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(54) **AN AUTOMATED CHEST COMPRESSION DEVICE TO INCREASE THE EFFICACY OF CARDIOPULMONARY RESUSCITATION BY MEANS OF ALTERNATING PHASES DURING WHICH THE PHYSICAL CHARACTERISTICS OF CHEST COMPRESSION ARE VARIED SO AS TO INCREASE OVERALL FORWARD BLOOD FLOW**

AUTOMATISIERTE BRUSTKOMPRESSIONSVORRICHTUNG ZUR ERHÖHUNG DER EFFIZIENZ DER KARDIOPULMONALEN WIEDERBELEBUNG MITTELS ALTERNIERENDER PHASEN, BEI DENEN DIE PHYSIKALISCHEN EIGENSCHAFTEN DER BRUSTKOMPRESSION ZUR ERHÖHUNG DES GESAMTEN VORWÄRTSBLUTFLUSSES VARIIERT WERDEN

DISPOSITIF DE COMPRESSION THORACIQUE AUTOMATISÉ POUR AUGMENTER L'EFFICACITÉ DE LA RÉANIMATION CARDIO-RESPIRATOIRE AU MOYEN DE PHASES ALTERNÉES PENDANT LESQUELLES LES CARACTÉRISTIQUES PHYSIQUES DE COMPRESSION THORACIQUE SONT MODIFIÉES DE FAÇON À AUGMENTER LE FLUX SANGUIN AVANT GLOBAL

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(56) References cited:
US-A1- 2006 089 574
US-A1- 2006 094 991
US-A1- 2014 155 792
US-A1- 2014 336 546
US-A1- 2015 265 497
US-A1- 2017 035 650

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Description

[0001] The present invention relates to automated chest compression. Devices performing automated mechanical cardiopulmonary resuscitation (CPR) have been developed for inducing blood flow by application of external force to the thorax.

BACKGROUND OF THE INVENTION

[0002] For performing automated chest compressions various mechanical devices have been developed. These devices are either based on a piston mechanism which repeatedly compresses the thorax or based on a circumferential or partial circumferential constriction for applying a force to the thorax. Circumferential and partial circumferential constrictions may incorporate a band around the front and sides of the patient, or a pneumatic bladder with a constricting outer circumference. A circumferential device for applying chest compressions using a bladder is described, for instance, in US2007/0010765 A1.

[0003] Alternatively, it is also known to use devices based on circumferential constriction, and on anteroposterior compression decompression of the chest as cardiopulmonary resuscitation. Anteroposterior compression decompression may be provided by a piston mechanism attached to a gantry above the patient. Circumferential constriction may be achieved by inflation pneumatic bladders or shortening of a band. For details of such a construction of a chest compression device reference is made to US 2016/0361228 A1.

[0004] The mechanical devices may perform chest compressions under control of a processer. The processor controls operation of the mechanical application of force to the patient.

[0005] Hemodynamics is the forward movement of blood. As such, it is required for the maintenance of life in any organism with a separate vascular system. In an intact organism, the vascular system is composed of a pumping mechanism - the heart - and a closed circuit of arteries and veins. Arteries deliver freshly oxygenated blood to the tissues and veins return blood to the heart and lungs for replenishment of oxygen.

[0006] The circulatory system is considered to have four components: 1) a pump, 2) an arterial compartment, 3) an organ and tissue compartment, and 4) a venous compartment. Forward blood flow is achieved through a combination of cardiac output and venous return. Additionally:

1) The pump - for these purposes the human or mammalian heart.
2) The arterial compartment - blood vessels connecting the heart to the various organs and tissues of the body. Generally filled with oxygenated blood under some differential pressure.
3) The tissue compartment - capillaries within the organs and tissues of the body. Oxygen exchange and waste product removal occur here.
4) The venous compartment - connecting the tissues and organs of the body to the heart. Filled with venous blood that is relatively deoxygenated and relatively enriched with carbon dioxide and other waste products of metabolism. The pressure in the venous compartment is generally lower than in the arterial compartment.

[0007] In the intact organism, the heart achieves circulation means of cardiac output and venous return, the pressure within the arterial compartment being greater than the venous compartment. In the steady-state, each heart beat is similar to any other and incorporates components intended to achieve cardiac output and venous return. Generally, mammals respond to the need for greater cardiac output by means of increasing stroke volume and heart rate.

[0008] It is possible to induce forward blood flow to during cardiac arrest by application of external force to the thorax. (Kouwenhoven, Jude, and Knickerbocker 1960; CARDIAC ARREST - The Science and Practice of Resuscitation Medicine 96) Most commonly, this has been achieved by providing anteroposterior compression of the mid-chest in the area of the sternum, usually with a piston like mechanism.

[0009] The combination of chest compressions and rescue breathing is called basic life support (BLS). Since its initial adoption, multiple improvements to basic life support have been proposed. Although incremental changes in parameters such as the rates of rescue breathing and chest compression have been widely adopted,(Kleinman et al. 2015) qualitatively different techniques have not become routine. While it has been possible to demonstrate some improvement in outcome in animal models with techniques such as abdominal counterpulsation,(Ralston, Babbs, and Niebauer 1982) circumferential constrict (Halperin et al. 1993) and active decompression,(Cohen, Tucker, Lurie, et al. 1992) the degree of improvement has been insufficient to result in widespread clinical adoption. In almost all cases, changes to basic life support have either a) not been evaluated in clinical trials, b) have failed in clinical trials, or c) have had only modest effectiveness when utilized clinically. Overall, there have not been large increases in the rate of return of spontaneous circulation once cardiac arrest has occurred.

[0010] Therefore, there is a significant and important need for improved techniques of cardiopulmonary resuscitation (CPR).

[0011] Normal cardiac output in a healthy adult is in the range of 4.7 liters per minute. This output maintains a mean arterial compartment blood pressure of approximately 90 mm Hg. The human heart responds to greater needs for blood flow by increasing rate and the force of contraction.

[0012] However, during cardiac arrest, CPR is only

able to generate hemodynamics that are a fraction of an intact circulation. Often, they are in the range of 20% of normal cardiac output. (Michael et al. 1984) This large decrease in cardiac output results in mean arterial blood pressures that are often in the range of 25 mm Hg. (Paradis et al. 1989) The low cardiac outputs and arterial compartment pressures result in poor vital organ perfusion, and increased blood transit times. Loss of vasomotor tone in both the atrial and venous compartment acts to exacerbate the loss in hemodynamics. Blood begins to collect in the venous compartment, which raises venous pressures. The motive force for arterial to venous circulation is the difference in pressures between the two compartments. The abnormally low atrial mean pressures and abnormally high venous mean pressures act together to create a low perfusion pressures.

[0013] All of these decrements to perfusion and hemodynamics during CPR mean that cardiac output, flow out of the arterial compartment, and return flow from the venous compartment are all only a fraction of native circulation.

[0014] In native circulation, cardiac outputs, ventricular stroke volumes, tissue flows, and venous return are generally in equilibrium. Under normal circumstances, one of the vascular compartments does not expand significantly with respect to the other compartments over time frames of minutes. This may not be the case under the extreme low-flow of cardiac arrest and CPR. The relative expansion of the venous compartment may result in inadequate volume on the arterial side of the circulation. This, in turn, may result in impaired cardiac output.

[0015] Relative to the volumes of the vascular compartments, the cardiac output during cardiac arrest and CPR is generally inadequate for optimal forward flow and restoration of spontaneous circulation. It has not previously been realized that this inadequacy may be exacerbated by CPR chest compression decompression cycles (**CCDC**s) of a single type that has been designed with the intention of being optimal overall. Such CCDCs may be a trade-off between compressions optimized for cardiac output **(cardiac output optimized CCDCs)** versus compressions optimized for venous return **(venous return optimized CCDCs).**

[0016] It may be possible to improve overall forward flow by first performing a series of CCDCs optimized for cardiac output followed by a series optimized for venous return or visa versa. Such an approach might first expand and pressurize the arterial compartment causing improved flow through the tissue compartment and into the venous compartment. If the patient then receives a series of CCDCs optimized for venous return, this might enhance flow back to the heart or thorax and act to optimize the subsequent cardiac output optimized compressions. Such a method may transform the arterial and venous compartments into components of a whole body CPR pump.

[0017] For the purposes of clarity, the following terms are used in describing CPR based on movement of the chest or abdomen:

1) **Chest compression:** during CPR this is the forceful downward movement of the anterior chest **(Figure 1) 1.** This may be achieved by a rescue provider or, in accordance with the present invention, mechanically with an automated chest compression device.

2) **Chest relaxation:** release of the anterior chest, allowing it to move forward towards its normal position **2.** This is usually achieved by releasing force on the piston device.

3) **Chest decompression:** for the purposes of this discussion, this may be either the same as chest relaxation **2,** or it may be active, that is forceful, decompression (Figure 4) **3.**

4) **Chest compression-decompression cycle:** For the purposes of this discussion, a single cycle incorporating the downward forceful compression of the chest **1,** the interval during which the chest remains compressed **4,** the upward release or forceful decompression **2,3** and the interval until the next compression **5. (Figure 1)** For these purposes, it is understood circumferential or partial circumferential constriction of the thorax may be the method of chest compression. (Halperin et al. 1993)

5) **Active chest decompression:** upward forceful decompression of the anterior chest **3.**

6) **Circumferential compression:** during CPR, elevation of the intrathoracic pressure for the purposes of creating hemodynamics achieved by application of force around the chest.

7) **Abdominal compression:** application of force to the anterior abdomen as a component of CPR.

8) **Abdominal counterpulsation:** application of force to the anterior abdomen during the relaxation or decompression phase of chest compressions.

9) **Conventional CPR:** CPR in which the CCDCs are identical **(Figures 1,2)** .

10) **Alternating pattern CPR (AP-CPR):** Implementing multiple methods of CPR such as, but not solely limited, to those described herein in an alternating pattern, which relates to the invention described herein. The CCDCs are varied so as to improve overall forward blood flow and/or hemodynamic efficacy **(Figures 5,6,7)** .

[0018] To understand the current invention, it is important to know that, the methods, techniques, compo-

nents/devices, **CCDCs** and enhancements of cardiopulmonary resuscitation based on manipulation of the external chest and/or abdomen may be considered to fall into two broad categories: 1) those that directly create or enhance arterial forward flow (cardiac output), and 2)those that create or enhance venous return.

[0019] Mechanistically, it is reasonable to assume that components/devices of the CPR cycle that create or enhance cardiac output act to pressurize the arterial compartment. This will increase flow from the arterial compartment into the tissue compartment. Subsequent increased flow in the tissue compartment will result in increased flow into the venous compartment. The expansion and increased pressure of the venous compartment will enhance flow back to the heart, which is venous return. And finally, enhanced venous return may prime the CPR pump for increased cardiac output and forward-flow on the next cycle.

[0020] The mechanistic understanding of CPR hemodynamics is limited by a general lack of agreement as to the actual pump. (Haas et al. 2003) Some authorities believe that the heart continues to function as a pump mechanism, (Bircher, Safar, and Stezoski 1982) while others believe that the thorax becomes functionally the pump during CPR. (Niemann et al. 1980; Weisfeldt, Chandra, and Tsitlik 1981) It is possible that the mechanism of CPR is a combination of cardiac and thoracic pumps, and that the proportional contribution of each mechanism is variable patient to patient. Alteration of device **CCDC**s between arterial optimized and venous optimized is independent of the CPR pump mechanism.

[0021] Devices applying methods intended to increase arterial cardiac output during CPR include, but are not limited to **(Figure 3):**

1. Greater compressive or constrictive force/speed **6**

2. Greater depth of compression **7**

3. More frequent compressions

4. Longer compression phase **8** - shorter relaxation phase **9**

[0022] Devices applying methods intended to increase venous return during cardiopulmonary resuscitation include, but are not limited to **(Figure 4):**

1. Active decompression **10**

2. Increased force/speed during active decompression **10**

3. Active decompressing the chest wall to a location above its native anatomic position **11**

4. Prolonged decompression phase **12** or shortened compression phase **13**

5. Airway occlusion during decompression so as to create greater relative negative intrathoracic pressure

6. Combination of active decompression and airway occlusion. (Wang et al. 2015)

[0023] Examples of forward flow cardiac output enhancing techniques include, but are not limited to, standard anteroposterior chest compression and circumferential constriction.(Kouwenhoven, Jude, and Knickerbocker 1960; Halperin et al. 1993) Examples of techniques that may enhance venous return include, but are not limited to, active decompression of the chest (Cohen, Tucker, Lurie, et al. 1992), abdominal counterpulsation (Voorhees, Niebauer, and Babbs 1983), and partial airway obstruction during inhalation - the so called impedance threshold device. (Wolcke et al. 2003)

[0024] The improvement in hemodynamics associated with active decompression may be mechanistically mediated by creation of increased negative intrathoracic pressure during the decompression phase of CPR **10,3** , with resulting enhancement of venous return. Additional enhancement of negative intrathoracic pressure and venous return may be achieved by briefly obstructing the airway during the decompression release phase.(Plaisance et al. 1999) Typically, this is achieved through utilization of a cracking valve mechanism called an impedance threshold device.

[0025] In addition to compression and decompression of the chest, compression and decompression of the abdomen, either independently or in a synchronized pattern with the chest compressions, has been proposed as potentially enhancing overall hemodynamics during CPR.(Ralston, Babbs, and Niebauer 1982; Babbs 1984) It is theoretically possible that these abdominal techniques may have independent and variable effects on cardiac output or venous return.

[0026] Additionally, alterations in ventilation, either independently or in a synchronized pattern with the chest compressions, has been proposed as potentially enhancing overall hemodynamics during CPR. (Segal 2014) In particular, transient occlusion of the airway during relaxation phase has been demonstrated to enhance negative intrathoracic pressure and venous return. It is theoretically possible that alterations in the parameters of ventilation may have independent and variable effects on cardiac output or venous return.

[0027] Previous to this disclosure, all existing methods and devices of CPR have incorporated patterns of CCDC in which each CCDC was intended to be of similar intent to the one before or after. All previous methods and devices have been intended to optimize hemodynamics during CPR by identifying an ideal CCDC optimized overall with respect to both cardiac or thoracic output and venous return, and to use that ideal pattern throughout. Changes to these idealized CCDCs have been limited to force, rate, and location.

[0028] All previous devices, methods, and systems have attempted to enhance overall CPR hemodynamic effectiveness only at the level of the single CCDC. It has not previously been taught that overall forward flow may be greater when alternating between single CCDCs or groups of CCDCs that are different with respect to their cardiac output and venous return enhancing components. Alternatively, there is no previous description of a single CCDC or group of CCDCs being intentionally suboptimal with respect to either cardiac output or venous return so as to enhance the other parameter and overall forward flow.

[0029] Previous attempts at improving overall CPR performance have included greater force, greater depth, greater frequency, active forceful decompression, abdominal counterpulsation, and synchronized ventilations (Berkowitz et al. 1989) among others. Additionally, feedback related to operator performance or patient status has been used to adjust the CCDC patterns. (Abella et al. 2007; Yeung et al. 2009) But importantly, the adjustments in response to feedback have been limited to an increase or decrease in the already chosen CCDC pattern, or a wholesale change to another pattern (i.e. a change from standard CPR to active compression-decompression CPR) not a variable pattern of alternating CCDCs.

[0030] The previous universal limitation of CPR chest compressions to one type at any given moment may have reflected a belief that CPR should mimic native circulation, and the assumption that an optimized single CCDC pattern provided the best solution with respect to maximal overall hemodynamics and patient outcome. This assumption is unproven, and may be detrimental in the extreme low-flow state of cardiac arrest and CPR.

[0031] Once it has been learned that alternating either single or multiple CCDCs optimized for arterial cardiac output with single or multiple CCDCs optimized for venous return might result in overall improved systemic hemodynamics and patient outcome, mechanisms and devices to design and achieve arterial cardiac output and venous return optimized CCDCs may be considered.

[0032] Importantly, examination of the list of parameters believed to enhance cardiac output, and the alternative list of parameters believed to enhance venous return demonstrates that some of these parameters are mutually exclusive. In example, consider the possibility that the forces creating cardiac output are greatest during the chest compression phase, and forces creating venous return are greatest during relaxation phase. Of necessity, extending compression phase to augment cardiac output must occur at the expense of venous return during relaxation phase, and vice versa. Thus, it is not be possible to design a single CCDC optimized with both prolonged relative compression and relaxation phases. It may also not be possible to design a single CCDC pattern that optimally pressurizes the arterial compartment and optimally decompresses the venous compartment.

Field of the Invention

[0033] The invention disclosed here relates in general to the field of cardiopulmonary resuscitation (CPR), and more particularly, to an automated chest compression or constriction device for improving hemodynamics and clinical outcome.

Description of the Related Art

[0034] Automated chest compression or constriction devices for providing anteroposterior compression CPR are well known.(McDonald 1982) Generally, these are piston based devices, with the piston held in position anterior to the patient by a structural arm or arch that acts like a gantry. Constriction may be achieved with a circumferential or semi-circumferential band or bladder. (Halperin 1993)

[0035] Devices for providing active anteroposterior decompression are well known.(Cohen, Tucker, Redberg, et al. 1992)

[0036] Devices to enhance negative intrathoracic pressure and venous return are well known. (Plaisance et al. 1999)

[0037] US 2017/035650 A1 discloses an example of a chest compression system.

Summary

[0038] In accordance with a first aspect of the invention, there is provided an automated chest compression device according to claim 1. There are alternating sets of CCDCs, a first set optimized for cardiac output and a second set optimized for venous return.

Brief Description of the Drawings

[0039] Current recommendations for the treatment of adults in cardiac arrest are that chest compressions be performed at a rate of **100** to **120 compressions per minute** to a depth of at least **2 inches.** Please note that one inch equals 0.0245 meters.

[0040] (Kleinman et al. 2015) For the purposes of the figures below, the rate of 100 compressions per minute and a depth of 2 inches will be utilized as standard. At this rate, each CCDC will have a duration of 600ms and standard compression and relaxation phases durations of 300ms.

[0041] A person having ordinary skill in the art will understand that the waveforms in the figures below may equally well represent intrathoracic pressure.

Figure 1 - Idealized chest displacement during standard mechanical chest compressions (two compressions and one intervening relaxation)

Figure 2 - Chest displacement during standard manual chest compressions (two compressions and one

intervening relaxation)

Figure 3 - Chest displacement during mechanical CPR, CCDCs enhanced for arterial cardiac output relative to venous return. Specifically illustrated are: a greater rate and depth of compression (slope down)**6,** a greater duration of compression **8,** and a shorter durations of relaxation **9** (two compressions and one intervening relaxation)

Figure 4 - Chest displacement during mechanical CPR, CCDCs enhanced for venous return relative to cardiac output. Specifically illustrated are: active decompression (slope **up)10,** relaxation phase chest wall location above baseline **3,** and longer durations of relaxation **12.** (two compressions and a relaxation)

Figure 5: Chest displacement during mechanical CPR, alternating CCDCs enhanced for arterial cardiac output and CCDCs enhanced for venous return (1:1 ratio)

Figure 6: Chest displacement during mechanical CPR, alternating CCDCs enhanced for cardiac output and CCDCs enhanced for venous return (3:3 ratio)

Figure 7: Chest displacement during mechanical CPR, alternating CCDCs enhanced for arterial cardiac output and CCDCs enhanced for venous return (3:1 ratio)

Detailed Description

[0042] Previous to this disclosure, conventional devices and techniques of CPR were applied with a uniform pattern of CCDCs.

[0043] Previous to this disclosure, it has not been taught that overall forward flow and efficacy might be augmented by devices with alternating intervals or phases during which CCDCs are optimized toward different objectives. By way of example, but not limitation, it might be more effective overall to have alternating time intervals during which one phase has CCDCs optimized for cardiac output and another composed of CCDCs optimized for venous return.

[0044] Once taught the invention, a person having ordinary skill in the art may appreciate that with this enhancement the major compartments of the circulatory system may not be in continuous equilibrium. Rather, during the phase of the cycle in which the device CCDCs are optimized for cardiac output, the arterial compartment may become pressurized relative to the tissue and venous compartments. If this pressure differential moves blood from the arterial compartment to the tissue compartment and then into the venous compartment, the venous compartment may then become relatively pressurized. Subsequently, during the phase in which the CCDCs are optimized for venous return, the venous compartment would be drained with increased returned blood flow to the heart.

[0045] Under this alternating pattern CPR (**AP-CPR**), a pattern may be established in which there is sequential volume expansion and pressurization of first the arterial compartment, then the tissue compartment and finally the venous compartment. As such, the arterial and venous compartments may be considered components of a systemic pumping mechanism rather than simply conduits. Flow within the tissues may take on a more sinusoidal pattern.

[0046] As a result of alternating between cardiac-output optimized CCDCs and venous-return optimized CCDCs, the overall hemodynamic efficacy, for example the minute-volume of blood flow through an organ of interest, is improved relative to what could be achieved by either of the two types of CCDCs alone.

[0047] In implementing such a preferred embodiment, a practitioner of ordinary skill in the art would know that CCDCs optimized for cardiac output would include, but are not limited to CCDCs of:

1. Greater compressive force/speed than a previous target which may have been otherwise recommended or set for compressive force/speed. For example, the speed and/or force of compression may be increased, or the time interval of the chest compression relaxation phase **9** to less than 100 milliseconds while maintaining force unchanged. Additionally, greater than standard compression depths may be used (i.e. 2.0 - 2.4 inches) **7.** Hence, the force applied to the chest to reach a target range of 2.0 - 2.4 inches may be greater during a time interval of less than 100 milliseconds in comparison to a time interval of 100 milliseconds or longer. The application of such force during compression may result in greater cardiac output of blood from the heart to the arterial compartment.

2. Greater depth of compression than a previous target which may have otherwise been recommended or set for compression depth **7.** For example, the target compression depth that would normally be set to a recommended standard compression depth of 2.0 - 2.4 inches may be increased to a range of compression depths of 2.4 - 4 inches. By compressing to a greater depth than the typically recommended 2.0 - 2.4 inches, more blood would be expected to be output from the heart to the surrounding tissues.

3. More frequent compressions than a previous target, which may have otherwise been recommended or set for a standard compression rate. For example, the target compression rate that may typically be set to a standard rate of 100-120 compressions per minute may be increased to a range of compression

rate of 120 - 200 compressions per minute. Compressing the chest at such an increased rate may result in an overall larger volume of blood being output from the heart to surrounding tissues than would otherwise be the case at lower rates of compression.

4. Shortened relaxation phase **9** as compared to conventional time intervals **5** for the relaxation phase of a chest compression. For example, the time interval of the relaxation/decompression phase, may be decreased from a standard duration of approximately 400 milliseconds to a duration of 1 - 300 milliseconds. Shortening the duration of the relaxation/decompression may allow for a subsequent chest compression to be initiated sooner, resulting in increased overall rate and/or force/pressure on the chest of the patient to move blood forward.

[0048] A person having ordinary skill in the art, may additionally appreciate that alterations in the abdomen and/or ventilations may adjunctively augment overall hemodynamics during CCDCs optimized for cardiac output. These alterations may be synchronized with specific alterations in the cardiac output or venous return optimized CCDCs.

[0049] In implementing such a preferred embodiment of an automated chest compression device, a practitioner of ordinary skill in the art would also know that CCDCs optimized for venous return would include, but are not limited to CCDCs of:

1. Active decompression, involving the upward forceful decompression of the anterior of the chest **10, 3.** Such an upward forceful action resulting in a greater negative intrathoracic pressure within the chest cavity that results in enhanced venous return from surrounding tissues back to the heart.

2. Increased force/speed active decompression as compared to typical decompression **10, 3.** For example, the speed at which the anterior of the chest is forcefully pulled upward may be increased by lowering the time interval of the decompression to less than 100 milliseconds for a standard compression depth of 2.0 - 2.4 inches. The application of a relatively greater upward force on the anterior of the chest due to the increased speed of the active decompression phase would lead to an increased magnitude of negative intrathoracic pressure, resulting in improved venous return of blood to the heart from the surrounding tissues.

3. Prolonged decompression phase **12** to provide increased opportunity for movement of blood back to the heart. For example, the time interval of the relaxation/decompression may be increased from a standard duration of approximately 400 milliseconds to a duration of 400 - 1500 milliseconds. This increase in duration may allow for enhanced negative intrathoracic pressure generated during active decompression to sufficiently overcome the presence of inertial resistance to flow such that blood is effectively able to be pulled from the surrounding tissues back toward the heart.

4. Airway occlusion during decompression to restrict unnecessary air from entering into the chest cavity during decompression. For example, a valve such as that provided by the ResQPOD® impedance threshold device manufactured by ZOLL Medical Corporation may be placed in the airway of the patient,(Jenkins et al. 2015) obstructing air from entering until a predetermined cracking pressure is achieved. By occluding the passage of air during the decompression phase, the effects of negative intrathoracic pressure on venous return are further enhanced.

[0050] A person having ordinary skill in the art, may additionally appreciate that alterations in the abdomen and/or ventilations may adjunctively augment overall hemodynamics during CCDCs optimized for venous return. These alterations may be synchronized with specific alterations in the venous return optimized CCDCs.

[0051] In an alternative specific embodiment, a practitioner of ordinary skill would produce a method for controlling an automated chest compression device in which there are alternating pairs of CCDCs, one cycle optimized for cardiac output, a second cycle optimized for venous return **(Figure 5).**

[0052] In an alternative specific embodiment, a practitioner of ordinary skill would produce a method for controlling an automated chest compression device in which there are alternating time intervals composed of multiple CCDCs, one interval composed of multiple cycles optimized for cardiac output, a second phase composed of multiple cycles optimized for venous return **(Figures 6,7).**

[0053] Once taught this invention, a person of ordinary skill in the art, wound understand that any one of a number of ratios between cardiac output enhanced CCDCs and venous return enhanced CCDCs are possible. Additionally, this ratio may be adjusted dynamically based on feedback of the patient's status.

[0054] In an alternative specific embodiment, a practitioner of ordinary skill would produce a method for controlling an automated chest compression device in which there are repeating time intervals composed of multiple CCDCs, each repeating interval composed of CCDCs that transition from cycles optimized for cardiac output to cycles optimized for venous return.

[0055] In an alternative specific embodiment, a practitioner of ordinary skill would produce a method for controlling an automated chest compression device in which there are repeating intervals composed of multiple CCDCs, each repeating interval composed of multiple CCDCs cycles that transition from cycles optimized for venous

return to cycles optimized for cardiac output.

[0056] In an alternative specific embodiment, a practitioner of ordinary skill would produce a method for controlling an automated chest compression device in which the CCDCs are optimized for cardiac output through incorporation of one or more selected from the group consisting of: greater compressive force, greater compressive speed, greater depth of compression, more frequent compressions, prolonged compression phase relative to relaxation, lessened active decompression, decreased force of decompression, decreased speed of decompression, shortened decompression phase.

[0057] In an alternative specific embodiment, a practitioner of ordinary skill would produce a method for controlling an automated chest compression device in which the CCDCs are optimized for venous return through incorporation of one or more selected from the group consisting of: greater active decompression, increased force of decompression, increased speed of decompression, lengthened decompression phase, lessened compressive force, lessened compressive speed, lessened depth of compression, prolonged decompression phase.

[0058] Alternatively, CCDCs may be provided that transition incrementally from ones that are solely intended to enhance venous return through CCDCs that blend venous return and cardiac output enhancing characteristics to CCDCs that are solely intended to enhance cardiac output. The oscillation through this cycle would be alternated with a time period that is itself optimized empirically or through feedback to enhance overall system forward flow.

[0059] For purposes of illustration and not limitation, a practitioner of ordinary skill in the art would, once taught the invention, be able to construct particular preferred embodiments of automated chest compression devices wherein:

1. The ratio of the time intervals is one to one.

2. The ratio of the time intervals is not one to one.

3. The duration of the time intervals is equal.

4. The duration of the time intervals is not equal.

5. The duration or ratio patterns of the two time intervals is adjusted based on a biomarker measurement obtained from the patient that assists in determining hemodynamic efficacy.

6. The pattern of transition from CCDCs optimized for cardiac output to CCDCs optimized for venous return is adjusted based on a biomarker measurement obtained from the patient that assists in determining hemodynamic efficacy.

7. The cardiopulmonary resuscitation is provided by circumferential or partial circumferential constriction and relaxation.

8. The CCDCs are provided by a mechanical or pneumatic device.

9. The CCDCs are provided by an automated chest compression device.

10.The ratio or sequence of CCDCs is variable based on feedback of patient status.

11.The cardiac output enhancing CCDCs, or their respective phases, are further enhanced by phasic manipulation of the abdomen. By way of example but not limitation, an automated chest compression device may provide respective signals for controlling operation of automated mechanical compression and decompression of the abdomen by a respective device receiving such control signals. The operation of both chest and abdominal devices can be synchronized in this manner for an improved joint effect.

12.The venous output enhancing CCDCs, or their respective phases, are further enhanced by phasic manipulation of the abdomen. By way of example but not limitation, an automated chest compression device may provide respective signals for controlling operation of automated mechanical compression and decompression of the abdomen by a respective device receiving such control signals. The operation of both chest and abdominal devices can be synchronized in this manner for an improved joint effect.

13.The cardiac output enhancing CCDCs, or their respective phases, are further enhanced by phasic alteration in ventilation pattern or pressures. By way of example but not limitation, an automated chest compression device may provide respective signals for controlling operation of automated alterations in ventilation by a respective device receiving such control signals. The operation of both devices can be synchronized in this manner for an improved joint effect.

14.The venous output enhancing CCDCs, or their respective phases, are further enhanced by phasic alteration in ventilation pattern or pressures. By way of example but not limitation, an automated chest compression device may provide respective signals for controlling operation of automated alterations in ventilation by a respective device receiving such control signals. The operation of both devices can be synchronized in this manner for an improved joint effect.

15.The cardiac output enhancing CCDCs, or their respective phases, are further enhanced by phasic alteration in the patient's body position or a portion

of the patient's body chosen from a list that includes the head, neck, chest, abdomen, arms or legs.

16.The venous output enhancing CCDCs, or their respective phases, are further enhanced by phasic alteration in the patient's body position or a portion of the patient's body chosen from a list that includes the head, neck, chest, abdomen, arms or legs.

17.The alternating CCDCs and the phases of alternating CCDCs are provided by manually or mechanically applied compressions in which the person or device providing chest compressions is assisted in the provision of cardiac output enhancing CCDCs and venous return enhancing CCDCs by biomarker and performance feedback.

18.The patients whole body is accelerated intermittently and in a manner synchronized to specific portions of the CCDCs such that cardiac output or venous return are further enhanced.

[0060] There are components of the invention that, while sufficient, are interchangeable within the context of the invention. With the benefit of the present disclosure, a practitioner skilled in the art would know which specific embodiments of these components to incorporate in optimizing performance of the invention.

Usefulness of the Disclosed Invention

[0061] Once it is understood and appreciated that the invention disclosed herein is for a method to improve CPR hemodynamics and the clinical outcome of patients suffering cardiac arrest, the usefulness will be manifest to anyone with ordinary skill in the art.

Non-Obviousness and No Prior Art

[0062] The non-obviousness of the invention herein disclosed is demonstrated by the complete absence of its description, appreciation or discussion in the medical or intellectual property literature. Additionally, a number of large commercial enterprises produce devices for mechanical CPR; despite extensive research and development enterprises, none of these companies have disclosed or developed methods or systems such as disclosed herein.

[0063] Previous methods and systems have attempted to enhance overall CPR hemodynamic effectiveness at the level of the single compression. Extensive review of the medical/patent literature has revealed no description of a method or system in which any single CPR compression/decompression is intentionally made sub-optimal with respect to its effect on arterial side forward flow so as to enhance venous side forward flow - essentially proving that the methods described herein have not previously been envisioned.

Critical Component

[0064] Once it is understood and appreciated that the invention disclosed herein is for improving the efficacy of CPR delivered or controlled by electrical and/or mechanical devices, it will be immediately appreciated that the particular control of the chest compression devices described is the critical component of the relevant structures within these devices.

Sufficiency of Disclosure

[0065] Once taught the invention by means of this specification, a person of ordinary skill would be able to adapt known techniques and devices that provide chest compression by way of motor or pneumatic driven pistons or belts such that their standard control systems direct the device to provide CCDCs that are alternatively cardiac output and venous return enhancing as described. These CCDCs have been described in similar sufficient detail.

Modifications

[0066] It will be understood that many changes in the details, materials, steps and arrangements of elements, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art without departing from the scope of the present invention.

[0067] Since many modifications, variations and changes in detail can be made to the described embodiments of the invention, it is intended that all matters in the foregoing description and shown in the accompanying drawings be interpreted as illustrative and not in a limiting sense. Thus, the scope of the invention should be determined by the appended claims.

Claims

1. An automated chest compression device for performing chest compressions during cardiopulmonary resuscitation on a patient, the device configured to apply two or more different chest compression-decompression cycles CCDCs to the patient, wherein the two or more CCDCs include a first set of CCDCs optimized for cardiac output and a second set of CCDCs optimized for venous return; **characterized in that**

   the set of CCDCs optimized for cardiac output are **characterized by** a relaxation phase of from 1 to 300 milliseconds; and

   the set of CCDCs optimized for venous return are **characterized by** active forceful decompression and/or a relaxation phase of from 400 to 1500 milliseconds; and

wherein the set of CCDCs optimized for cardiac output is performed alternately with the set of CCDCs optimized for venous return to enhance overall hemodynamic efficacy.

2. An automated chest compression device according to claim 1, wherein at least one of the first and second sets of CCDCs comprises CCDCs all having the same parameters.

3. An automated chest compression device according to claim 1 or 2, wherein at least one of the first and second sets of CCDCs comprises at least five CCDC cycles.

4. An automated chest compression device according to any of claims 1 to 2, wherein at least one of the first and second sets of CCDCs comprises a duration of at least 5 seconds.

5. An automated chest compression device according to any of claims 1 to 4, wherein a ratio of time intervals of the first and second set of CCDCs is one to one.

6. An automated chest compression device according to any of claims 1 to 4, wherein a ratio of time intervals of the first and second set of CCDCs is not one to one.

7. An automated chest compression device according to any of claims 1 to 6, wherein the first set of CCDCs optimized for cardiac output comprises a first interval of multiple CCDCs and the second set of CCDCs optimized for venous return comprises a second interval of multiple CCDCs.

8. An automated chest compression device according to any of claims 1 to 7, wherein an incremental transition occurs from the first set of CCDCs optimized for cardiac output to the second set of CCDCs optimized for venous return.

9. An automated chest compression device according to any of claims 1 to 8, wherein applying the first set of CCDCs optimized for cardiac output and applying the second set of CCDCs optimized for venous return comprises applying the first and second sets of CCDCs in a repeating interval and pattern.

10. An automated chest compression device according to any of claims 1 to 9, wherein a duration or ratio of patterns of at least one of the first and second CCDCs is adjusted based on a biomarker measurement obtained from the patient.

11. An automated chest compression device according to any of claims 1 to 10, wherein a pattern of transition from the first set of CCDCs optimized for cardiac output to the second set of CCDCs optimized for venous return is adjusted based on a biomarker measurement obtained from the patient.

12. An automated chest compression device according to any of claims 1 to 11, wherein the cardiopulmonary resuscitation is provided by circumferential or partial circumferential constriction and relaxation of the chest.

13. An automated chest compression device according to any of claims 1 to 12, wherein a ratio of time intervals of the first and second set of CCDCs is 3 to 2.

14. An automated chest compression device according to any of claims 1 to 13, wherein a signal is outputted from the device for enabling synchronization to further enhance CCDCs or their respective phases by phasic automatic manipulation of the abdomen or alteration of ventilation pattern or pressures.

Patentansprüche

1. Automatische Thoraxkompressionsvorrichtung zum Durchführen von Thoraxkompressionen während einer kardiopulmonalen Reanimation an einem Patienten, wobei die Vorrichtung dazu konfiguriert ist, zwei oder mehr unterschiedliche Thoraxkompressions-/- dekompressionszyklen CCDC auf den Patienten anzuwenden, wobei die zwei oder mehr CCDC einen ersten Satz von CCDC, die für das Herzminutenvolumen optimiert sind, und einen zweiten Satz von CCDC, die für den venösen Rückfluss optimiert sind, beinhalten; **dadurch gekennzeichnet, dass**

der Satz von CDCC, die für das Herzminutenvolumen optimiert sind, durch eine Entspannungsphase von 1 bis 300 Millisekunden gekennzeichnet ist und
der Satz von CDCC, die für den venösen Rückfluss optimiert sind, durch eine aktive kraftvolle Dekompression und/oder eine Entspannungsphase von 400 bis 1500 Millisekunden gekennzeichnet ist; und
wobei der Satz von CCDC, die für das Herzminutenvolumen optimiert sind, abwechselnd mit dem Satz von CDCC, die für den venösen Rückfluss optimiert sind, durchgeführt wird, um die hämodynamische Gesamteffizienz zu verbessern.

2. Automatische Thoraxkompressionsvorrichtung nach Anspruch 1, wobei mindestens einer von dem ersten und dem zweiten Satz von CDCC CCDC umfasst, die alle dieselben Parameter aufweisen.

3. Automatische Thoraxkompressionsvorrichtung nach Anspruch 1 oder 2, wobei mindestens einer

von dem ersten und dem zweiten Satz von CDCC mindestens fünf CDCC-Zyklen umfasst.

4. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 2, wobei mindestens einer von dem ersten und dem zweiten Satz von CDCC eine Dauer von mindestens 5 Sekunden umfasst.

5. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 4, wobei ein Verhältnis von Zeitintervallen des ersten und des zweiten Satzes von CDCC eins zu eins beträgt.

6. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 4, wobei ein Verhältnis von Zeitintervallen des ersten und des zweiten Satzes von CDCC nicht eins zu eins beträgt.

7. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 6, wobei der erste Satz von CDCC, die für das Herzminutenvolumen optimiert sind, ein erstes Intervall von mehreren CDCC umfasst und der zweite Satz von CDCC, die für den venösen Rückfluss optimiert sind, ein zweites Intervall von mehreren CDCC umfasst.

8. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 7, wobei ein inkrementeller Übergang von dem ersten Satz von CDCC, die für das Herzminutenvolumen optimiert sind, zu dem zweiten Satz von CDCC, die für den venösen Rückfluss optimiert sind, stattfindet.

9. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 8, wobei das Anwenden des ersten Satzes von CDCC, die für das Herzminutenvolumen optimiert sind, und das Anwenden des zweiten Satzes von CDCC, die für den venösen Rückfluss optimiert sind, ein Anwenden des ersten und des zweiten Satzes von CDCC in einem sich wiederholenden Intervall und Muster umfasst.

10. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 9, wobei eine Dauer oder ein Verhältnis von Mustern mindestens eines von dem ersten und dem zweiten Satz von CDCC auf der Basis eines Biomarkermesswerts, der von dem Patienten erhalten wird, justiert wird.

11. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 10, wobei ein Muster des Übergangs von dem ersten Satz von CDCC, die für das Herzminutenvolumen optimiert sind, zu dem zweiten Satz von CDCC, die für den venösen Rückfluss optimiert sind, auf der Basis eines Biomarkermesswerts, der von dem Patienten erhalten wird, justiert wird.

12. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 11, wobei die kardiopulmonale Reanimation durch zirkumferentielle oder partielle zirkumferentielle Verengung und Entspannung des Thorax bereitgestellt wird.

13. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 12, wobei ein Verhältnis von Zeitintervallen des ersten und des zweiten Satzes von CDCC 3 zu 2 beträgt.

14. Automatische Thoraxkompressionsvorrichtung nach einem der Ansprüche 1 bis 13, wobei ein Signal von der Vorrichtung zum Ermöglichen einer Synchronisierung ausgegeben wird, um CCDC oder ihre jeweiligen Phasen durch phasische automatische Manipulation des Abdomens oder Veränderung von Beatmungsmuster oder -drücken weiter zu verbessern.

Revendications

1. Dispositif automatisé de compression thoracique pour réaliser des compressions thoraciques au cours d'une réanimation cardiopulmonaire sur un patient, le dispositif étant configuré pour appliquer deux cycles de compression-décompression thoraciques CCDC différents ou plus au patient, dans lequel les deux CCDC ou plus incluent un premier ensemble de CCDC optimisés pour le débit cardiaque et un second ensemble de CCDC optimisés pour le retour veineux ; **caractérisé en ce que**

l'ensemble de CCDC optimisés pour le débit cardiaque sont **caractérisés par** une phase de relaxation allant de 1 à 300 millisecondes ; et
l'ensemble de CCDC optimisés pour le retour veineux sont **caractérisés par** une décompression forcée activée et/ou une phase de relaxation allant de 400 à 1500 millisecondes ; et
dans lequel l'ensemble de CCDC optimisés pour le débit cardiaque est réalisé en alternance avec l'ensemble de CCDC optimisés pour le retour veineux pour amplifier l'efficacité hémodynamique globale.

2. Dispositif automatisé de compression thoracique selon la revendication 1, dans lequel au moins un des premier et second ensembles de CCDC comprend des CCDC ayant tous les mêmes paramètres.

3. Dispositif automatisé de compression thoracique selon la revendication 1 ou 2, dans lequel au moins un des premier et second ensembles de CCDC comprend au moins cinq cycles de CCDC.

4. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 2, dans lequel au moins un des premier et second ensembles de CCDC comprend une durée d'au moins 5 secondes.

5. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 4, dans lequel un rapport d'intervalles de temps des premier et second ensembles de CCDC est d'un sur un.

6. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 4, dans lequel un rapport d'intervalles de temps des premier et second ensembles de CCDC n'est pas d'un sur un.

7. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 6, dans lequel le premier ensemble de CCDC optimisés pour le débit cardiaque comprend un premier intervalle de multiples CCDC et le second ensemble de CCDC optimisés pour le retour veineux comprend un second intervalle de multiples CCDC.

8. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 7, dans lequel une transition incrémentale se produit du premier ensemble de CCDC optimisés pour le débit cardiaque au second ensemble de CCDC optimisés pour le retour veineux.

9. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 8, dans lequel appliquer le premier ensemble de CCDC optimisés pour le débit cardiaque et appliquer le second ensemble de CCDC optimisés pour le retour veineux comprend appliquer les premier et second ensembles de CCDC à un intervalle et selon un schéma répétitifs.

10. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 9, dans lequel une durée ou un rapport de schémas d'au moins un des premier et second CCDC est ajusté(e) en fonction d'une mesure de biomarqueur obtenue du patient.

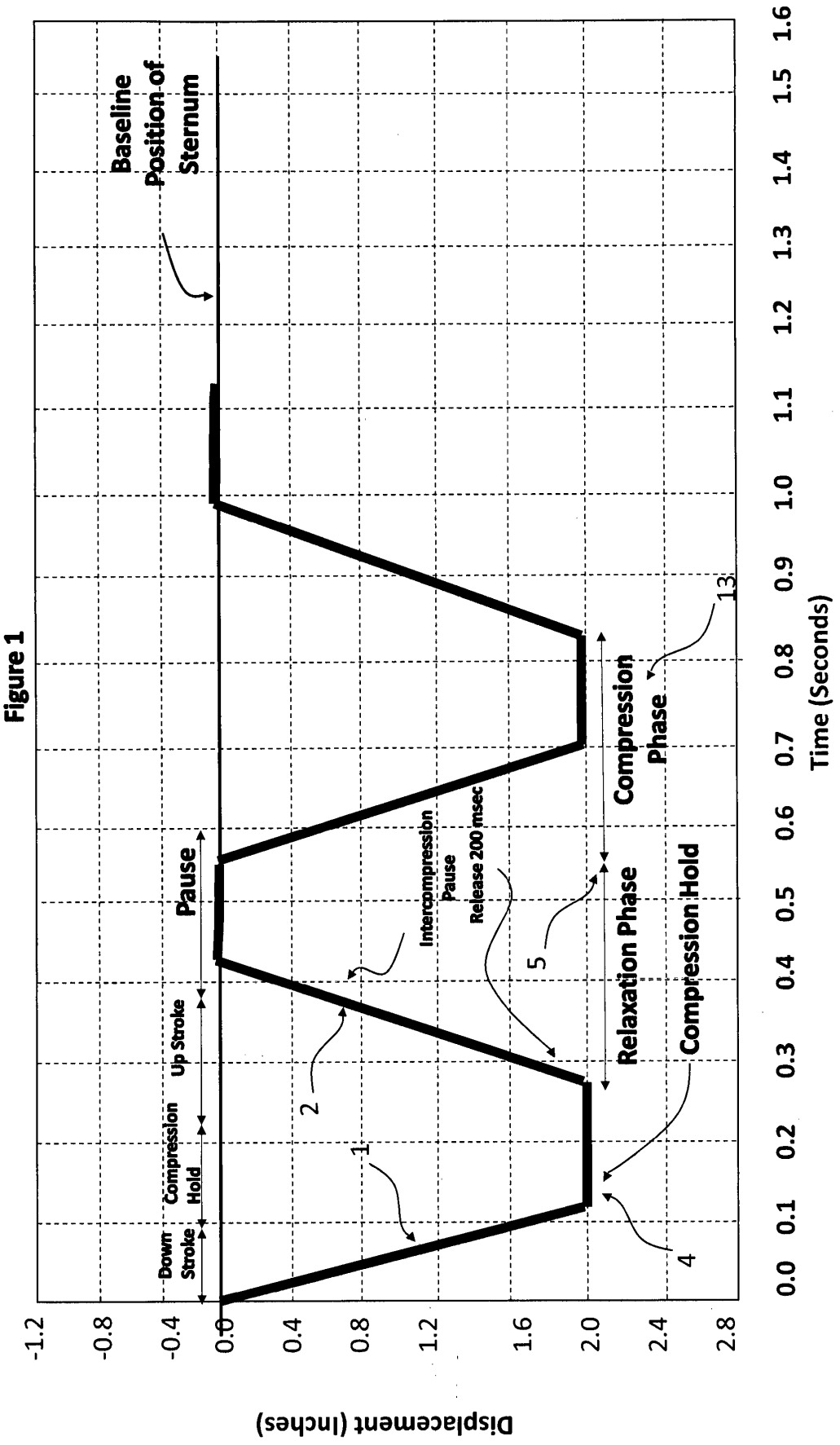
11. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 10, dans lequel un schéma de transition du premier ensemble de CCDC optimisés pour le débit cardiaque au second ensemble de CCDC optimisés pour le retour veineux est ajusté en fonction d'une mesure de biomarqueur obtenue du patient.

12. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 11, dans lequel la réanimation cardiopulmonaire est fournie par constriction circonférentielle ou circonférentielle partielle et relaxation du thorax.

13. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 12, dans lequel un rapport d'intervalles de temps des premier et second ensembles de CCDC est de 3 sur 2.

14. Dispositif automatisé de compression thoracique selon l'une quelconque des revendications 1 à 13, dans lequel un signal est émis du dispositif pour activer la synchronisation pour amplifier davantage des CCDC ou leurs phases respectives par manipulation automatique phasique de l'abdomen ou altération de schéma ou pressions de ventilation,

Figure 1


Baseline Position of Sternum
Pause
Up Stroke
Compression Hold
Down Stroke
Intercompression Pause
Release 200 msec
Compression Phase
Relaxation Phase
Compression Hold
1
2
4
5
13
Displacement (Inches)
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
Time (Seconds)

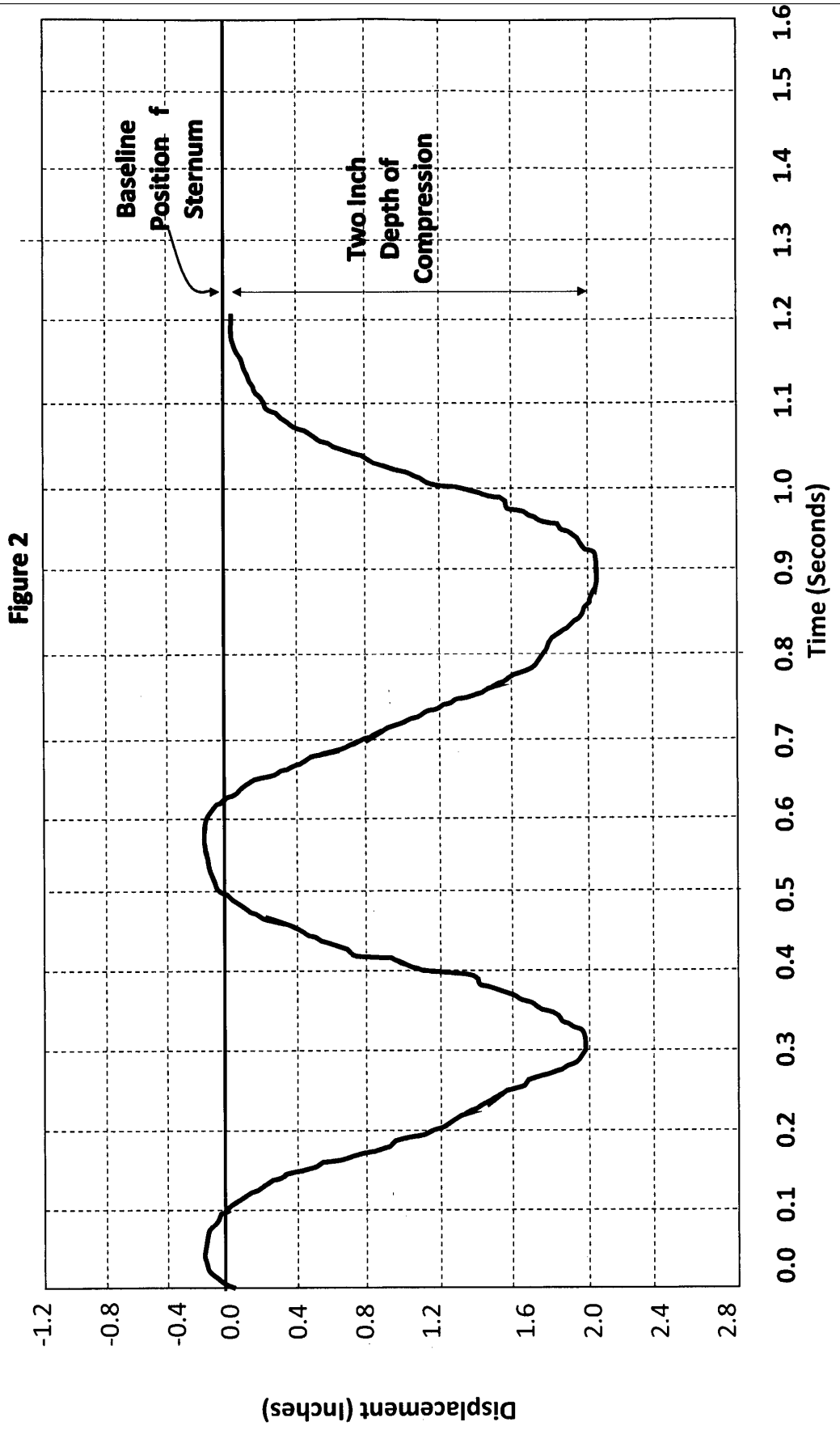
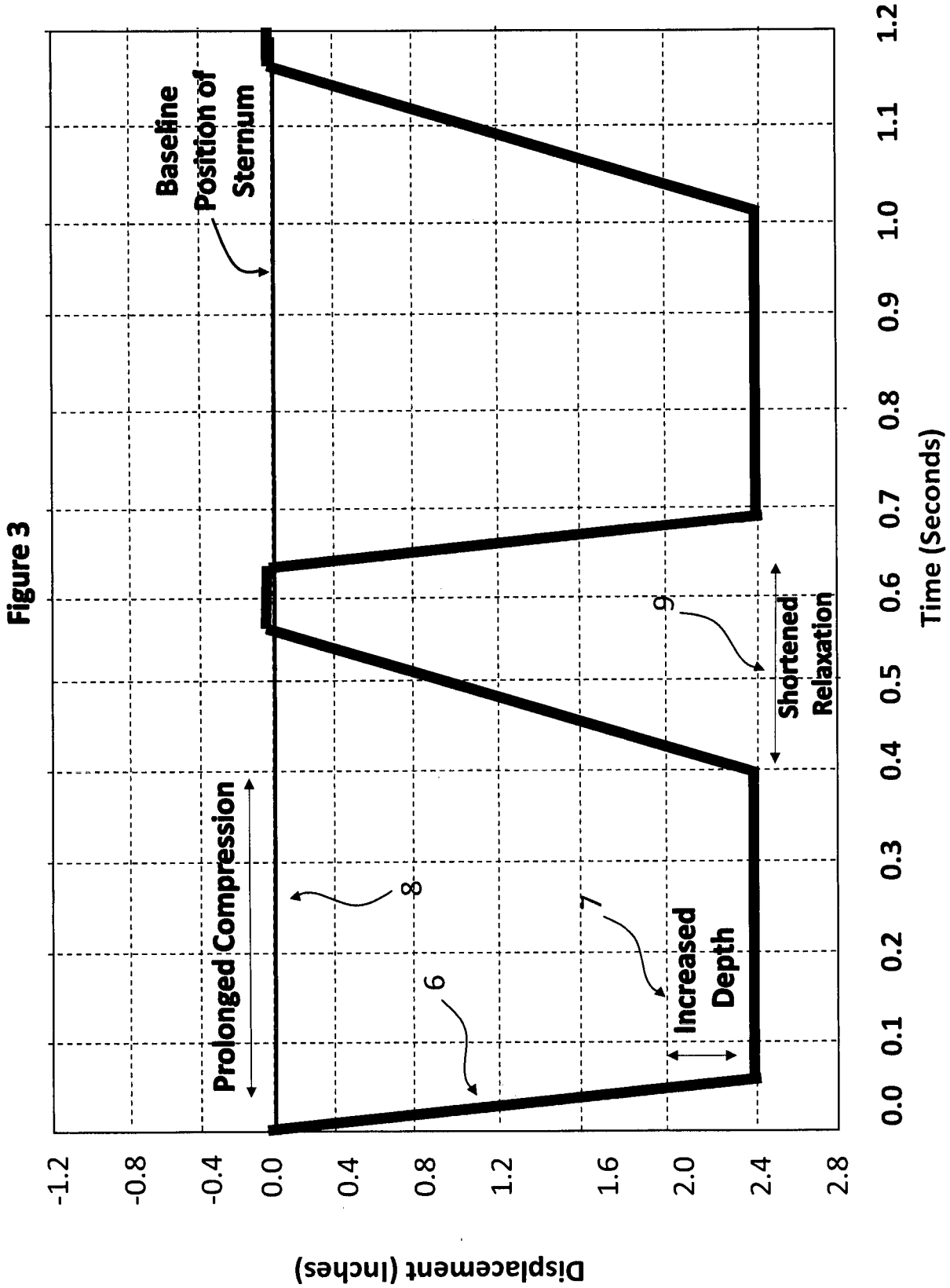

Baseline Position of Sternum
Two Inch Depth of Compression
Displacement (Inches)
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
Time (Seconds)

Figure 2

Figure 3


Baseline Position of Sternum
Prolonged Compression
Increased Depth
Shortened Relaxation
6
7
8
9
Displacement (Inches)
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Time (Seconds)

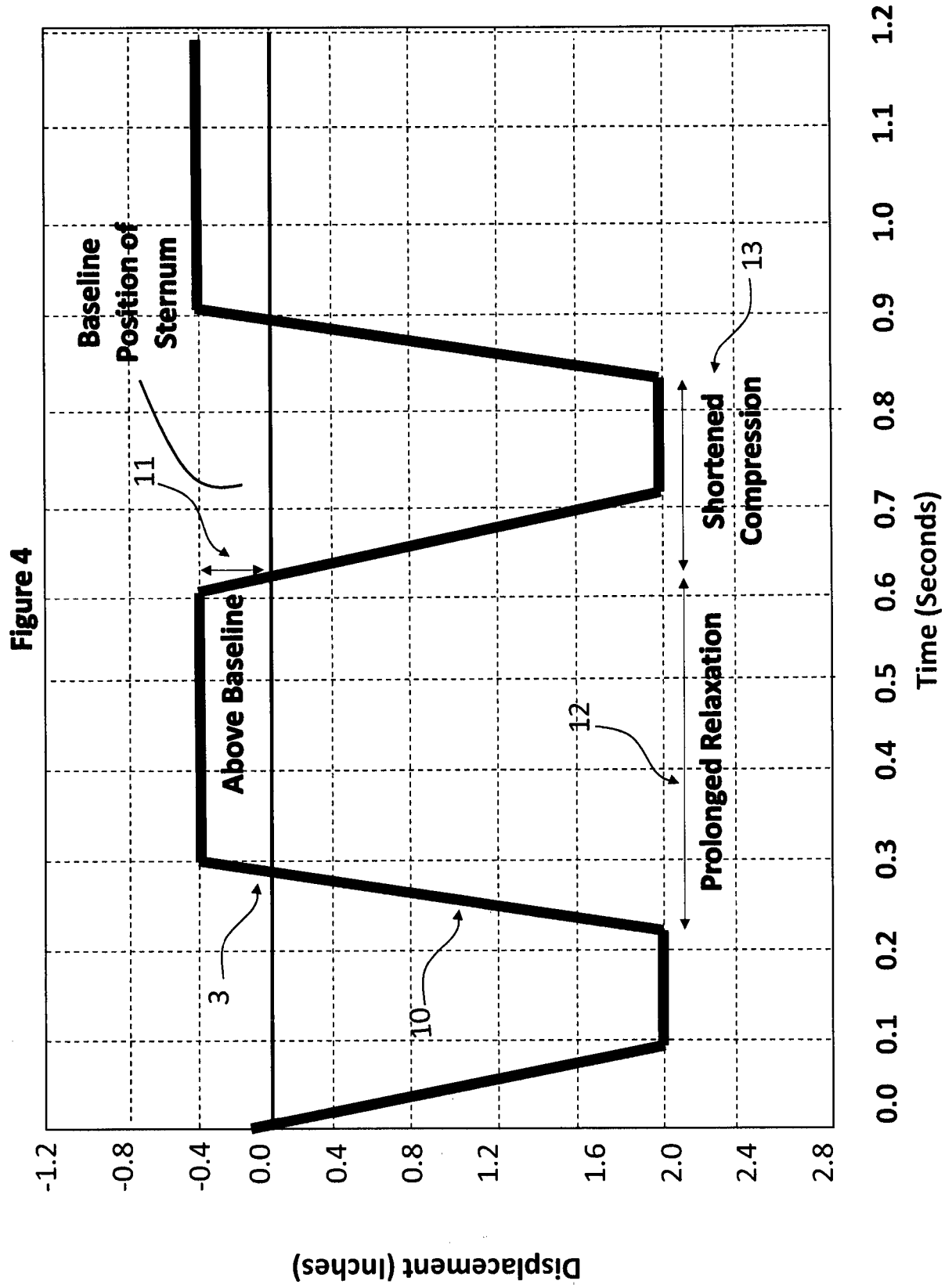

Displacement (Inches)
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
Time (Seconds)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
Baseline Position of Sternum
Above Baseline
Shortened Compression
Prolonged Relaxation
3
10
11
12
13

Figure 4

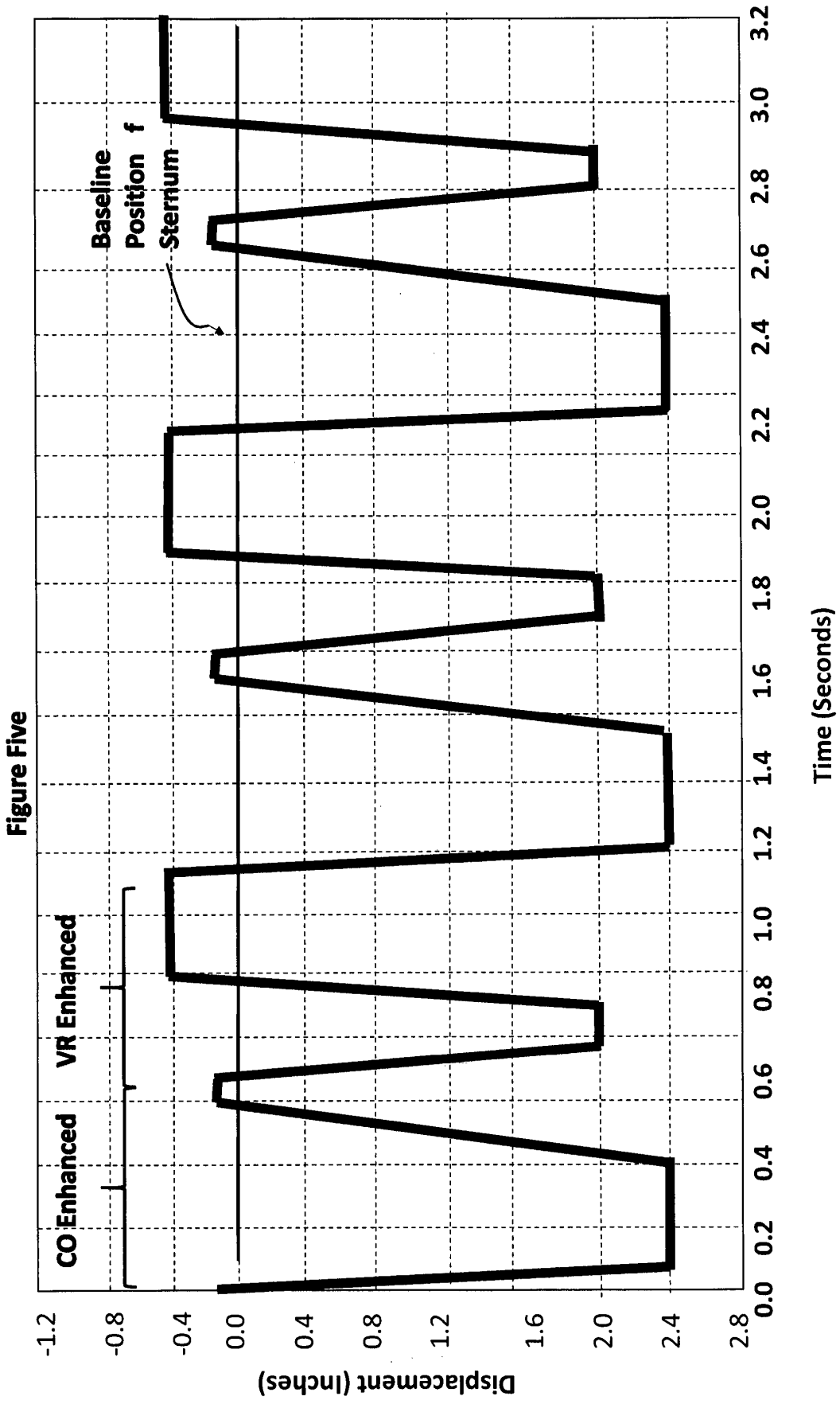


Figure Five
CO Enhanced
VR Enhanced
Baseline Position of Sternum
Displacement (Inches)
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
Time (Seconds)

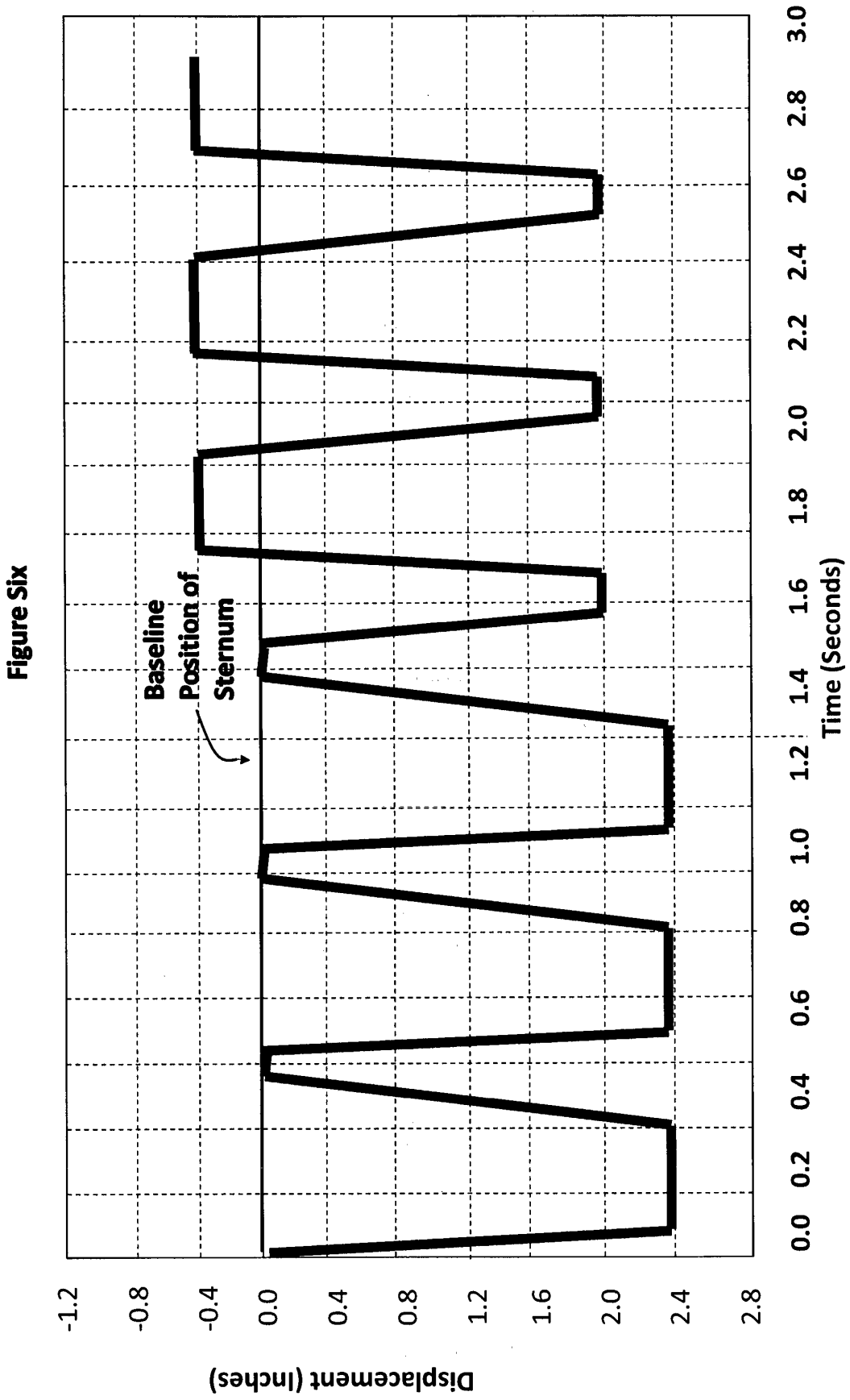
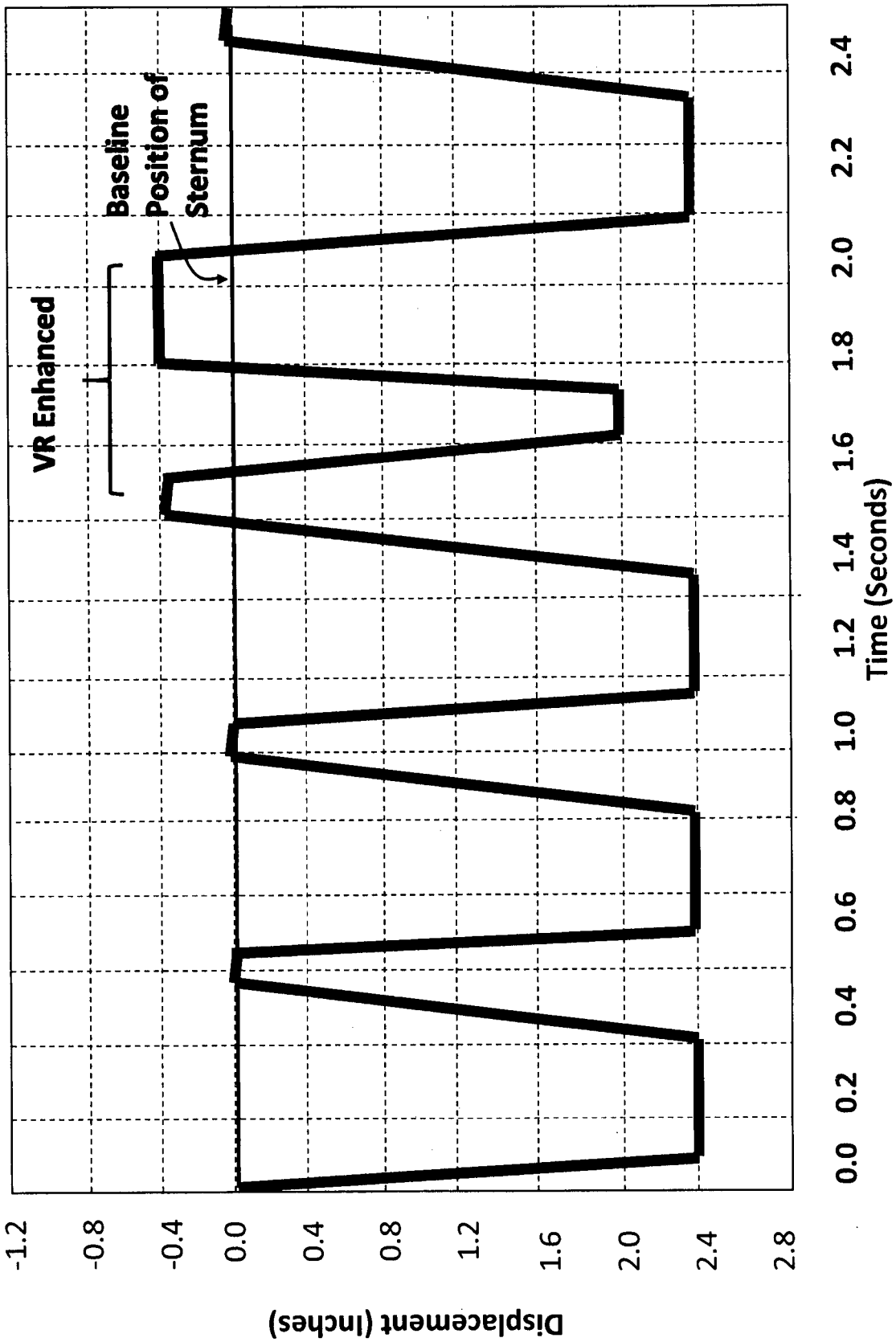


Figure Six
Baseline Position of Sternum
Displacement (Inches)
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
Time (Seconds)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0

Figure Seven



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20070010765 A1 **[0002]**
- US 20160361228 A1 **[0003]**
- US 2017035650 A1 **[0037]**

Non-patent literature cited in the description

- **KOUWENHOVEN ; JUDE ; KNICKERBOCKER.** *CARDIAC ARREST - The Science and Practice of Resuscitation Medicine,* 1960, vol. 96 **[0008]**