

- a first accelerometer for producing an acceleration signal indicative of the displacement of a CPR recipient's chest, said first accelerometer disposed within the housing;

- a second accelerometer for producing an acceleration signal indicative of rotation of the accelerometer assembly, said second accelerometer rotatably mounted within the housing;

- a control system being programmed to convert the acceleration signal from the first accelerometer into a distance value indicative of the displacement of the CPR recipient's chest caused by CPR;

said control system being further programmed to interpret the acceleration signal from the second accelerometer to determine a starting point for a compression, and interpret subsequent acceleration of the first acceleration as displacement of the CPR recipient's chest due to applied compressions, and interpret accelerations not preceded by a rotation of the second accelerometer as movement not associated with

displacement of the CPR recipient's chest due to applied compressions.

20. The chest compression monitor of claim 19, wherein:

said control system is further programmed to output a signal corresponding to the distance value indicative of the displacement of the CPR recipient's chest.

21. The chest compression monitor of claim 19, wherein:

said control system is further programmed to calculate downward displacement of the chest using the acceleration signal from the first accelerometer, and, based on comparison of the calculated displacement with predetermined desired displacement and rate of compressions, provide prompts to the rescuer indicating the quality of compressions achieved by the rescuer.

Fig. 1

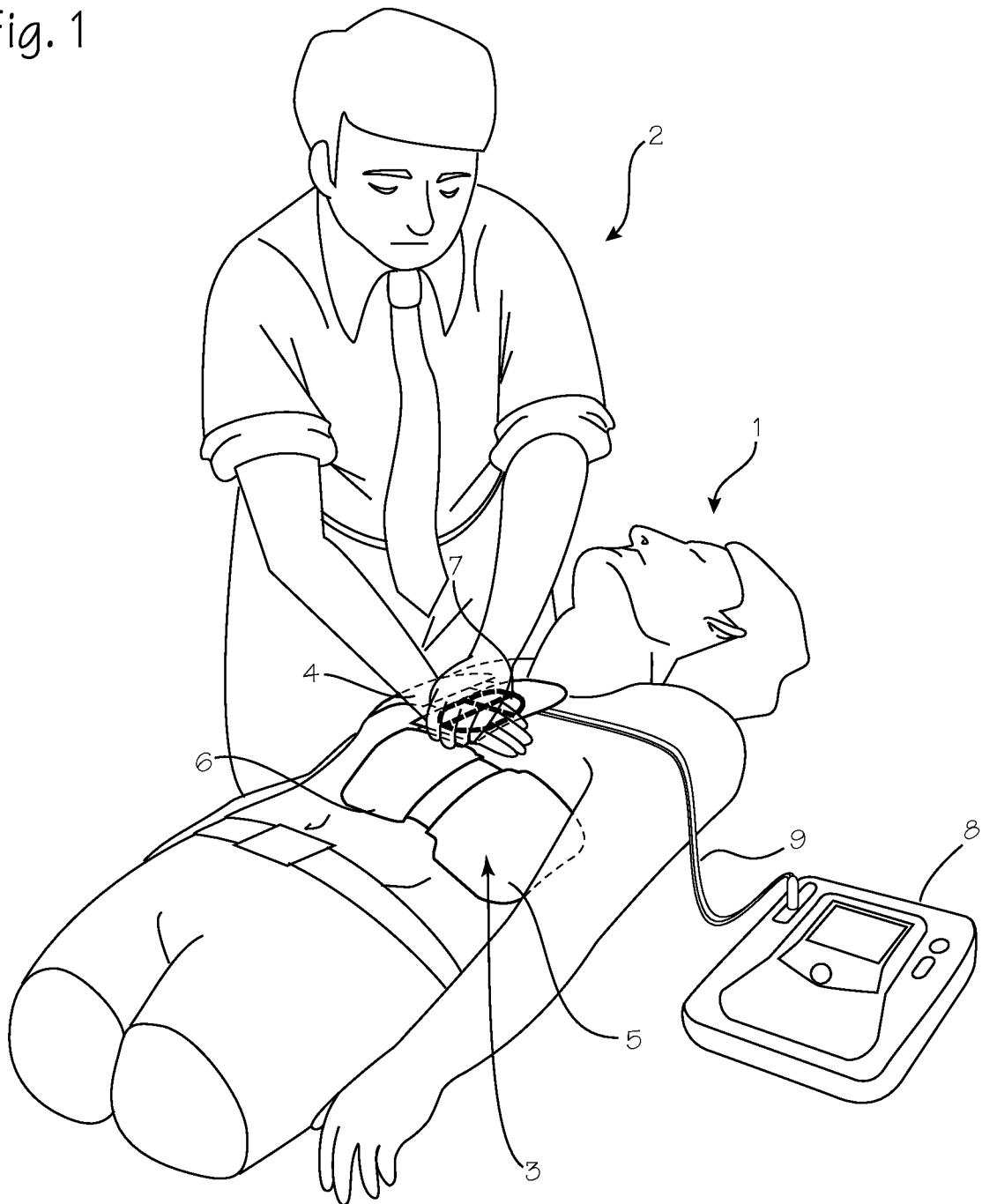


Fig. 2

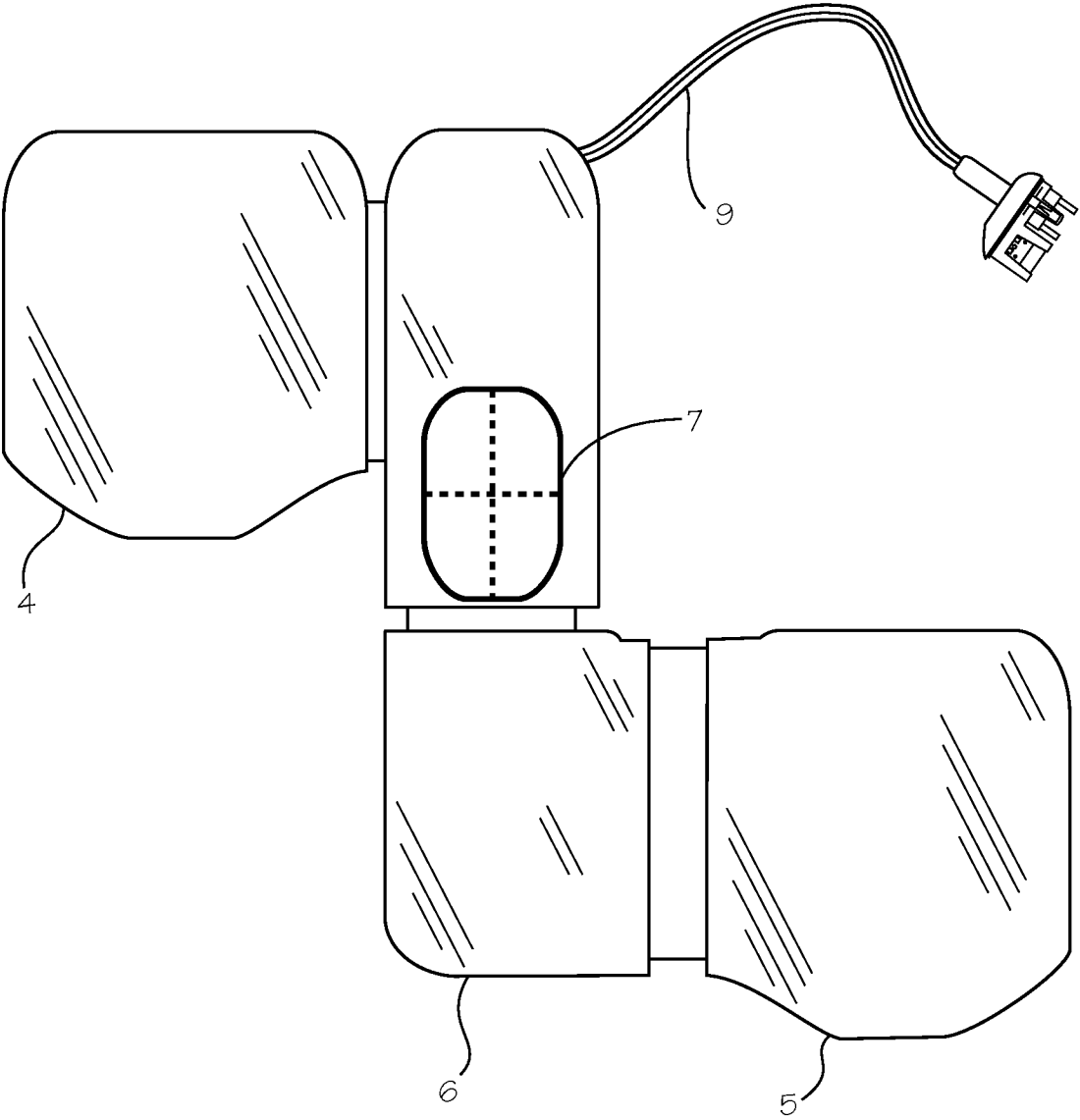
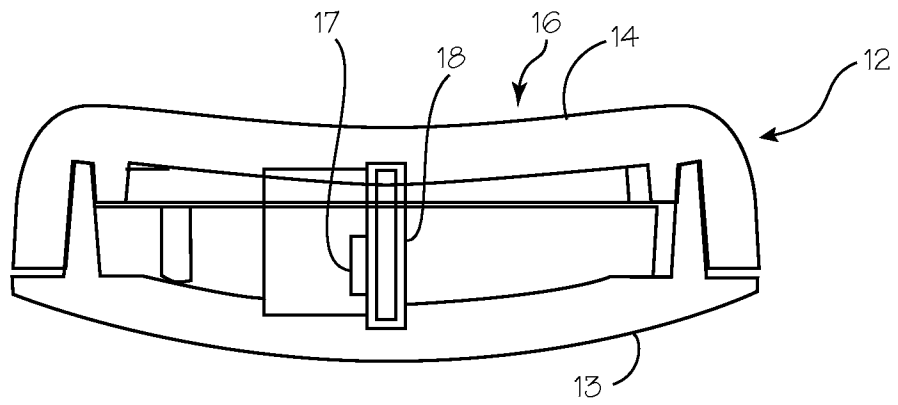
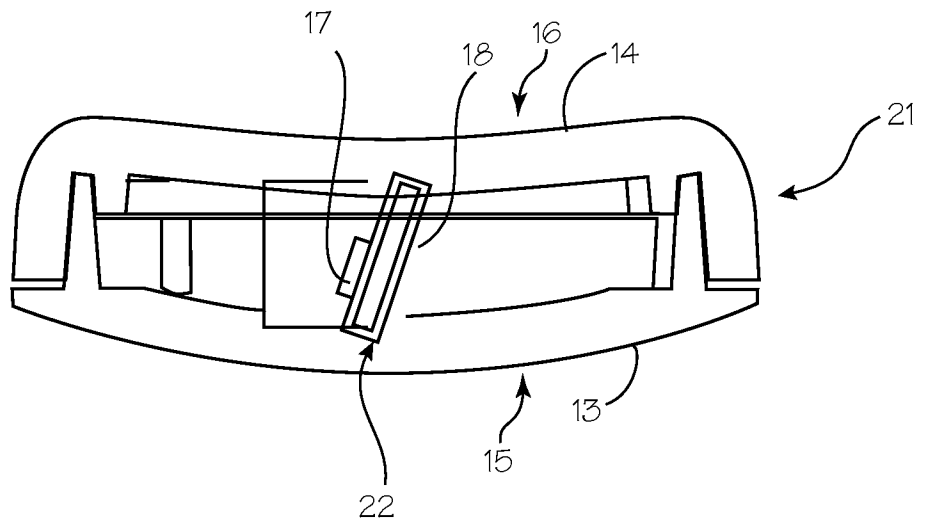


Fig. 3



(prior art)

Fig. 4



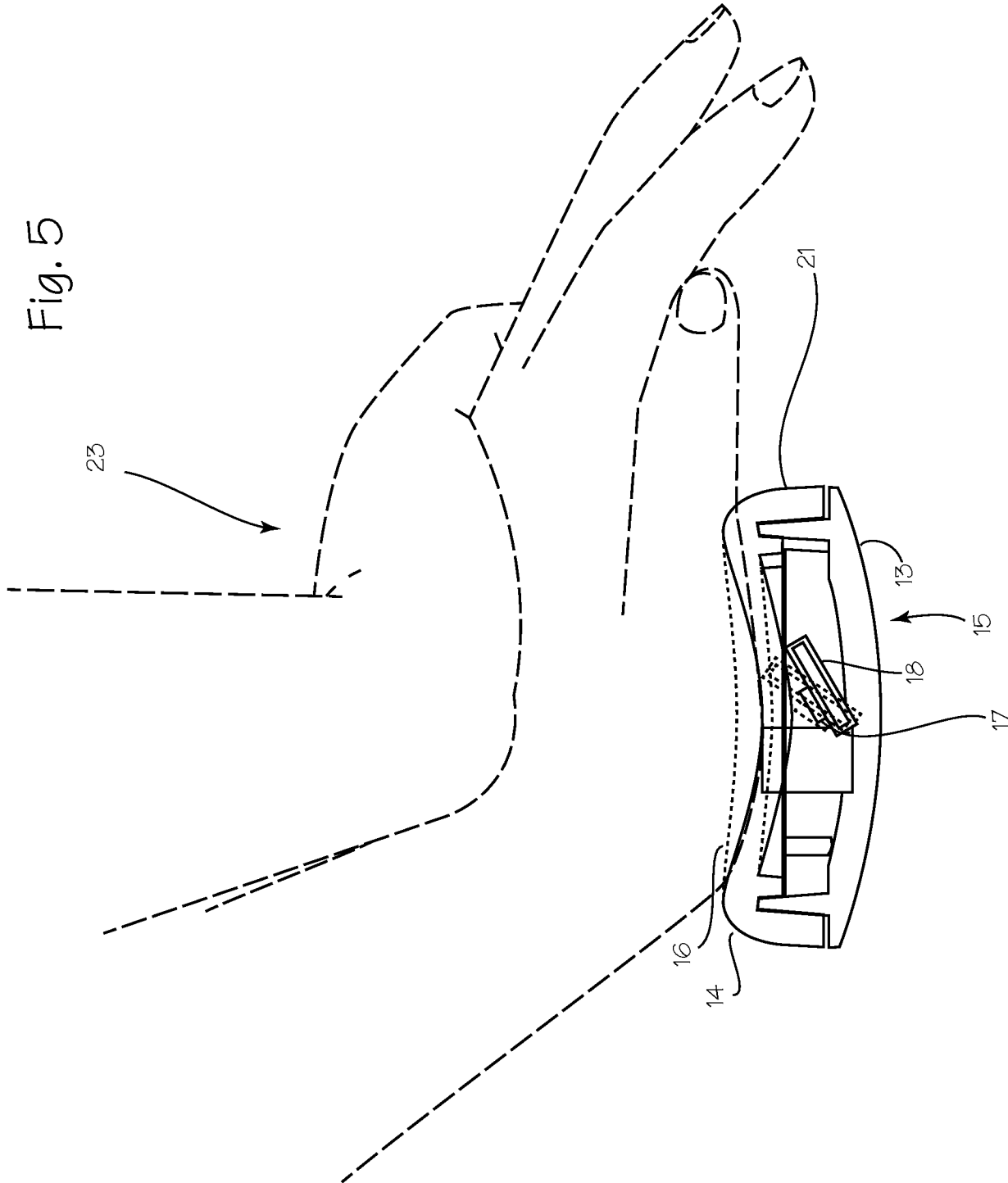


Fig. 6

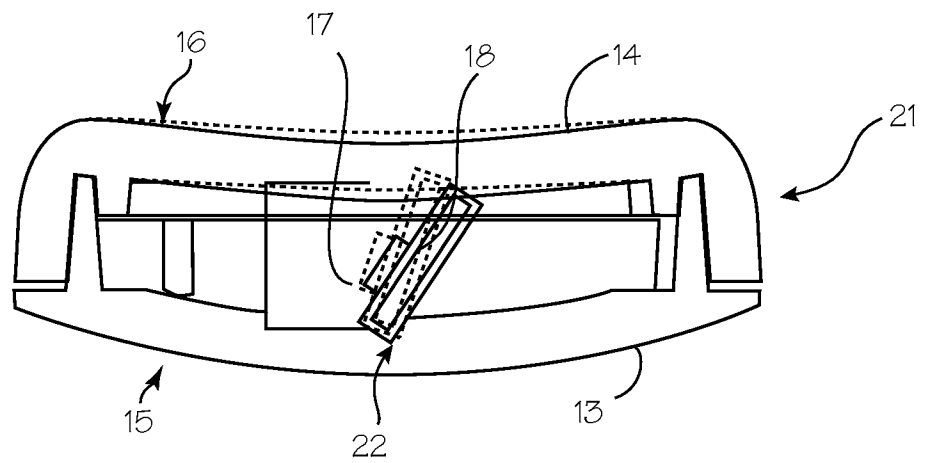


Fig. 7

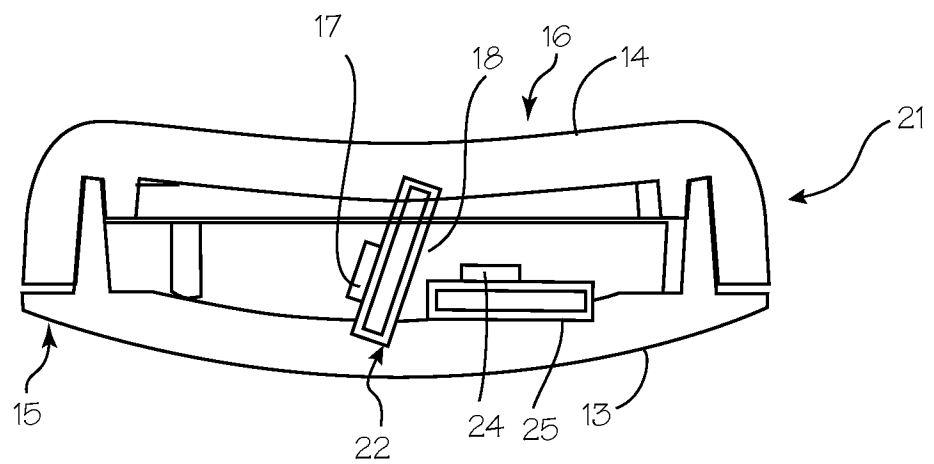


Fig. 8

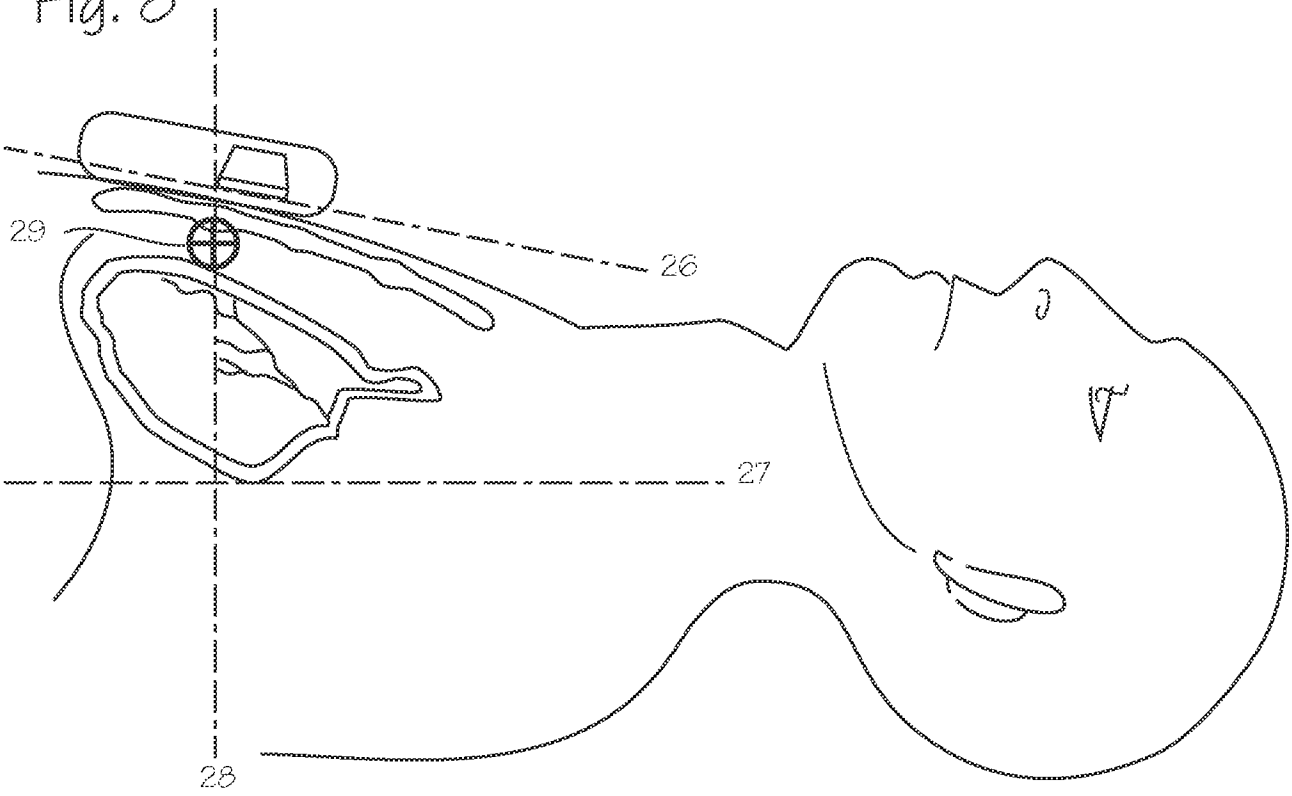


Fig. 9

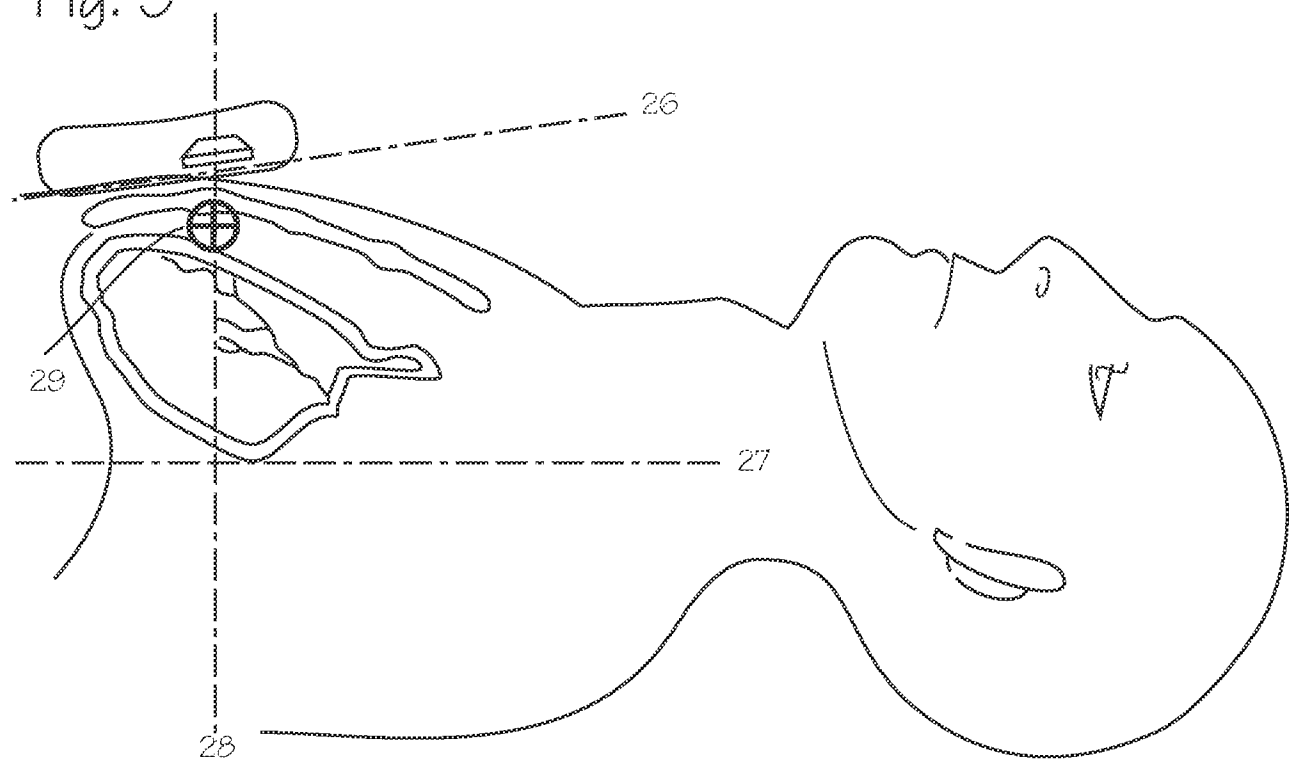


Fig. 10

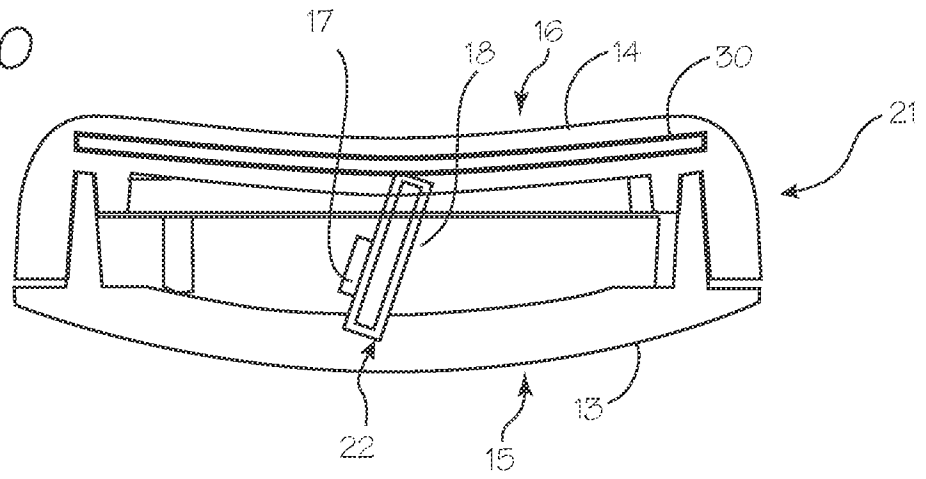


Fig. 11

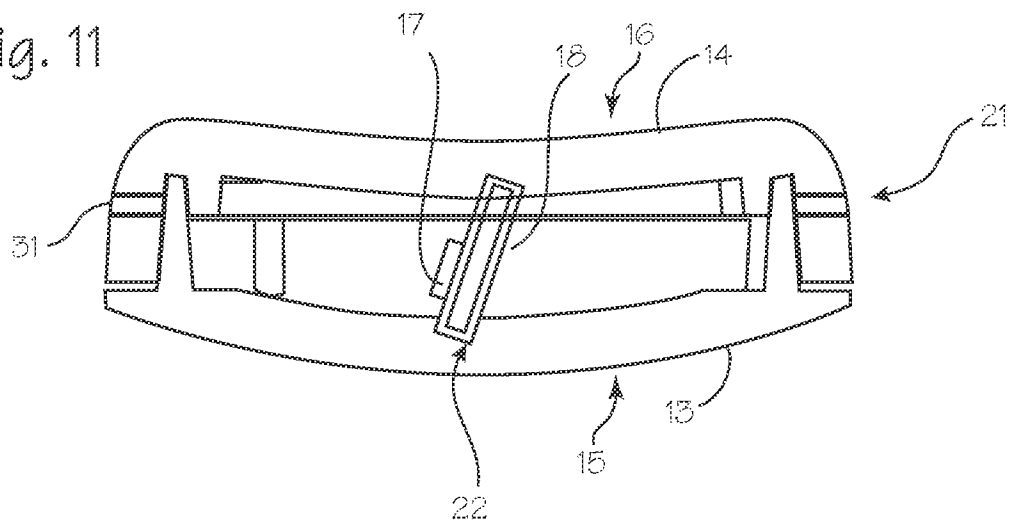


Fig. 12

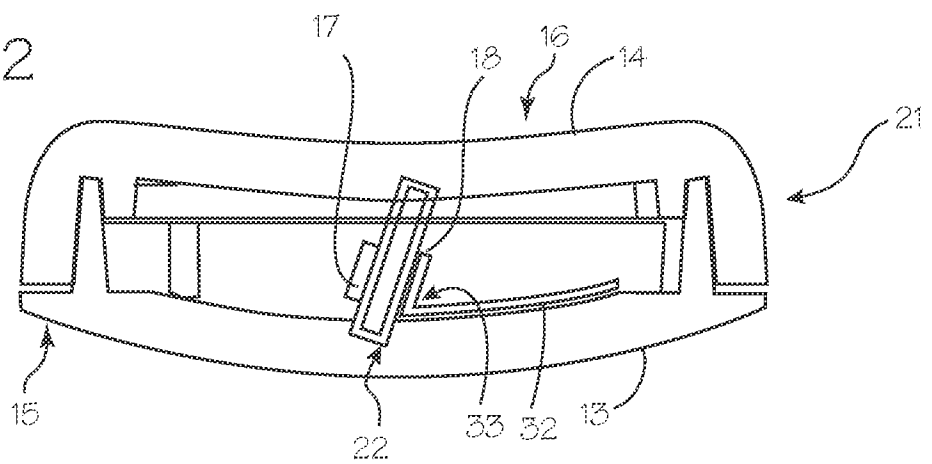


Fig. 13

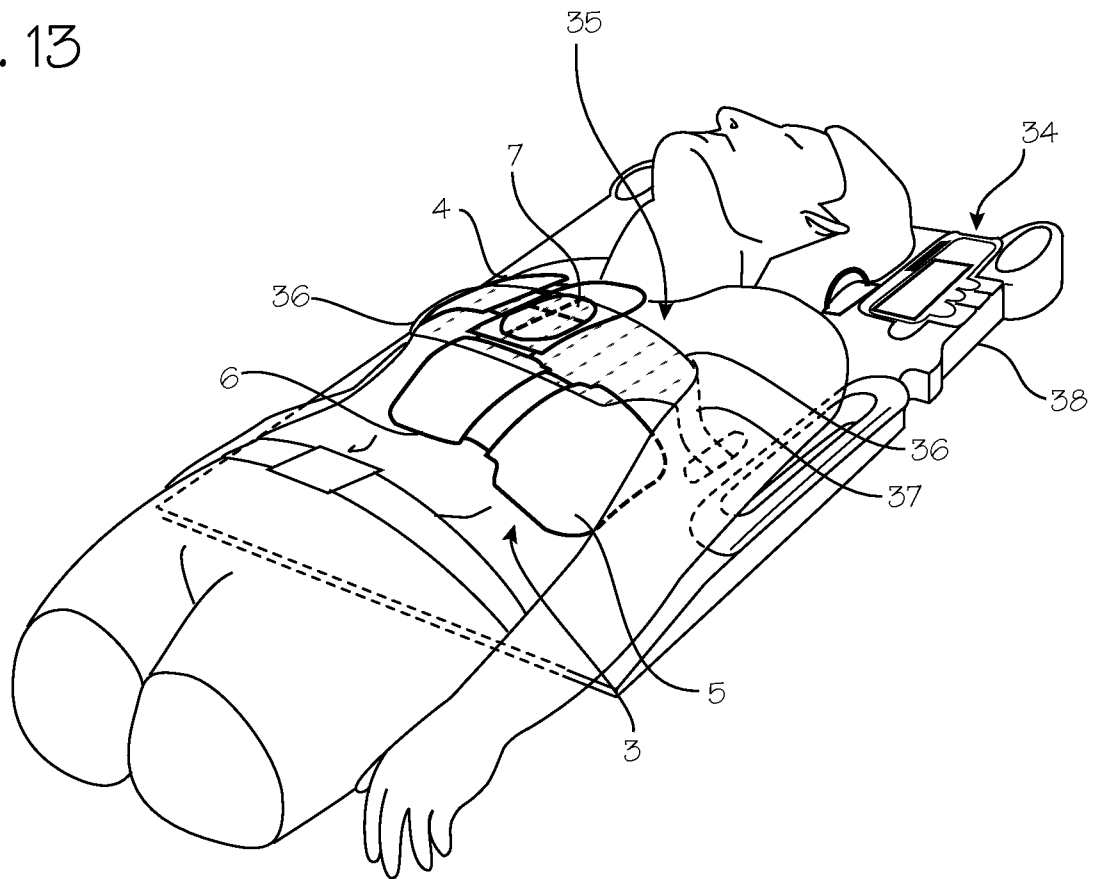
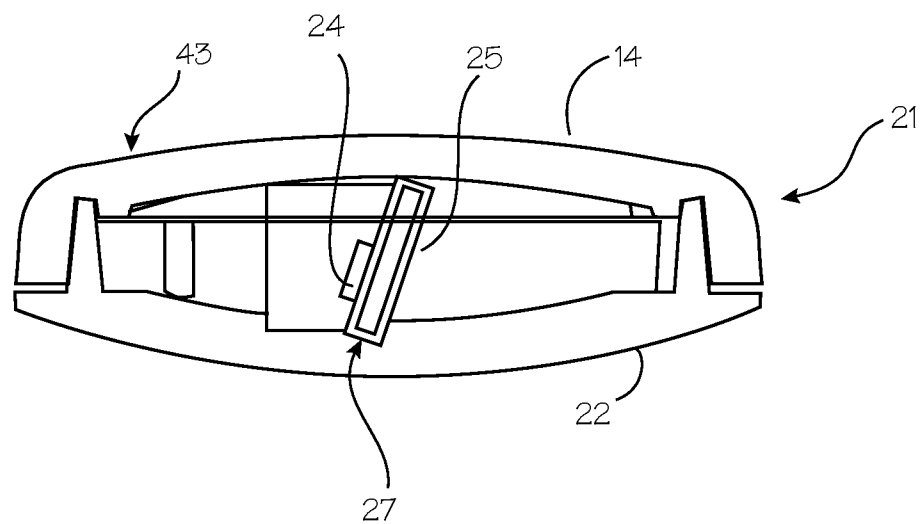


Fig. 14



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/069849**A. CLASSIFICATION OF SUBJECT MATTER****A61H 31/00(2006.01)i, A62B 33/00(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61H 31/00; G01P 7/00; G01P 15/00; A61N 1/00; A62B 33/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords:chest compression monitor, accelerometer, deformation

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2012-0191024 A1 (HALPERIN et al.) 26 July 2012 See paragraphs [0042]-[0047], [0057]-[0059], [0065]-[0068]; and claims 1-3.	1-21
A	US 5831164 A (REDDI et al.) 03 November 1998 See claims 1-14.	1-21
A	US 2007-0135739 A1 (HALPERIN et al.) 14 June 2007 See claims 1-4.	1-21
A	US 8160698 B2 (ELGHAZZAWI et al.) 17 April 2012 See claims 1 and 2.	1-21
A	US 2008-0146974 A1 (LUND et al.) 19 June 2008 See claims 1-13.	1-21



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

20 February 2014 (20.02.2014)

Date of mailing of the international search report

21 February 2014 (21.02.2014)

Name and mailing address of the ISA/KR


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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/069849

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012-0191024 A1	26/07/2012	AU 2146500 A	29/05/2000
		EP 1128795 A2	05/09/2001
		EP 1128795 B1	15/05/2013
		EP 1609453 A2	28/12/2005
		EP 2275027 A2	19/01/2011
		JP 2002-529157 A	10/09/2002
		JP 2009-285475 A	10/12/2009
		JP 2011-156371 A	18/08/2011
		JP 2013-166022 A	29/08/2013
		JP 2013-166023 A	29/08/2013
		JP 2013-166024 A	29/08/2013
		JP 2013-166025 A	29/08/2013
		JP 4566404 B2	20/10/2010
		JP 5189575 B2	24/04/2013
		JP 5313283 B2	09/10/2013
		US 2002-055694 A1	09/05/2002
		US 2002-165471 A1	07/11/2002
		US 2002-193711 A1	19/12/2002
		US 2005-004484 A1	06/01/2005
		US 2006-247560 A1	02/11/2006
		US 2007-135739 A1	14/06/2007
		US 2008-064971 A1	13/03/2008
		US 2011-034836 A1	10/02/2011
		US 2012-238884 A1	20/09/2012
		US 6390996 B1	21/05/2002
		US 6865413 B2	08/03/2005
		US 7074199 B2	11/07/2006
		US 7108665 B2	19/09/2006
		US 7295871 B2	13/11/2007
		US 7429250 B2	30/09/2008
		US 7818049 B2	19/10/2010
		US 8147433 B2	03/04/2012
		WO 00-27464 A2	18/05/2000
US 5831164 A	03/11/1998	None	
US 2007-0135739 A1	14/06/2007	AU 2000-21465 A1	29/05/2000
		AU 2146500 A	29/05/2000
		EP 1128795 A2	05/09/2001
		EP 1128795 A4	14/07/2004
		EP 1128795 B1	15/05/2013
		EP 1609453 A2	28/12/2005
		EP 1609453 A3	01/12/2010
		EP 2275027 A2	19/01/2011
		JP 2002-529157 A	10/09/2002
		JP 2009-285475 A	10/12/2009
		JP 2011-156371 A	18/08/2011
		JP 2013-166022 A	29/08/2013
		JP 2013-166023 A	29/08/2013

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/069849

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		JP 2013-166024 A	29/08/2013
		JP 2013-166025 A	29/08/2013
		JP 4566404 B2	20/10/2010
		JP 5189575 B2	24/04/2013
		JP 5313283 B2	09/10/2013
		US 2002-0055694 A1	09/05/2002
		US 2002-0165471 A1	07/11/2002
		US 2002-0193711 A1	19/12/2002
		US 2005-0004484 A1	06/01/2005
		US 2006-0247560 A1	02/11/2006
		US 2008-0064971 A1	13/03/2008
		US 2011-0034836 A1	10/02/2011
		US 2012-191024 A1	26/07/2012
		US 2012-238884 A1	20/09/2012
		US 6390996 B1	21/05/2002
		US 6865413 B2	08/03/2005
		US 7074199 B2	11/07/2006
		US 7108665 B2	19/09/2006
		US 7295871 B2	13/11/2007
		US 7429250 B2	30/09/2008
		US 7818049 B2	19/10/2010
		US 8147433 B2	03/04/2012
		WO 00-27464 A2	18/05/2000
US 8160698 B2	17/04/2012	CN 1750857 A	22/03/2006
		EP 1603637 A2	14/12/2005
		EP 1603637 A4	14/06/2006
		EP 1603637 B1	25/05/2011
		JP 2006-518637 A	17/08/2006
		JP 4531746 B2	25/08/2010
		US 2004-0162585 A1	19/08/2004
		US 2006-0122648 A1	08/06/2006
		US 2012-245648 A1	27/09/2012
		US 6961612 B2	01/11/2005
		WO 2004-073493 A2	02/09/2004
US 2008-0146974 A1	19/06/2008	AU 2007-249065 A1	03/07/2008
		CA 2615470 A1	15/06/2008
		EP 1933114 A1	18/06/2008
		EP 1933114 B1	09/06/2010
		JP 2008-250291 A	16/10/2008
		US 7993290 B2	09/08/2011