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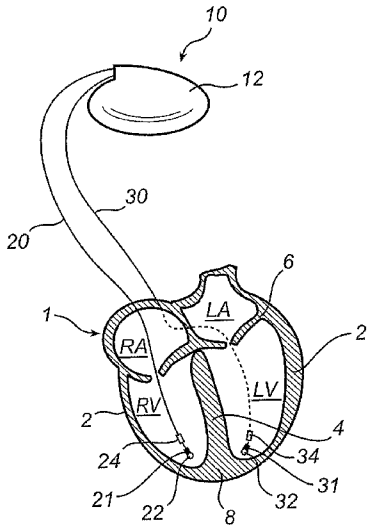
(54) **Title:** IMPLANTABLE CARDIAC STIMULATOR, DEVICE AND METHOD FOR MONITORING THE HEART CYCLE IN A HUMAN HEART



(57) **Abstract:** A device for monitoring the heart cycle of a human heart such that coronary flow may be maintained at a desired level, and a heart stimulator including such a device. The monitoring device is connectable to a first sensor adapted to be positioned at a first location of the heart and arranged for sensing cardiac wall movements at said first location, and to a second sensor adapted to be positioned at a second location of the heart and arranged for sensing cardiac wall movements at said second location. The device comprises processing circuitry arranged for receiving output signals from said first and second sensors, which output signals are indicative of myocardial relaxation at said first and second locations. The processing circuitry is further arranged for determining the time of myocardial relaxation at said first and second locations, and providing a diastolic synchronization signal indicative of the synchrony in the time of myocardial relaxation between said first and said second location.

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IMPLANTABLE CARDIAC STIMULATOR, DEVICE AND METHOD FOR MONITORING THE HEART CYCLE IN A HUMAN HEART

Technical field

The present invention generally relates to the field of implantable heart stimulation devices, such as pacemakers, implantable cardioverter-defibrillators (ICD), and similar cardiac stimulation devices that also are capable of monitoring and detecting electrical activities and events within the heart. More specifically, the present invention relates to a device for monitoring the heart cycle of a human heart such that coronary flow may be maintained at a desired level, a cardiac stimulator comprising such a device, and a method of monitoring the heart cycle of a human heart.

Background art

Implantable heart stimulators that provide stimulation pulses to selected locations in the heart, e.g. selected chambers, have been developed for the treatment of cardiac diseases and dysfunctions. Heart stimulators have also been developed that affect the manner and degree to which the heart chambers contract during a cardiac cycle in order to promote the efficient pumping of blood. The heart will pump more effectively when a coordinated contraction of both atria and both ventricles can be provided. In a healthy heart, the coordinated contraction is provided through conduction pathways in both the atria and the ventricles that enable a very rapid conduction of electrical signals to contractile tissue throughout the myocardium to effectuate the atrial and ventricular contractions. If these conduction pathways do not function properly, a slight or severe delay in the propagation of electrical pulses may arise, causing asynchronous contraction of the ventricles which would greatly diminish the pumping efficiency of the

heart. Patients who exhibit pathology of these conduction pathways, such as patients with bundle branch blocks, etc., can thus suffer compromised pumping performance.

Various prior art procedures have been developed for addressing these and other disorders. For instance, cardiac resynchronization therapy (CRT) can be used for effectuating synchronous atrial and/or ventricular contractions. Furthermore, cardiac stimulators may be provided that deliver stimulation pulses at several locations in the heart simultaneously, such as biventricular stimulators. The stimulation pulses could also be delivered to different locations with a selected delay in an attempt to optimize the hemodynamic performance, e.g. maximize cardiac output, in relation to the specific cardiac dysfunction present at the time of implant. During follow-up, a physician may alter the delay settings in adaptation to altered cardiac status. However, none of the prior art procedures addresses the issue of maintaining the coronary flow for providing oxygen-rich blood to the myocardium at a desired level.

Summary of the invention

An object of the present invention is to address the problem of maintaining coronary flow at a desired level.

This and other objects are achieved by a device and a cardiac stimulator as claimed in the independent claims. Further embodiments are defined in the dependent claims.

According to one aspect of the present invention, there is provided a device for monitoring the heart cycle of a human heart such that coronary flow may be maintained at a desired level, the device being connectable to a first sensor adapted to be positioned at a first location of the heart and arranged for sensing cardiac wall movements at said first location, and to a second sensor adapted to be positioned at a second location of the heart and arranged for sensing cardiac wall movements

at said second location. The device comprises processing circuitry arranged for receiving output signals from said first and second sensors, said output signals being indicative of myocardial relaxation at said first and second locations, determining the time of myocardial relaxation at said first and second locations, and providing a diastolic synchronization signal indicative of the synchrony or synchronicity in the time of myocardial relaxation between said first and said second location.

According to another aspect of the present invention, there is provided an implantable cardiac stimulator for delivering stimulation pulses to a human heart. The cardiac stimulator comprises a housing, a pulse generator enclosed in said housing for generating said stimulation pulses, control circuitry for controlling the delivery of said stimulation pulses to the heart, and a device for monitoring the heart cycle of a human heart as described above, the stimulator being connectable to a lead arrangement for conducting said stimulation pulses to the heart and sensed electrical signals from the heart to the control circuitry. It is to be noted that the term "implantable cardiac stimulator" is intended to encompass any implantable device arranged for providing electrical stimuli for controlling the operation of a human heart, such as an ICD or a pacemaker, e.g. of biventricular, dual-chamber, AV-sequential, or any other type known in the art.

Thus, the present invention is based on the advantageous idea of monitoring the heart cycle for determining the synchronization of myocardial relaxation during the diastolic phase of the heart cycle. Thereby, conditions that are necessary for maintaining coronary flow at a desired level can be monitored, which enables the detection of the demand for suitable corrective action when the conditions change or deteriorate.

All coronary blood supply, or cardiac perfusion, occurs during the diastolic phase of the heart cycle, i.e. when the myocardium relaxes between contractions. At the onset of the systolic phase, the myocardial tissue is contracted, thereby also contracting the coronary arteries and arterioles such that coronary flow virtually comes to a stop during systole. When the myocardial tissue relaxes and dilates, the arteries and arterioles also become dilated and the pressure gradient built up during the systolic phase forces the flow of blood through the coronary arteries and veins. Thus, the diastolic phase should be sufficiently long for providing sufficient time for coronary flow to occur.

It has been found that disturbances in the diastolic phase may have an adverse effect on the cardiac perfusion, i.e. such that the coronary flow is decreased. Thereby, the myocardium may not get the amount of oxygen that is required for a sufficient or desired cardiac performance, resulting in an ischemic situation. Such disturbances can be due to asynchronous systole, and post-systolic contractions (PSC). All of these may result in localized contractions of the myocardium during the diastolic phase, that will disturb the coronary flow locally and may also disturb or prevent a simultaneous onset of the diastolic phase.

As understood from the above, in cardiac stimulation therapy, the stimulator settings should be adapted such that a synchronous diastole with an adequately long duration is achieved. Thus, the aim at the time of implant would be to localize a region with the occurrence of possible PSC that would disturb the synchronous onset or duration of diastole, and then to stimulate the heart using a stimulation therapy pattern such that the occurrences of PSC is removed or decreased. This can be performed by adjusting the timing parameters for the delivery of the stimulation pulses.

However, even though ventricular and atrial diastolic synchrony may be present at the time of implant, possibly supported by suitable cardiac stimulation therapy, this may not necessarily be the case at a later stage. For instance, during progression of cardiac therapy after implantation of a cardiac stimulator, the cardiac tissue may adapt itself to the new conditions. Then, the function of hibernating myocardial tissue may be at least partially restored, and the overall cardiac function may become different from that at the time of implant.

In other words, diastolic synchrony from the time of implant may turn into diastolic asynchrony at a later stage, possibly supported or induced by stimulation therapy, as a result of a local improvement in the local function of myocardial tissue. For instance, the functions of myocardial portions or regions that at the time of implant were affected by slow conduction or post-systolic contractions (PSC), could at a later stage have improved their behavior such that there is no longer any slow conduction or PSC, or the PSC patterns have changed. Thus, even though there is an improvement in the behavior of myocardial tissue through the remodulation or recovery of the heart during progression of cardiac therapy, a new cardiac situation has arisen by this improvement and an improvement of the changed overall function of the heart may be desired for adaptation to the new situation.

According to the invention, the heart cycle is monitored by sensing the heart wall movements during the heart cycle at a plurality of locations. The heart wall movements are sensed using at least two sensors that are attached to the heart wall and provide output signals indicative of the heart wall movements, in order for distinguishing between contractions and relaxations of the muscular heart wall tissue, i.e. the myocardium. The output signals from each sensor are provided through cardiac leads to processing circuitry provided in an

implantable heart stimulator and used for determining onset and cessation of myocardial relaxation at the location of the sensor.

The processing circuitry receives the output signals provided by the respective sensors and determines any differences in time of myocardial relaxation for the myocardial tissue at the respective sensor location. If there are no differences, an indication of diastolic synchrony may be provided, which means that a satisfactory coronary flow is enabled.

The term "time of myocardial relaxation" may refer to the point in time of onset of myocardial relaxation, which indicates the onset of the diastolic phase. If there is a time difference between the onsets of myocardial relaxation at one sensor as compared to at the other sensor(s), the coronary flow may be greatly impaired during the time of asynchrony, i.e. when a portion of the myocardium is relaxed and another portion is contracted. Thereby, the time available between ventricular systole for supplying oxygen to the myocardial tissue is compromised, possibly resulting in impaired cardiac performance.

Furthermore, the term "time of myocardial relaxation" may additionally or alternatively refer to the time duration of myocardial relaxation, i.e. the portion of the diastolic phase that is not interrupted by any myocardial contraction, such as a regular systolic contraction or a PSC. Thus, not only the onset of myocardial relaxation is determined, but also the time duration during which the myocardium is in the relaxed state. Thereby, the time duration of simultaneous relaxation, i.e. diastole, for the myocardial locations at which the sensors are positioned may be determined, which indicates the time duration when the blood may flow through and oxygenate the myocardium. Thus, this time duration should be as large as possible for enabling

optimal oxygenation of the myocardium during the heart cycle.

Since it is the diastolic phase that is of interest for the calculation of the synchronization index, an intracardiac electrogram, IEGM, could be used for providing an indication related to when the output signals of the sensors may be used for determining onset and end of the diastolic phase. Then, the processing circuitry could be arranged to only receive sensor output signals provided during the diastolic phase. Thereby, there will be no risk of misinterpreting an asynchrony that may be present in the systolic phase as an asynchrony in the diastolic phase.

Moreover, the processing circuitry calculates a synchronization signal or index, related to the diastolic phase, on the basis of the output signals from the respective sensors. These calculations could be performed in a plurality of different manners, as understood by the person skilled in the art. For instance, the synchronization index or signal could be the actual difference time for the sensed onset of myocardial relaxation between the different sensors. In another example, the index could be related to the duration of simultaneous myocardial relaxation, for instance as a percentage of a measured or calculated optimal time duration.

In a further example, the difference between the sensor output signals could be calculated, for the diastolic phase, for instance by simply subtracting one output signal from another. The resulting difference signal could then be used as said synchronization signal per se, or statistical calculations could be applied to the difference signal to arrive at a suitable value indicative of the synchronization. If more than two sensors are used, a plurality of difference signals could be provided, for selected sensor combinations or for all combinations. The plural difference signals could then simply be aggregated to obtain a synchronization signal

that would take into account all sensors, or be subject to suitable statistical calculations to arrive at a synchronization index.

In yet further examples, the synchronization index or signal could be obtained through plotting of the sensor output signals in x-y plots and detecting patterns between the plots, for instance by cross-correlation, neural network signal processing, or loop discrimination. Such loop discrimination is disclosed in U.S. Patents Nos. 5,427,112 and 5,556,419, which are incorporate herein by reference.

However, the present invention is not intended to be restricted to the examples of methods for calculating a synchronization index or signal presented herein. On the contrary, any suitable method for calculating a synchronization signal or index from the output signals of the sensors is contemplated within the scope of the present invention.

According to embodiments of the present invention, the processing circuitry is arranged for comparing the obtained synchronization index or signal with a threshold value or signal. Then, the threshold value would be an indicator whether the diastolic synchronization lies within an acceptable range or not. In other words, as long as the synchronization index is within a selected range, as defined by one or more threshold values, a desired level of coronary flow is considered to be enabled. However, should the synchronization index fall outside the intended range, an indication of diastolic asynchrony, or insufficient diastolic synchrony, may be provided.

Such an indication could in exemplifying embodiments of the invention be used for triggering a change in the stimulation therapy for the patient. Such a change could for example refer to an adjustment in the VV-interval, e.g. for a biventricular heart stimulator; a change in the AV-interval, e.g. for a dual chamber or an AV-

sequential heart stimulator; or combinations thereof. Thereby, the diastolic synchrony can be monitored during remodulation of the patient's heart, and the pacing therapy can be adjusted in adaptation to the remodulation such that the coronary flow may be maintained at a desired level.

The changes in the timing parameters of the stimulation pulse delivery can, according to exemplifying embodiments, be performed in order to avoid or eliminate an asynchrony in the onset of the myocardial relaxation, i.e. an onset of the diastolic phase. Thus, if it is determined that there is an undesired difference in the time of onset of myocardial relaxation between the sensed, different portions of the myocardium, i.e. the portions for which the sensors are sensitive for cardiac wall movements, then the timing parameters of the stimulation pulse delivery may be amended such that a synchronized onset of myocardial relaxation is provided.

Furthermore, according to further exemplifying embodiments, changes in the timing parameters of the stimulation pulse delivery can be performed in order to reduce or avoid the occurrences of post-systolic contractions, PSC, which generally are localized events. As mentioned above, the occurrences of PSC during the diastolic phase, whether localized or involving the entire myocardium, will undoubtedly have a detrimental effect on the coronary flow locally. It may also disturb coronary flow that occurs in coronary arteries located downstream of those affected coronary arteries that are located in the myocardial region that contracts as a result of the PSC. Thus, by amending the timing parameters, suitably in a manner that has been previously determined to have an inhibiting effect on the occurrences of PSC, for instance at the time of implantation of the cardiac stimulator, the occurrences of undesired and detrimental PSC can be reduced and possibly even avoided.

Moreover, according to still further exemplifying embodiments, the changes in the timing parameters of the stimulation pulse delivery can be performed in order to lengthen the duration of simultaneous myocardial relaxation between the different portions of the myocardium for which cardiac wall movements are sensed. In other words, timing parameters are adjusted for obtaining as long time duration of simultaneous diastole as possible. Thereby, as long time as possible for enabling coronary flow to occur is provided. The detection and determination of simultaneous myocardial relaxation is interrupted if a PSC should occur within the diastolic phase. Thus, the term "simultaneous myocardial relaxation" refers to the time period from the onset of diastole for all sensed portions of the heart, until the onset of a myocardial contraction at any of the sensed portions of the heart, whether the contraction is a regular systolic contraction or an irregular post-systolic contraction.

As understood by the skilled person, the above described three objectives, i.e. simultaneous onset of myocardial relaxation, reduction or possible minimization of PSC, and extension or possible maximization of simultaneous duration of myocardial relaxation, is preferably combined when possible. Also, there may be situations when one must be prioritized over the other. Such prioritizing may be the subject of physician settings, or be pre-programmed shipping settings.

According to further embodiments of the invention, said three objectives can be adapted to the current heart rate, either intrinsic or stimulation induced stimulation. For example, it may be the aim for the changes in the timing parameters of the stimulation pulse delivery to achieve simultaneous onset at a basic heart rate, while at a higher heart rate the aim may be to extend the time duration of simultaneous myocardial relaxation, or vice versa.

Furthermore, according to still further exemplifying embodiments, if an asynchrony is detected at a high heart rate, the control circuitry of the cardiac stimulator may be arranged to reduce the heart rate. This may lead to a reduction of the cardiac output, but may on the other hand increase coronary flow since the time duration of diastole increases as a result of increased interval between cardiac contractions. Thus, for heart stimulators in which the pacing therapy may be automatically adjusted by the heart stimulator in order to optimize or maximize cardiac output, a synchronized and elongated diastolic phase may be given priority over the optimization of cardiac output. For instance, in patients suffering from ischemic heart disease, it may be more important to ensure synchronized diastole and, thereby, adequate coronary flow at all times rather than maximized cardiac output.

Suitable adjustments for avoiding or eliminating undesired diastolic asynchrony and restoring a suitable level of diastolic synchrony could according to exemplifying embodiments be determined or set prior to or during implantation of the cardiac stimulator. In such embodiments, sensor signals could be registered during a pre-set stimulation protocol, and synchronization index then be calculated for different pre-set stimulation conditions and settings. Examples of such pre-set stimulation protocols triggering changes in the timing parameters of stimulation pulse delivery could include an AV stimulation protocol with varying AV delays, a VV stimulation protocol with varying VV delays, etc. During implantation, i.e. when the heart is studied with the sensors during no stimulation and various stimulation protocols, the expected changes in synchronization index at heart decompensation can be outlined. The term decompensation refers to a situation where changes in the demand for cardiac output of the patient, for instance when the patient rises from a sitting to a standing position or

switches from walking to running, is not compensated for by the heart.

In further embodiments, the indication of diastolic asynchrony could be used for triggering an alarm signal to the patient. This alarm signal could be intended for prompting the patient to seek medical assistance for care or follow-up.

It should be understood that the indication of diastolic asynchrony does not have to be a binary value. On the contrary, the asynchrony indication preferably also provides information of the severity of asynchrony. Thus, the threshold value as referred to above, may in fact be a number of threshold values. For instance, a first value could be an indication of slight asynchrony to be used for diagnostic purposes, a second value could trigger a change in the pacing therapy, and a third value could be used for triggering an alarm to the patient that he needs to see his/her physician.

Furthermore, the change in timing parameters for the delivery of stimulation pulses may be performed in adaptation to the synchronization signal, or to the output signals from the wall movement sensors. Thus, the synchronization signal may provide an indication of the loss of synchrony, as well as further information which will provide information on how the lost synchrony is to be recovered. Furthermore, the sensor output signals may for instance provide information of the cause of the asynchrony. For instance, occurrences of diastolic asynchrony detected by two out of three sensors may provide an indication of where the source of the asynchrony occurred or originated. Moreover, the sensor output signals and/or the synchronization may suitably be stored for future use by the physician for diagnosis of occurred events at follow-up.

The monitoring of diastolic synchrony and/or detection of diastolic asynchrony is preferably performed at predetermined time intervals. As an example, the

monitoring could be performed by receiving the output signals from the sensors, and providing a diastolic synchronization signal at any suitable predetermined or varied time interval given the current cardiac situation, e.g. once a week, every three days, once a day, every 8 hours, etc. Preferably, the time interval is set such that monitoring is performed often enough for an asynchrony to be detected at such an early stage that corrective action may be immediately taken and possible detrimental effects avoided, and seldom enough such that an unduly large energy consumption resulting from the monitoring procedure may be avoided.

In some embodiments, the time interval may be varied in adaptation to expected possible changes in the function of the heart. For instance, it may be expected that variations and changes in the myocardial function is most likely to occur, and to occur most frequently, in the time immediately following implantation. Thus, the monitoring interval can be set at a short interval for the period immediately following implant, and then be automatically extended as the time from implantation increases.

Furthermore, the time interval may be shortened as a result of detected changes in the diastolic synchrony. Thus, following a change in diastolic synchrony, possibly into asynchrony with ensuing corrective actions taking place, the time interval is suitably decreased in order to frequently monitor for possible further deterioration, or for an improvement as a result of the corrective actions taken.

Moreover, immediately following a change in the pacing therapy, determinations of possible asynchrony should take place. Also, if the synchronization signal or index is a quantitative value directly indicating the level of synchrony, the change in synchronization based on any pacing therapy variations can be monitored and the pacing therapy further adjusted accordingly.

In further examples, if the monitoring should indicate that diastolic asynchrony has arisen, then one or more further measurements and determinations of diastolic synchronization may be performed before an indication of diastolic asynchrony is provided and possible ensuing actions are initiated. Thereby, a sudden, isolated asynchronous event will not have an undue impact on the overall stimulation pacing therapy.

In exemplifying embodiments of the present invention, the synchronization monitoring is based on the output of two sensors, in which a first sensor is positioned at a location related to the right ventricle of the heart and arranged for sensing cardiac wall movements of the right ventricle, and the second sensor is positioned at a location related to the left ventricle of the heart and arranged for sensing cardiac wall movements of the left ventricle. Preferably, the right ventricle sensor is positioned within the right ventricle and attached to the ventricular wall, and the left ventricle sensor is positioned in the coronary sinus region outside the left ventricle and in contact with the left ventricular wall. In this example, interventricular diastolic synchronization is monitored. As used herein, the phrase "coronary sinus region" refers to the vasculature of the left ventricle, including any portion of the coronary sinus, great cardiac vein, left marginal vein, left lateral vein, left posterior ventricular vein, middle cardiac vein, and/or small cardiac vein or any other cardiac vein accessible via the coronary sinus.

In further exemplifying embodiments of the present invention, the synchronization monitoring is based on the output of two sensors positioned in or at the same ventricle. Then, the sensors are suitably used for monitoring intraventricular diastolic synchronization, for instance in the right ventricle. However, if one sensor is positioned within the right ventricle and attached to the cardiac septum, or in the immediate

vicinity thereof, the sensor could be arranged to sense cardiac wall movements related to myocardial contraction and relaxation originating from the left ventricle.

Moreover, one or more additional sensors could in further examples of the invention be provided in or at the left or the right ventricle for providing additional output signal(s) on which the monitoring of diastolic synchronization is based. Also, sensors could be provided in the atrium for delivering output signal(s) on which the diastolic synchronization is based.

It should be noted that a number of different sensors could be used in the context of this invention for sensing cardiac wall movements, which are known per se to the person skilled in the art. For example, the sensors could be in the form of accelerometers, of any suitable type, or in the form of piezoelectric pressure transducers. Thus, the scope of the present invention is not restricted to the particular sensor alternatives disclosed herein.

In the examples that will be presented in the following, the sensors are provided at the distal end of cardiac leads that are arranged for providing stimulation pulses to the atria and/or ventricles of the heart, or for conducting sensed intrinsic cardiac signals from the heart to the heart stimulator. However, it should be noted that sensors provided on separate implantable leads, or other implantable devices, are also contemplated in the context of this application. Thus, the scope of the present invention is not restricted to sensors arranged on such implantable leads for stimulation and sensing as will be discussed below.

Further objects and advantages of the present invention will be discussed below by means of exemplifying embodiments.

Brief description of the drawings

Exemplifying embodiments of the invention will be described below with reference to the accompanying drawings, in which:

Fig. 1 is a simplified, partly cutaway view illustrating an implantable stimulator according to one exemplifying embodiment of the present invention;

Figs. 2 and 3 are partly cut-away views of a human heart provided with leads and sensors according to further exemplifying embodiments;

Fig. 4 is an illustration in a block diagram form of an implantable stimulator according to the embodiment shown in Fig. 1;

Fig. 5 is an illustration in a block diagram form of an analysis device arranged to receive signals from three cardiac wall motion sensors;

Figs. 6a-6c are schematic illustrations of the determination of diastolic synchrony according to embodiments of the present invention,

Figs. 7a-7c are schematic illustrations corresponding to those of Figs. 6a-6c, but in which a diastolic asynchrony is determined;

Figs. 8a-8c illustrate the determination of a diastolic asynchrony resulting from a local post-systolic contraction;

Figs. 9a-9d illustrate examples of sensor positions where all sensors are positioned at the left ventricle;

Figs. 10a-10d illustrate examples of sensor positions where sensors are positioned at both the right and the left ventricle, respectively;

Figs. 11a and 11b illustrate in diagram form a first example of how a synchronization index may be obtained; and

Figs. 12a and 12b illustrate in diagram form a second example of how a synchronization index may be obtained.

Description of exemplifying embodiments

The following is a description of exemplifying embodiments in accordance with the present invention. This description is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of the invention. Thus, even though particular types of heart stimulators will be described, such as biventricular pacemakers with or without atrial sensing and/or stimulation, the invention is also applicable to other types of cardiac stimulators, such as univentricular or dual chamber pacemakers, implantable cardioverter defibrillators (ICD's), etc.

With reference first to fig. 1, there is shown a stimulation device 10 in electrical communication with a patient's heart 1 by way of two leads 20 and 30 suitable for delivering multi-chamber stimulation (and possible shock therapy). The heart illustrated portions of the heart 1 include the right atrium RA, the right ventricle RV, the left atrium LA, the left ventricle LV, cardiac walls 2, the ventricular septum 4, the valve plane 6, and the apex 8. The valve plane 6 refers to the annulus fibrosis plane separating the ventricles from the atria and containing all four heart valves, i.e. the aortic, pulmonary, mitral, and tricuspid valves.

In order to sense right ventricular cardiac signals and to provide stimulation therapy to the right ventricle RV, the stimulation device 10 is coupled to an implantable right ventricular lead 20 having a ventricular tip electrode 22, a ventricular annular or ring electrode 24, and a cardiac wall movement sensor 21. The ring electrode 24 is arranged for sensing electrical activity, intrinsic or evoked, in the right ventricle RV. The right ventricular tip electrode 22 is arranged to be implanted in the endocardium of the right ventricle, e.g. near the apex 8 of the heart. Thereby, the tip electrode 22 becomes attached to the cardiac wall and follows the cardiac wall movements, which movements can be sensed by

the sensor 21 arranged near the tip electrode. In this example, the sensor is fixedly mounted in a distal header portion of the lead 20, in which the tip electrode 22 is also fixedly mounted. Furthermore in this example, the sensor is in the form of an accelerometer. However, other arrangements sensor types are contemplated for the cardiac wall motion sensor 21.

In order to sense left ventricular cardiac signals and to provide pacing therapy for the left ventricle LV, the stimulation device 10 is coupled to a "coronary sinus" lead 30 designed for placement via the coronary sinus in veins located distally thereof, so as to place a distal electrode adjacent to the left ventricle. Also, additional electrode(s) (not shown) could thereby be positioned adjacent to the left atrium. The coronary sinus lead 30 is designed to receive ventricular cardiac signals from the cardiac stimulator 10 and to deliver left ventricular LV pacing therapy using at least a left ventricular tip electrode 32 to the heart 1. In the illustrated example the LV lead 30 comprises an annular ring electrode 34 for sensing electrical activity related to the left ventricle LV of the heart. Furthermore, a cardiac wall movement sensor 31 is arranged at the tip electrode 32 for sensing left ventricular LV cardiac wall movements.

Turning briefly to Figs. 2 and 3, two alternative embodiments for placement of cardiac leads, cardiac electrodes and cardiac wall movement sensors for sensing longitudinal valve plane movements are illustrated. In Fig. 2, the RV and LV leads 20, 30 have been supplemented with a right atrial RA lead 80. The lead comprises an RA tip electrode 82 positioned in the patient's right atrial appendage for delivering electrical stimuli to the right atrium, and an RA ring electrode 84 for sensing and conducting cardiac signals from the right atrium to the cardiac stimulator. A cardiac wall motion sensor is provided at the RA tip electrode 82 for sensing cardiac

wall movements of the RA wall. Furthermore, the LV lead 30 is provided with an additional cardiac wall movement sensor 33 arranged at the valve plane 6, as well as an additional stimulating electrode, of the ring type, arranged distally of the movement sensor 33. Thereby, cardiac wall movements at a plurality of locations, i.e. three or four, may be sensed and conducted via the cardiac leads 20, 30, 80 to the cardiac stimulator.

Furthermore, Fig. 3 illustrates yet another example of lead, electrode and sensor placements. Here, the RV, RA and LV leads 20, 30 and 80 have been supplemented by an external epicardial lead 90 connected to the implantable stimulator 10. The epicardial lead 90 may be arranged for delivering stimulation pulses to the left ventricle LV of the heart, but is in this example only arranged for sensing cardiac wall movements and comprises a cardiac wall motion sensor 91. Thus, even though the LV lead 30 terminates and the stimulation electrode 32 for stimulation of the left ventricle arranged at a position near the valve plane 6 of the heart, local wall movements occurring in the LV cardiac wall further down towards the apex 8 may still be sensed.

Even though three examples have been illustrated in Figs. 1-3, the invention is not restricted to the illustrated examples of lead, electrode and sensor placement. For example, several epicardial electrodes and/or wall motion sensors could be used, wall motion sensors could be arranged at plural positions in the ventricles only, all wall motion sensors could be arranged in the same ventricle, plural atrial wall sensors could be used, etc. Also, in the illustrated examples, the wall motion sensors are of accelerometer type. However, other types of sensors for sensing and measuring wall movements are to be comprised in the scope of the present application. Further examples of sensor placements will be presented in relation to the further embodiments that will be described below.

Turning now to Fig. 4, the heart stimulator 10 of Fig. 1 is shown in a block diagram form. For illustrative purposes, reference is made to Fig. 1 for the elements of the leads that are intended for positioning in or at the heart. The heart stimulator 10 is connected to a heart 1 in order to sense heart signals and emit stimulation pulses to the heart 1. A first tip electrode 22 is anchored in the right ventricle RV of the heart 1 and connected, via a first electrode conductor in the lead 20, to a first pulse generator 26 in the heart stimulator 2. A first ring electrode 24 is connected near the first tip electrode 22 and, via a second electrode conductor in the first lead 20, to the first pulse generator 26. A stimulation pulse to the right ventricle can be delivered to heart tissue by the first pulse generator via the first lead 20 and the first tip electrode 22. The stimulation pulse is then returned, via the first ring electrode 24 and the first lead 20, to the first pulse generator 26. Alternately, the stimulation pulse can be delivered via the first tip electrode 22 and an indifferent electrode 12 which, in this instance, consists of the enclosure of the heart stimulator 10 but can also consist of a separate electrode located somewhere in the body. The indifferent electrode 12 is connected to the first pulse generator 26 via an electrode conductor 14 in order to return stimulation pulses from the right ventricle. A first detector 28 is connected in parallel across the output terminal of the first pulse generator 26 in order to sense right ventricular activity in the heart.

In corresponding manner, a second tip electrode 32 is positioned in a vein distally of the coronary sinus and, thus, connected to the left ventricle LV of the heart 1, and, via a conductor in the second lead 30, to a second pulse generator 36. A second ring electrode 34 is located near the second tip electrode 32 and connected, via a further conductor in the second electrode lead 30,

to the second pulse generator 36. Delivery of a stimulation pulse to the ventricle can be bipolar via the second tip electrode 32 and the second ring electrode 34, or unipolar via the second tip electrode 32 and the indifferent electrode 12. A second detector 38 is connected in parallel across the output terminal of the second pulse generator 36 in order to sense left ventricular activity in the heart. The pulse generators 26 and 36 and the detectors 28 and 38 are controlled by a control unit 40 which regulates the stimulation pulses with respect to amplitude, duration and stimulation interval, the sensitivity of the detectors 28 and 38 etc.

A physician using an extracorporeal programmer 56 can, via a telemetry unit 54, communicate with the heart stimulator 10 and thereby obtain information on identified conditions and also reprogram the different functions of the heart stimulator 10.

Fig. 4 further shows a first embodiment of the analysis device. The analysis device 50 is connected to the first sensor 21 via the first electrode lead 20, and to the second sensor via the second electrode lead 30. The analysis device 50 includes a measurement unit 52 which is capable of selectively receiving signals from any of the sensors, and which filters and amplifies the incoming signals in an appropriate manner, e.g. such that sensor signal contribution resulting from the systolic phase is removed from the measurement unit output signal.

The output signal from the measurement unit 52, which is proportional to the measurement signal, is then sent to a buffer 54 and to a differentiating circuit 56. Buffering is performed so that the differentiated signal is in phase with the proportional signal when they are sent to a calculator unit 58. The calculator unit 58 calculates a diastolic synchronization or synchrony value or signal based on the output signals from the respective sensors. The calculated synchronization signal 58 is sent to a comparator 60 for comparison with a threshold value,

for instance indicative of when insufficient diastolic synchrony is present.

The output signal from the comparator comprises information of whether the synchronization signal passes the threshold value, or one of the threshold values for embodiments where a plurality of threshold values are utilized, and is forwarded to a microprocessor 62 which communicates with the control unit 40. If, e.g., an arisen asynchrony is identified, the control device 40 can institute therapeutic treatment with stimulation pulses in order to restore diastolic synchrony. The microprocessor 62 further controls the measurement unit 52 with respect to the measurement signal to be sent to the analysis device 50 and can also control the comparator 60, for example for varying threshold values in response to altered pacing therapy or due to altered settings by the physician.

With reference now to Fig. 5, there is shown an alternative analysis device 51. This alternative analysis device 51 basically comprises the same or similar elements as described in relation to the measurement unit analysis device 50 of Fig. 4. However, the alternative analysis device 51 is arranged for receiving output signals from three cardiac wall motion sensors via conductors 70, 72 and 74, the analysis device thus being arranged to provide a synchronization signal indicative of diastolic synchrony between three different locations of the heart.

Furthermore, a fourth conductor 76 provides an IEGM signal for the measurement unit. The IEGM signal is used by the analysis device 50, or rather by the differentiating circuit 54 and the calculator unit 58, as an aid in discriminating between the systolic and the diastolic phases of the heart cycle. Thereby, the analysis device can be arranged to only process sensor output signals provided during the diastolic phase. Thus, there will be no risk of misinterpreting an asynchrony that may be

present in the systolic phase as an asynchrony in the diastolic phase.

Turning now to Figs. 6-6c and 7a-7c, there will be shown in schematic form the presence and determination of diastolic synchrony and asynchrony, respectively. In Figs. 6a, 6b, 7a, and 7b, a heart is schematically illustrated with three cardiac wall motion sensors a, b and c positioned in the left ventricle LV of the heart.

In Fig. 6b, the position of the sensors, i.e. the cardiac wall portions in which the sensors are arranged, are illustrated at the instant of myocardial relaxation onset. Thus, even though myocardial relaxation has been initiated, the sensors and the wall portions thereof are still in a respective position obtained during myocardial contraction, i.e. immediately before movement of the cardiac wall tissue to the position during relaxation. In Fig. 6a, the very instant when the myocardium has just become fully dilated at the state of myocardial relaxation is illustrated. Thus, the movement of the sensors and the wall portions into the dilated positions have just ceased. The output signals of the sensors are illustrated in Fig. 6c, and it can be seen that the movements sensed by the three sensors are substantially simultaneous. Therefore, the processing circuitry, or analysis device, of the cardiac stimulator determines that there is diastolic synchrony. As a consequence, no further actions related to change in pacing therapy is performed.

In Fig. 7a, the position of the sensors and the respective cardiac wall portions thereof at instant of myocardial relaxation onset. Furthermore, at the instant depicted in Fig. 7b c, only sensors a and c have reached the position of the obtained in the fully dilated state of the myocardium. Sensor b, and the cardiac wall portion to which sensor b is attached, is on the other hand still in a position obtained during myocardial contraction. Hence, there is lack in synchrony between the cardiac

wall portions at which the sensor a, b and c are attached, respectively. In particular, it seem to be a difference in the time of myocardial relaxation onset between the cardiac wall portion sensed by sensor b as compared to the cardiac wall portions sensed by sensors a and c. This lack in synchrony also appears in the output signals a, b and c of the cardiac wall motion sensors a, b and c, respectively. Thus, upon performing a synchronicity analysis for the output signals in the diastolic phase of the heart cycle, it can be determined that diastolic asynchrony is present and that suitable measures should be taken. Such measures could include restoring the cardiac synchrony or to derive an alarm signal indicative of the diastolic asynchrony.

Turning now to Figs. 8a-8c, there is shown a further example of the occurrence and detection of diastolic asynchrony. In Fig. 8a, the positions of the cardiac wall motion sensors a, b and c at an instant where the myocardium has assumed a dilated state is shown. In Fig. 8b, a post-systolic contraction PSC occurs in the portion where sensor a is arranged for sensing cardiac wall movements. Consequently, sensor a is subjected to a movement at an instant when sensors b and c remain substantially stationary. This appears in the combined sensor signal outputs a, b and c and can be detected and determined as an asynchrony in the diastolic phase by the analysis device 50 of the stimulator 10. In the signal diagram of Fig. 8c, the portion comprising the signal output during the PSC is encircled. Thus, as a result of the determined asynchrony, appropriate adjustment of the pacing therapy may be executed in order to restore the diastolic synchrony.

In Figs. 6a through 8b, substantially only one example of the positioning of cardiac wall motion sensors is provided. However, there are a vast number of sensor positioning alternatives that are contemplated within the scope of the present application. In fact, any placement

of sensors for measuring cardiac wall motions occurring during the diastolic phase of the heart cycle may be used, as long as there is in fact movements of the particular portion to which the sensor is located and attached during the diastolic phase. Thus, the present application are not limited to a particular number of wall motion sensors, or to particular positioning thereof.

Turning to Figs. 9a-9d, further examples of wall motion sensors are provided. In these examples, the sensors a, b and c are arranged at the same ventricle, i.e. for measuring cardiac wall movements at several locations in the left ventricle LV of the heart. Fig. 9a is intended to illustrate the orientation of the valve plane, which is indicated by numeral 6 in Fig. 1. In the example illustrated in Fig. 9b, the sensors are positioned in the actual valve plane. Then, the sensors could in one alternative be positioned in the actual annulus fibrosis tissue, or epicardially outside the annulus fibrosis plane.

In Fig. 9c and 9d, two alternative examples of sensor positionings are presented. In Fig. 9c, the sensors a, b and c have been positioned at equal distances from the valve plane, thus forming a sensor plane parallel to the valve plane. Thereby, the sensors are assumed to be subjected to movements of substantially the same distance during the heart cycle, which may be beneficial when calculating and determining synchrony and possible sudden or expected appearance of asynchrony. In the example shown in Fig. 9d, the sensors are positioned at different levels at one ventricle along the longitudinal axis, or long-axis, of the heart. In this example, the physician has positioned the sensors at selected regions of interest, for instance regions suffering from a conductive disorder or having hibernating tissue which is expected or suspected to become active during remodulation of the heart due to progressing stimulation therapy.

Turning now to Figs. 10a to 10d, further examples of sensor positioning are illustrated. In the examples, the sensors are arranged in or at both ventricles of the heart. First, Fig. 10a illustrates the valve plane and the longitudinal direction of the heart. Then, Fig. 10b illustrates the example where the cardiac wall motion sensors are positioned and arranged to sense cardiac wall movements at the valve plane. In the same manner as mentioned above in relation to Fig. 9b, the sensors could in one alternative be positioned in the actual annulus fibrosis tissue, or epicardially outside the annulus fibrosis plane. Suitable, the right ventricular sensor a is arranged endocardially in the valve plane, and the left ventricular sensor c is arranged epicardially. The sensor b arranged at the septum 4 could be arranged epicardially either directly or via a coronary vein, or endocardially, via the right atrium and ventricle. Possibly, the RV sensor a arranged at the valve plane could be replaced for an RA sensor arranged in or at the valve plane, e.g. in the annulus fibrosis tissue.

In fig. 10c, the sensors a, b and c have been positioned in or at the right and the left ventricle, respectively, at equal distances from the valve plane, thus forming a sensor plane parallel to the valve plane. Thereby, similar to the example shown in Fig. 9c, the sensors are assumed to be subjected to movements of substantially the same distance during the heart cycle, which may be beneficial when calculating and determining synchrony and possible sudden or expected appearance of asynchrony.

Finally, in the example illustrated in Fig. 10d, the sensors are positioned at different levels, in or at the right and the left ventricle, along the longitudinal axis of the heart. In this example, similar to the example shown in Fig. 9d, the physician has positioned the sensors at selected regions of interest, for instance regions suffering from a conductive disorder or having

hibernating tissue which is expected or suspected to become active during remodulation of the heart due to progressing stimulation therapy.

When the signal output from the sensors a, b and c is received by the analysis device 50, a calculation of a synchronization index or signal is performed, which can be used for determining synchrony of the heart. In Fig. 11a, the output signals a, b and c, stemming from the sensors a, b and c, respectively, indicative of cardiac wall movements are illustrated in a diagram. In the portion of the diagram illustrating sensor output signal a, the sensor output signal b has been added as shown by the dotted line. Similarly, the sensor output signal c has been added to the portion of the diagram illustrating sensor output signal b. In this example, the difference between the sensor output signals a and b and the difference between the sensor output signals is calculated for the diastolic phase. This is performed by simply subtracting sensor output signal b from a and sensor output signal c from b.

The resulting difference signals are shown in Fig. 11b. These signals could be further added to each other in order to arrive at the synchronization index or signal. Alternatively, the difference signals could be used separately in order to provide dual synchronization indices or signals. Furthermore, statistical calculations could be applied to the difference signal(s) to arrive at a suitable value indicative of the synchronization.

Fig. 12a and 12b illustrate a further example of deriving one or more synchronization indices or signals. Here, the upper and lower portions of the diagram in Fig. 12a illustrates two signals obtained from two sensor output signals, respectively. One signal is indicated with a solid line, and the other one with a dotted line, respectively. These pairs of sensor output signals are cross-correlated in order to arrive at a cross-correlation result which is used as said synchronization indices

or signals. In the illustrated example, two cross-correlation results in the form of synchronization index A and synchronization index B are obtained. The synchronization signals can then be compared with a threshold value, which is illustrated in Fig. 12b with the dotted straight line, and appropriate measures be taken when the synchronization signal exceeds the threshold level.

When the monitoring of diastolic synchronization has revealed that a diastolic asynchrony has arisen, or that a reduction of diastolic synchrony has occurred, the parameters for timing of stimulation pulse delivery may be changed in order to restore or improve the diastolic synchrony. Such a change could for example refer to an adjustment in the VV-interval, e.g. for a biventricular heart stimulator; a change in the AV-interval, e.g. for a dual chamber or an AV-sequential heart stimulator; or combinations thereof. Thereby, the diastolic synchrony can be monitored and the pacing therapy adjusted such that the coronary flow may be maintained at a desired level.

In further embodiments, the indication of diastolic asynchrony could be used for triggering an alarm signal to the patient. This alarm signal could be intended for prompting the patient to seek medical assistance for care or follow-up.

It should be noted that the sensors may be subjected to pressures, movements and/or accelerations that are not derived from or related to the intrinsic movements of the myocardium and the cardiac walls thereof. For instance, accelerations derived from extra-cardiac movements of the patient, such as from running, vibrations in the patient environment, thoracic movements etc. However, output signal contributions deriving from intrinsic movements of the myocardial tissue can easily be discriminated from signal contributions from such extra-cardiac movements since the latter have a substantially identical impact on the respective sensor. Furthermore, by designing the

sensors to be sensitive for certain frequency ranges, the majority of the extra-cardiac signal contributions may be omitted. Furthermore, band-pass filtering of the sensor outputs may also be used for discriminating or filter out the signal contribution from extra-cardiac movements.

While the invention disclosed herein has been described by means of specific embodiments and applications thereof, numerous modifications and variations could be made therein by those skilled in the art without departing from the scope of the invention, which is defined by the appended claims.

CLAIMS

1. A device for monitoring the heart cycle of a human heart such that coronary flow may be maintained at a desired level, the device being connectable to a first sensor adapted to be positioned at a first location of the heart and arranged for sensing cardiac wall movements at said first location, and to a second sensor adapted to be positioned at a second location of the heart and arranged for sensing cardiac wall movements at said second location, comprising:

processing circuitry arranged for receiving output signals from said first and second sensors, said output signals being indicative of myocardial relaxation at said first and second locations; determining the time of myocardial relaxation at said first and second locations; and providing a diastolic synchronization signal indicative of the synchrony in the time of myocardial relaxation between said first and said second location.

2. The device as claimed in claim 1, wherein the time of myocardial relaxation includes the time when myocardial relaxation initially occurs after myocardial contraction.

3. The device as claimed in claim 1 or 2, wherein the time of myocardial relaxation includes time duration of myocardial relaxation that is uninterrupted by myocardial contraction.

4. The device as claimed in claim 3, wherein the processing circuitry is arranged for determining the time duration of simultaneous myocardial relaxation at said first and second locations, and wherein the diastolic synchronization signal holds information of said determined simultaneous myocardial relaxation.

5. The device as claimed in any one of the preceding claims, wherein the device is connectable to a third sensor adapted to be positioned at a third location of the heart and arranged for sensing cardiac wall movements at said third location, and

wherein the processing circuitry is further arranged for receiving output signals from said third sensor, said output signals being indicative of myocardial relaxation at said third location, determining the time of myocardial relaxation at said third location, and providing said diastolic synchronization signal indicative of the synchrony in the time of myocardial relaxation between said first, second and third locations.

6. The device as claimed in any one of the preceding claims, wherein the first and second sensors are positioned for sensing cardiac wall movements of a first ventricle of the heart.

7. The device as claimed in any one of claims 1-5, wherein the first sensor is positioned for sensing cardiac wall movements of a first ventricle of the heart, and the second sensor is positioned for sensing cardiac wall movements of a second ventricle of the heart.

8. The device as claimed in claim 6 or 7, wherein the third sensor is positioned for sensing cardiac wall movements at said first ventricle of the heart.

9. The device as claimed in any one of the preceding claims, wherein said processing circuitry is further arranged for comparing said diastolic synchronization signal with a threshold signal; and providing an output indicative of whether sufficient diastolic synchrony is present.

10. An implantable cardiac stimulator for delivering stimulation pulses to a human heart, comprising:

a housing;

a pulse generator enclosed in said housing for generating said stimulation pulses;

control circuitry for controlling the delivery of said stimulation pulses to the heart;

said stimulator being connectable to a lead arrangement for conducting said stimulation pulses to the heart, and for conducting sensed electrical signals from the heart to the control circuitry; and

a device for monitoring the heart cycle of a human heart as claimed in any one of claims 1-9.

11. The cardiac stimulator as claimed in claim 10, wherein the stimulator is arranged for receiving parameters for timing of stimulation pulse delivery for providing coronary flow at a desired level at implantation, monitoring the heart cycle for determining the synchrony in the time of myocardial relaxation after implantation, and adapting said parameters on the basis of said monitoring for maintaining said coronary flow at a desired level.

12. The cardiac stimulator as claimed in claim 11, wherein the control circuitry is arranged for adjusting the timing of stimulation pulse delivery when the processing circuitry indicates that sufficient diastolic synchrony is no longer present.

13. The cardiac stimulator as claimed in claim 11 or 12, wherein the control circuitry is arranged for adjusting the timing in adaptation to said diastolic synchronization signal.

14. The cardiac stimulator as claimed in any one of claims 11-12, wherein said device for monitoring the

heart cycle is arranged for measuring the diastolic synchrony and providing an output of whether sufficient diastolic synchrony is present after an adjustment of the timing of stimulation pulse delivery.

15. The cardiac stimulator as claimed in any one of claims 11-14, wherein the cardiac stimulator is arranged for delivering stimulation pulses to both ventricles of the heart, and wherein said timing of stimulation pulse delivery includes the V-V interval.

16. The cardiac stimulator as claimed in any one of claims 11-15, wherein the cardiac stimulator is arranged for delivering stimulation pulses to a ventricle of the heart, and for delivering stimulation pulses and/or sensing cardiac events in an atrium of the heart, and wherein said timing of stimulation pulse delivery includes the A-V interval.

17. The cardiac stimulator as claimed in any one of claims 10-16, wherein the lead arrangement comprises said sensors for arranged for sensing cardiac wall movements.

18. The cardiac stimulator as claimed in claim 17, wherein said lead arrangement comprises a plurality of leads for conducting said stimulation pulses to the heart and/or said sensed electrical signals from the heart, and wherein each of said sensors is comprised in one of said plurality of leads.

19. The cardiac stimulator as claimed in claim 17 or 18, wherein said sensors are accelerometers.

20. The cardiac stimulator as claimed in claim 17 or 18, wherein said sensors are piezoelectric pressure sensors.

21. A method of monitoring the heart cycle of a human heart such that coronary flow may be maintained at a desired level, comprising the steps of:

sensing cardiac wall movements at a first location of the heart;

sensing cardiac wall movements at a second location of the heart;

determining the time of myocardial relaxation at said first and second locations; and

providing a diastolic synchronization signal indicative of the synchrony in the time of myocardial relaxation between said first and said second location.

22. The method as claimed in claim 21, wherein the step of determining the time of myocardial relaxation includes the step of determining the time when myocardial relaxation initially occurs after myocardial contraction.

23. The method as claimed in claim 21 or 22, wherein the step of determining the time of myocardial relaxation includes the step of determining the time duration of myocardial relaxation that is uninterrupted by myocardial contraction.

24. The method as claimed in claim 23, further comprising the step of determining the time duration of simultaneous myocardial relaxation at said first and second locations, wherein the diastolic synchronization signal holds information of said determined simultaneous myocardial relaxation.

25. The method as claimed in any one of claims 21-24, further comprising the steps of:

sensing cardiac wall movements at a third location of the heart;

determining the time of myocardial relaxation at said third location; and

providing a diastolic synchronization signal indicative of the synchrony in the time of myocardial relaxation between said first, second and third locations.

26. The method as claimed in any one of claims 21-25, wherein said first location and said second location are locations for sensing cardiac wall movements of a ventricle, respectively, of the heart.

27. The method as claimed in claim 26, wherein at the first location, cardiac wall movements of the right ventricle of the heart is sensed, and at the second location, cardiac wall movements of the left ventricle of the heart is sensed, and wherein the cardiac synchrony is interventricular synchrony.

28. The method as claimed in any one of claims 21-27, further comprising the steps of:

comparing said diastolic synchronization signal with a threshold signal; and

providing an output indicative of whether sufficient diastolic synchrony is present.

29. A method of controlling the delivery of stimulation pulses to a human heart, comprising the steps of:

generating stimulation pulses;

controlling parameters for the timing of stimulation pulse delivery to the heart;

delivering said stimulation pulses to the heart;

sensing cardiac wall movements at a first location of the heart;

sensing cardiac wall movements at a second location of the heart;

determining the time of myocardial relaxation at said first and second locations; and

providing a diastolic synchronization signal indicative of the synchrony in the time of myocardial relaxation between said first and said second location.

30. The method as claimed in claim 29, further comprising the steps of:

receiving parameters for timing of stimulation pulse delivery for providing coronary flow at a desired level at implantation;

monitoring the heart cycle for determining the synchrony in the time of myocardial relaxation after implantation; and

adapting said parameters on the basis of said monitoring for maintaining said coronary flow at a desired level.

31. The method as claimed in claim 29 or 30, further comprising the steps of:

comparing said diastolic synchronization signal with a threshold signal;

providing an output indicative of whether sufficient diastolic synchrony is present; and

adjusting the timing of stimulation pulse delivery when sufficient diastolic synchrony is no longer present.

32. The method as claimed in any one of claims 29-31, further comprising the step of:

adjusting the timing of stimulation pulse delivery in adaptation to said diastolic synchronization signal.

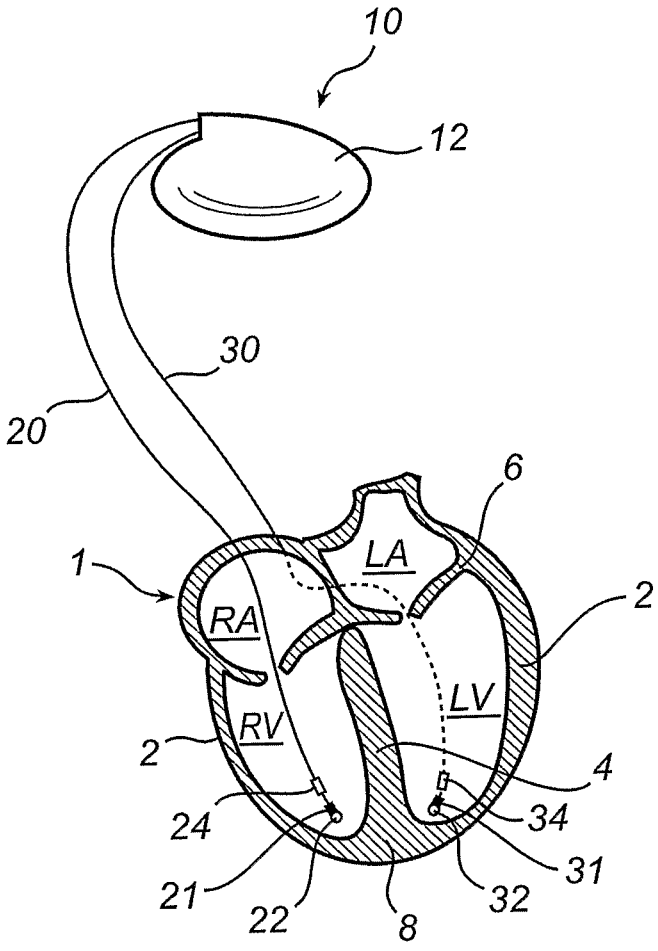

Fig. 1

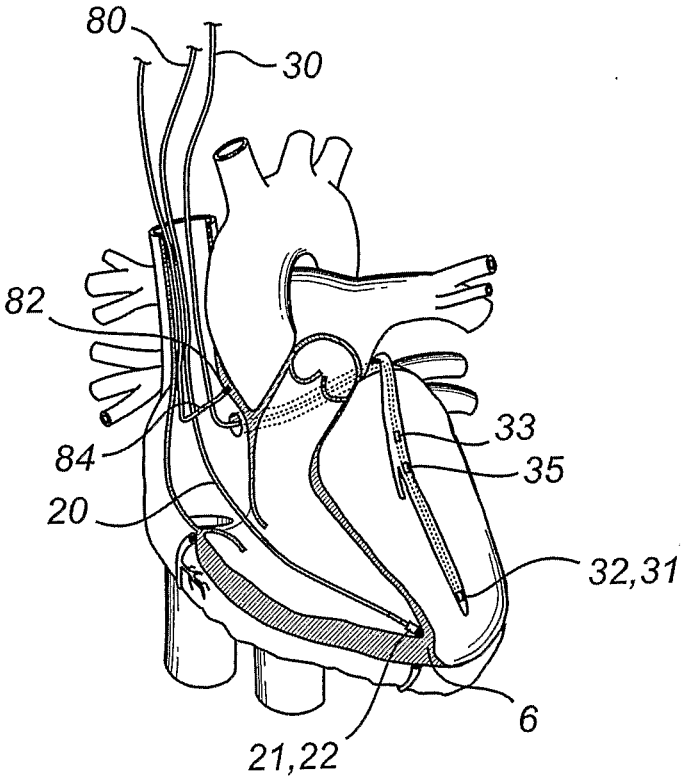

Fig. 2

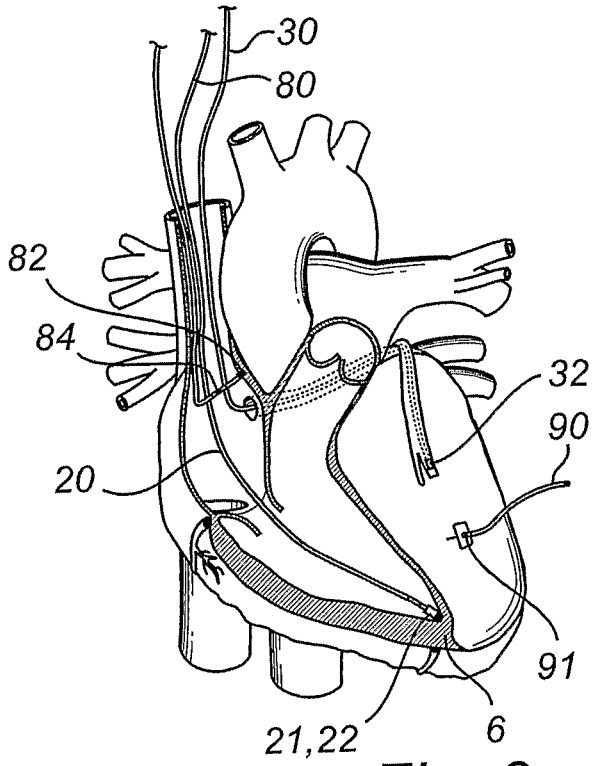

Fig. 3

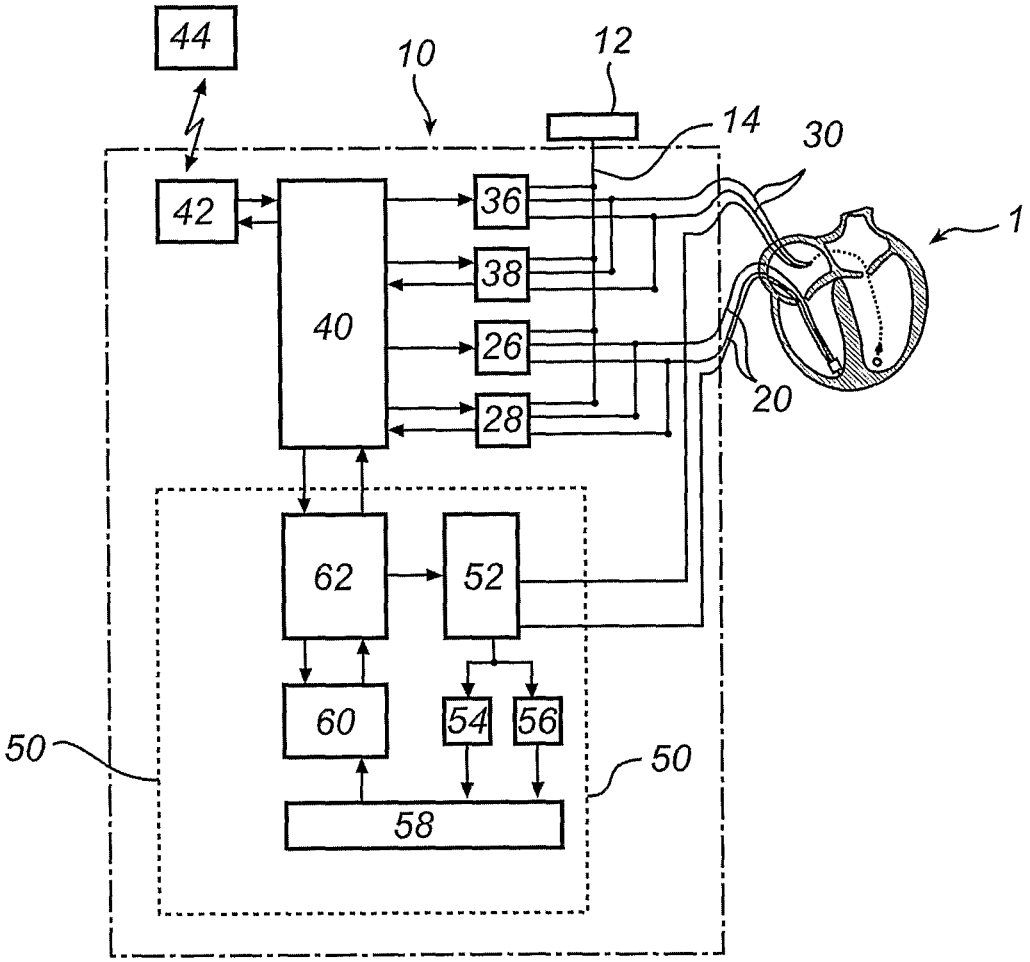
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Fig. 4

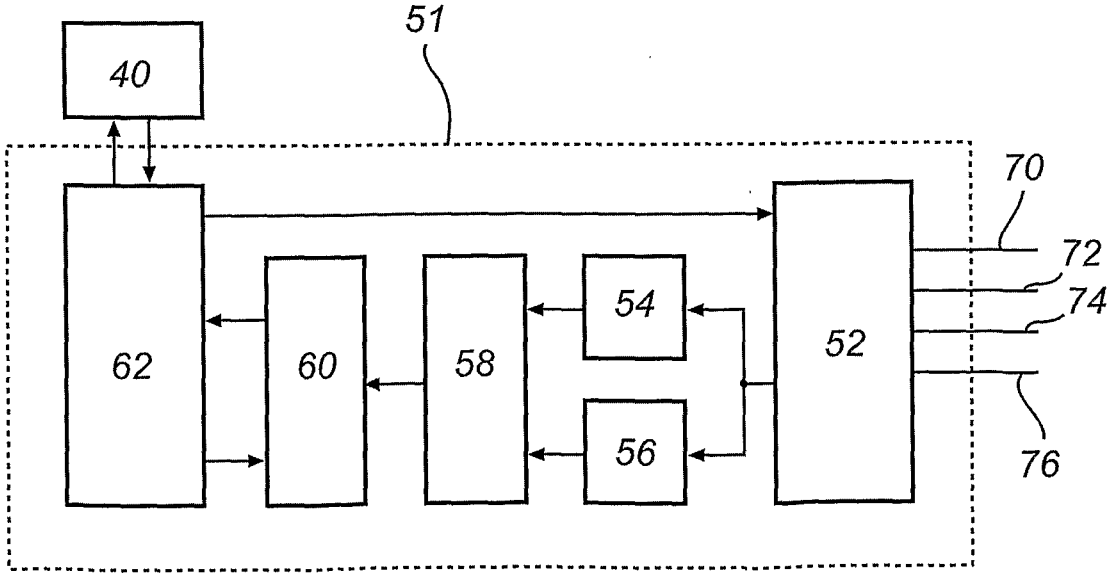
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Fig. 5

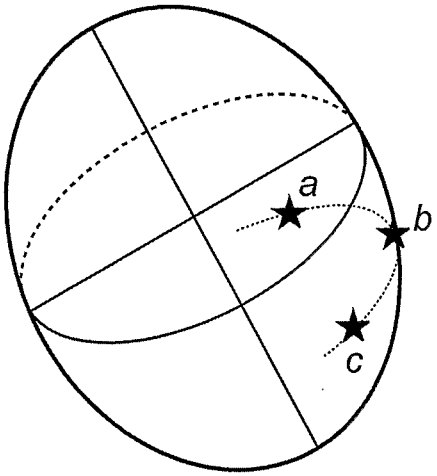

Fig. 6a

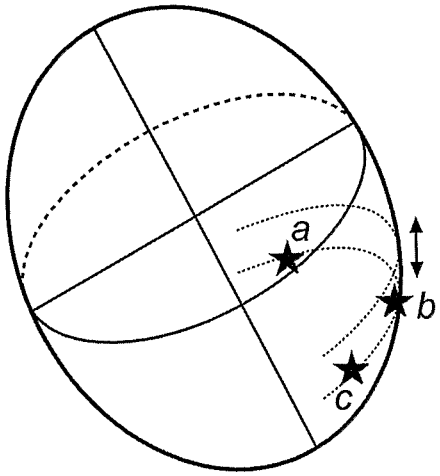

Fig. 6b

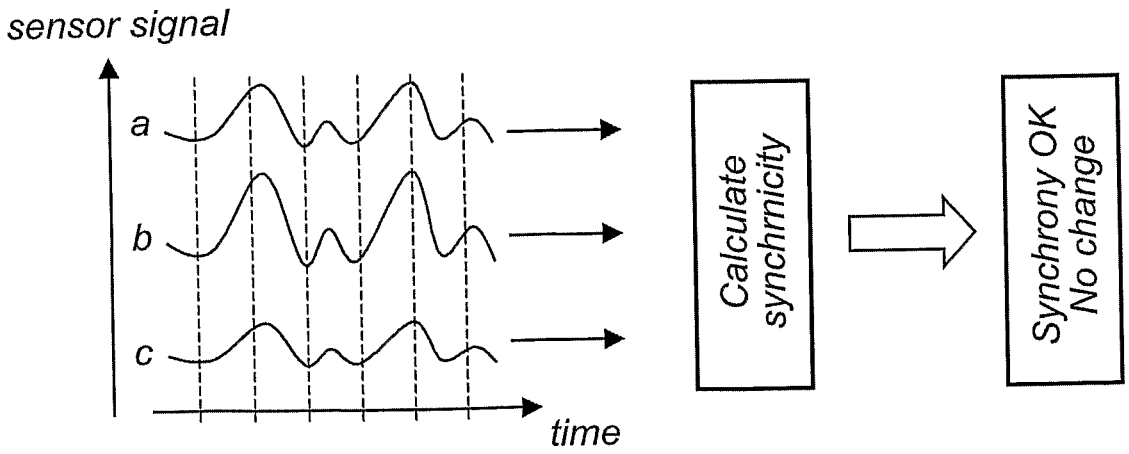

Fig. 6c

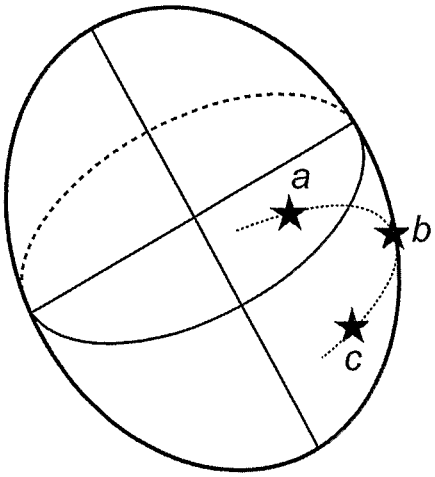

Fig. 7a

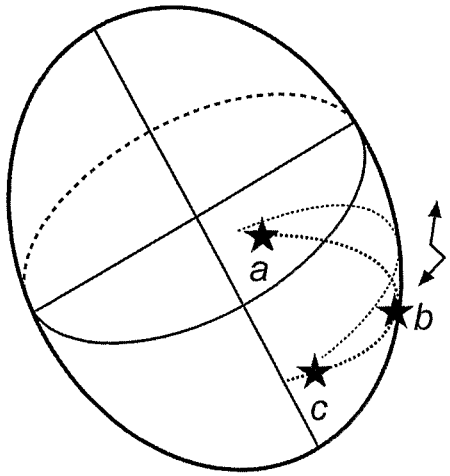

Fig. 7b

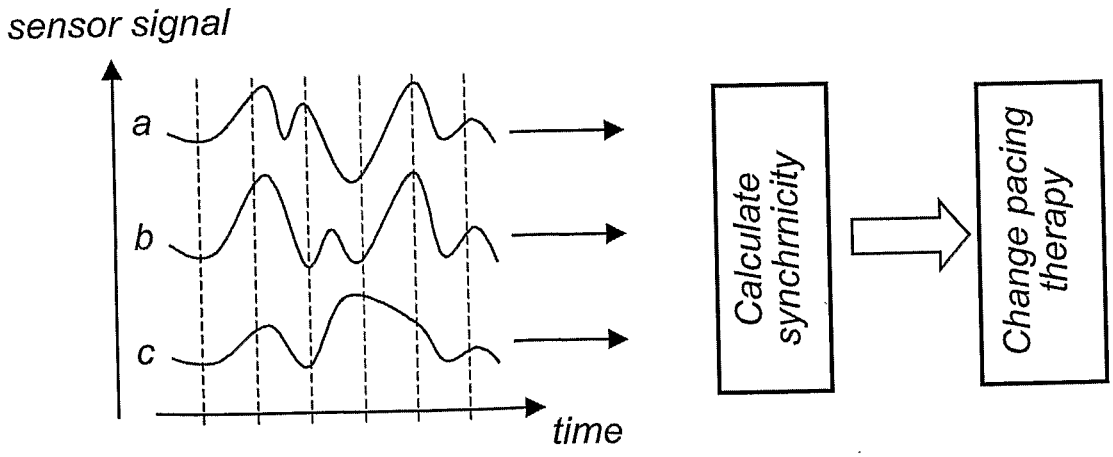

Fig. 7c

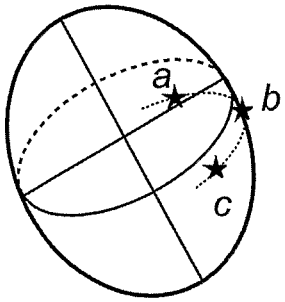

Fig. 8a

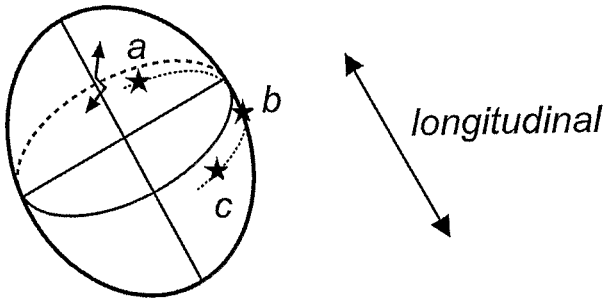

Fig. 8b

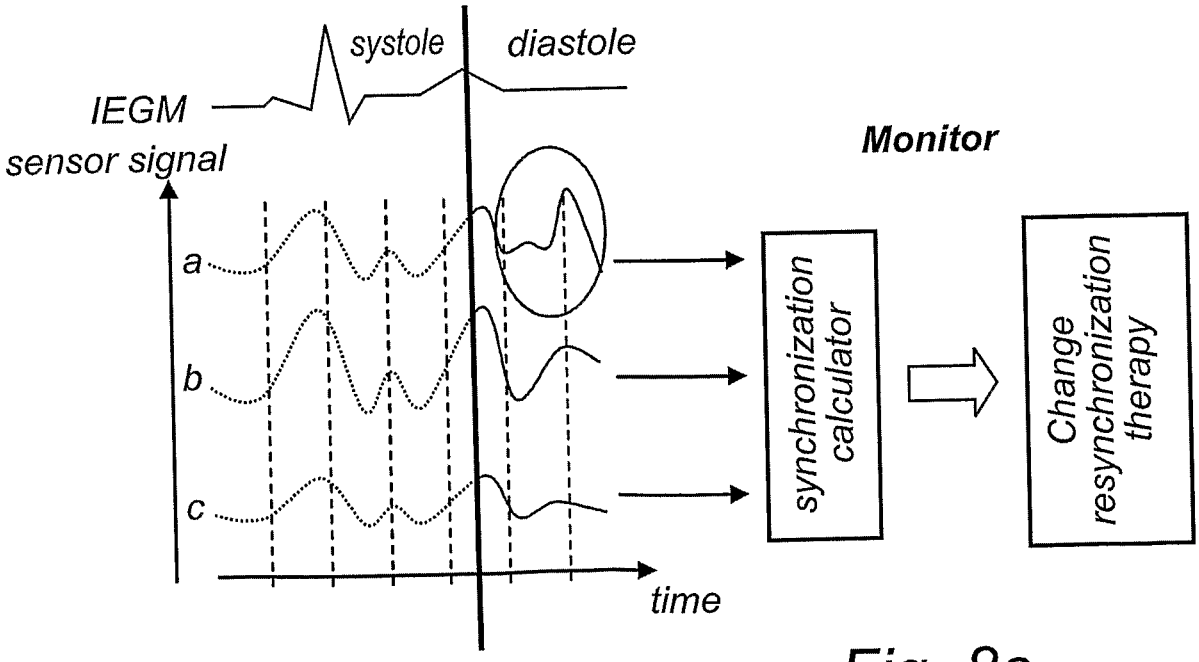

Fig. 8c

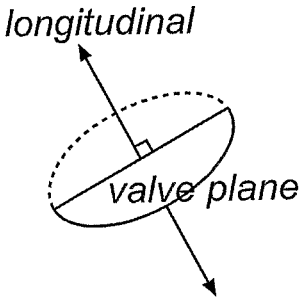

Fig. 9a

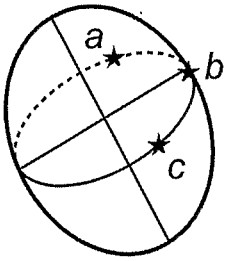

Fig. 9b

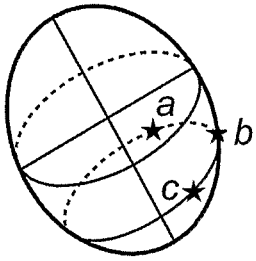

Fig. 9c

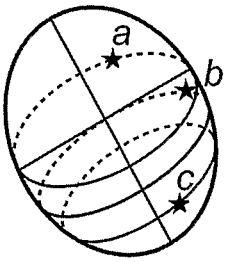

Fig. 9d

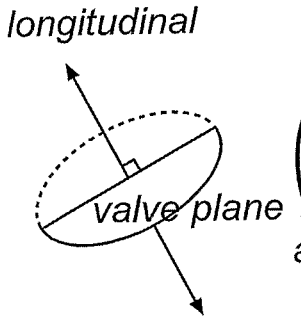

Fig. 10a

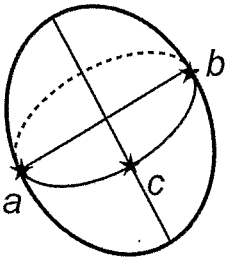

Fig. 10b

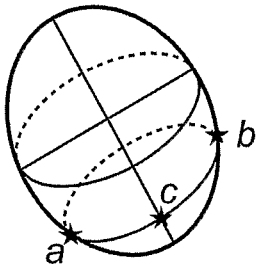

Fig. 10c

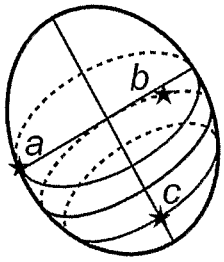

Fig. 10d

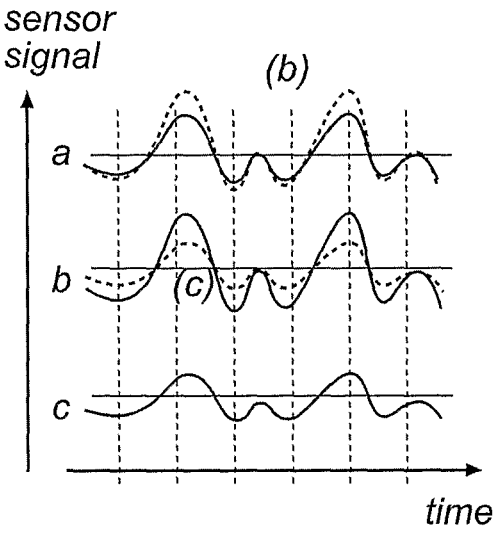

Fig. 11a

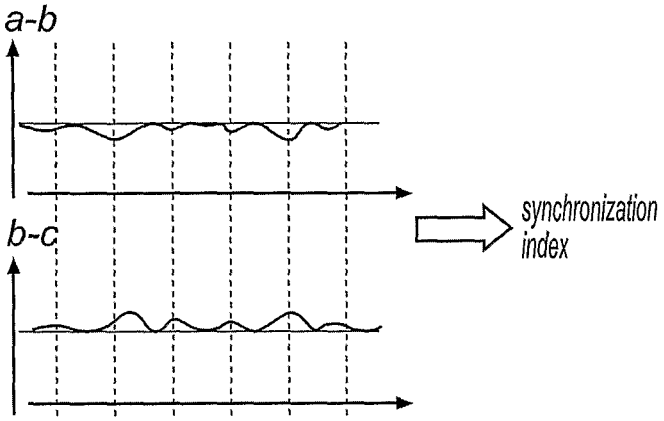

Fig. 11b

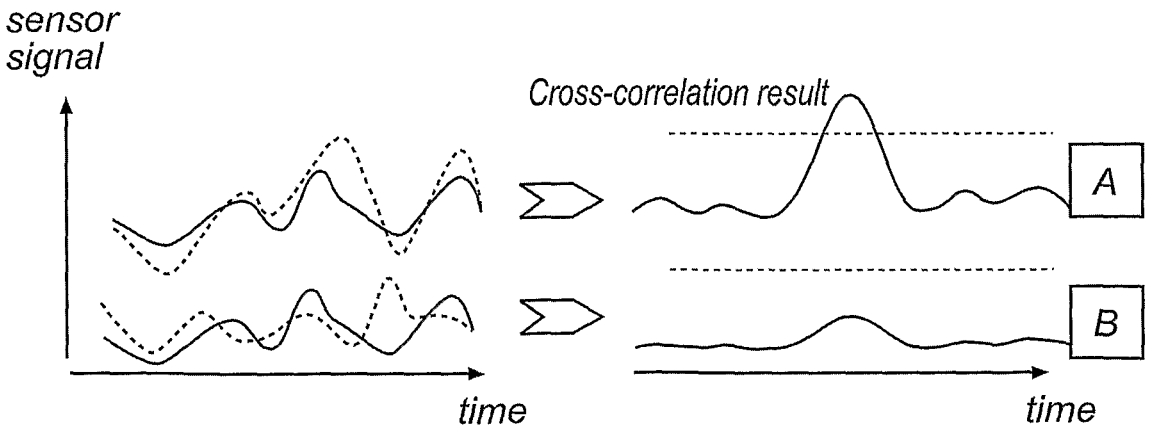

Fig. 12a

Fig. 12b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2005/001808

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
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)

IPC: A61N

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20040019365 A1 (DING, J ET AL), 29 January 2004 (29.01.2004), paragraphs [0006]; [0025]; [0026], figures 1,2 --	1-32
X	US 20040172078 A1 (CHINCHOY, E), 2 Sept 2004 (02.09.2004), paragraphs [0046]-[0050], figures 1b, 3,4 --	1-32
X	US 20030105496 A1 (YU, Y ET AL), 5 June 2003 (05.06.2003), the whole document --	1-32
A	US 4917115 A (FLAMMANG, D ET AL), 17 April 1990 (17.04.1990), claim 1 --	1-32

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 July 2006	12 -07- 2006
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Henrik Eriksson /LR Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2005/001808

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 21-32
because they relate to subject matter not required to be searched by this Authority, namely:

See extra sheet.

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Box II.1

Claims 21-32 relate to a method of treatment of the human or animal body by surgery or by therapy, as well as diagnostic methods /Rule 39.1(iv). Nevertheless, a search has been executed for these claims. The search has been based on the alleged effects of the device.

International patent classification (IPC)
A61N 1/362 (2006.01)
A61B 5/00 (2006.01)
A61N 1/365 (2006.01)

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- e-tjänster/anförda dokument(service in Swedish).

Use the application number as username.
The password is **EZFQFXTOLS.**

Paper copies can be ordered at a cost of 50 SEK per copy from PRV InterPat (telephone number 08-782 28 85).

Cited literature, if any, will be enclosed in paper form.

US	20040019365	A1	29/01/2004	AU	2003259215	A	00/00/0000
				EP	1525026	A	27/04/2005
				JP	2005533608	T	10/11/2005
				WO	2004011088	A	05/02/2004
US	20040172078	A1	02/09/2004	AU	2004218510	A	16/09/2004
				CA	2517138	A	16/09/2004
				EP	1601415	A	07/12/2005
				WO	2004078256	A	16/09/2004
US	20030105496	A1	05/06/2003	NONE			
US	4917115	A	17/04/1990	NONE			

专利名称(译)	可植入的心脏刺激器，用于监测人类心脏中心脏周期的装置和方法		
公开(公告)号	EP1957159A1	公开(公告)日	2008-08-20
申请号	EP2005813446	申请日	2005-11-30
申请(专利权)人(译)	ST.犹达医疗用品AB		
当前申请(专利权)人(译)	ST.犹达医疗用品AB		
[标]发明人	JARVERUD KARIN		
发明人	JÄRVERUD, KARIN		
IPC分类号	A61N1/362 A61B5/00 A61N1/365 A61N1/368		
CPC分类号	A61N1/3627 A61N1/36514 A61N1/36578 A61N1/368		
其他公开文献	EP1957159A4 EP1957159B1		
外部链接	Espacenet		

摘要(译)

一种用于监测人类心脏的心脏周期以使得冠状动脉血流可以维持在期望水平的装置，以及包括这种装置的心脏刺激器。监测装置可连接到第一传感器，第一传感器适于定位在心脏的第一位置并且布置成用于感测在所述第一位置处的心脏壁运动，并且可连接到第二传感器，所述第二传感器适于定位在心脏的第二位置并且被布置用于感测所述第二位置处的心脏壁运动。该装置包括处理电路，该处理电路被设置用于接收来自所述第一和第二传感器的输出信号，该输出信号指示所述第一和第二位置处的心肌舒张。处理电路还被布置用于确定在所述第一和第二位置处心肌舒张的时间，并且提供指示在所述第一和第二位置之间心肌舒张时间的同步的舒张同步信号。