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(54) Implantable heart stimulator and method for trending analysis of ventricular activation time

(57) The invention refers to a method and an apparatus for assessing ventricular activation time by determining a point in time t1 of an initial positive deflection on a far-field electrogram and a point in time t2 of a first peak of the negative deflection on a near-field electrogram of a same heart cycle and determining a time difference between points in time t1 and t2 said time difference representing the ventricular activation time.

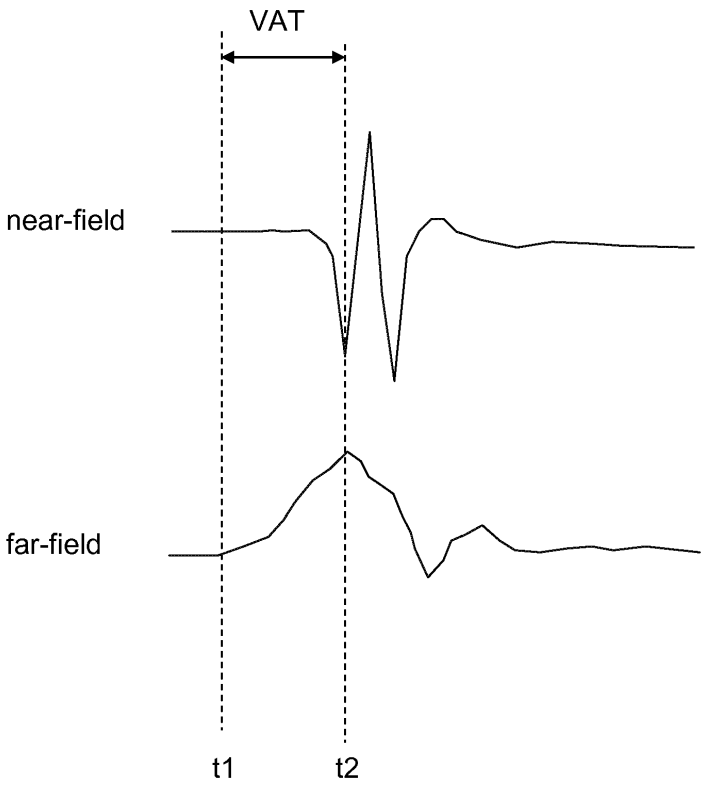


FIG. 4

EP 2 522 390 A1

Description

[0001] The present invention relates to an implantable heart stimulator such as dual-chamber (RA-RV), three-chamber (BiA-RV, or RA-BiV), or four-chamber (BiA-BiV) implantable cardiac devices including pacemakers, defibrillators and cardiovertors, which stimulate cardiac tissue electrically to control the patient's heart rhythm.

[0002] It is an object of the invention to provide an apparatus and a method for monitoring a progression of ventricular conduction disorders such as the left bundle branch block (LBBB) and the right bundle branch block (RBBB).

[0003] There is no existing solution on continuous monitoring the progression of LBBB/RBBB.

[0004] LBBB and RBBB are mainly diagnosed based on examination of the QRS morphology in surface ECG.

[0005] Implantable pacemakers and defibrillators traditionally measures the conduction time from atrial event (paced or sensed) to (sensed) ventricular event.

[0006] Continuous evaluation of QRS morphology for monitoring the progression of LBBB/RBBB is technically challenging, and there is no established method to quantify the QRS morphology variation as an indicator of ventricular conduction abnormality.

[0007] The atrium-ventricle conduction time measured by implantable devices is the lumped sum of atrial conduction time, AV nodal conduction time, and the ventricular conduction time. Therefore, it is difficult to isolate the ventricular conduction time and analyze its change over time.

[0008] The object mentioned supra is achieved by an apparatus and method for trending analysis of the ventricular activation time as a means to monitor the progression of ventricular conduction diseases.

[0009] In particular, an implantable heart stimulator is provided having a housing and electronic circuitry, wherein the housing encloses the electronic circuitry and has an at least partially electrically conducting outer surface and wherein the electronic circuitry is connected or can be connected to at least one electrode lead that carries at least two electrodes. The electronic circuitry comprises a far-field electrogram recording unit that is electrically connected or can be connected to said at least partially electrically conducting outer surface and to first one of said at least two electrodes. The electronic circuitry further comprises a near-field electrogram recording unit that is electrically connected or can be connected to at least two electrodes carried by said electrode lead. The electronic circuitry further comprises a ventricular activation time assessing unit that is operatively connected to the far-field electrogram recording unit and the near-field electrogram recording unit. The ventricular activation time assessing unit is configured to determine a point in time t1 of an initial positive deflection on a far-field electrogram and a point in time t2 of a first peak of the negative deflection on a near-field electrogram of a same heart cycle. The ventricular activation time assessing unit is further configured to determine a time difference between points in time t1 and t2 wherein this time difference represents the ventricular activation time.

[0010] According to a further aspect, a method for assessing a ventricular activation time is provided that comprises the steps of:

determining a point in time t1 of an initial positive deflection on a far-field electrogram and a point in time t2 of a first peak of the negative deflection on a near-field electrogram of a same heart cycle and
determining a time difference between points in time t1 and t2 wherein the time difference represents the ventricular activation time.

[0011] The invention includes the recognition that the ventricular activation time (VAT) can be derived from simultaneous recording of near-field and far-field ventricular electrogram. The VAT measures the time difference from the onset of QRS complex in the far-field electrogram to the intrinsic deflection of the near-field electrogram. Prolonged VAT measured in the left ventricle may reflect the progression of the left bundle branch block (LBBB), and prolonged VAT measured in the right ventricle may reflect the progression of the right bundle branch block (RBBB). Trending analysis of VAT can thus provide diagnosis of LBBB/RBBB and may predict the imminent myocardial ischemia.

[0012] Regarding the implantable heart stimulator it is preferred that the first electrode is a defibrillation electrode. It is further preferred that the electrode lead is a ventricular electrode lead. Preferably the near-field electrogram recording unit is a ventricular sensing unit.

[0013] According to a preferred embodiment the heart stimulator is configured to repeatedly measure the ventricular activation time in a right ventricle and/or a left ventricle after each ventricular sensed event.

[0014] Preferably, the heart stimulator is configured to continuously measure the ventricular activation time periodically or at predefined time of the day when ventricular senses are encouraged to occur. The occurrence of ventricular senses corresponding to intrinsic (natural) contractions of a ventricle can be promoted by prolonging a corresponding ventricular escape interval that is timed by then implantable heart stimulator if operated in a demand mode where a ventricular stimulation pulse is triggered at the end of a ventricular escape interval unless a natural contraction of the ventricle (a ventricular sense event) occurs prior to time out of the ventricular escape interval.

[0015] The implantable heart stimulator preferably comprises a device memory and is configured to store measured ventricular activation times in the device memory in such way that they can be used for trending analysis.

[0016] A ventricular activation time trend analyzing unit can be provided that is at least indirectly connected to said ventricular activation time assessing unit and that is

adapted to analyze a trend in ventricular activation time by comparing most recently measured ventricular activation time values with a moving average of the previously measured ventricular activation time values, and to trigger a warning signal when an increase in ventricular activation time values is detected that exceeds a predefined threshold.

[0017] The implantable heart stimulator preferably further comprises a telemetry unit and is configured to transmit stored ventricular activation time values and/or ventricular activation time trend data to a remote service center.

[0018] According to still another preferred embodiment, the implantable heart stimulator is configured to transmit ventricular activation time trend data at predetermined time of day or predetermined time interval.

[0019] Further, the implantable heart stimulator can be configured to transmit ventricular activation time trend data to a remote service center upon device detection of sudden increase of ventricular activation time that exceeds a predefined threshold, which can be either an absolute time interval or a percentage of a previous ventricular activation time average.

[0020] Regarding the method, it is preferred that the method includes repeated measurement of ventricular activation time in a right ventricle and/or a left ventricle after each ventricular sensed event.

[0021] Also, storing measured ventricular activation time values in such way that they can be used for trending analysis is preferred.

[0022] In particular, a method is preferred that comprises analyzing a trend in ventricular activation time by comparing most recently measured ventricular activation time values with a moving average of the previously measured ventricular activation time values, and triggering a warning signal when an increase in ventricular activation time values is detected that exceeds a predefined threshold.

[0023] According to a further preferred embodiment, the method comprises transmitting ventricular activation time trend data to a remote service center upon detection of sudden increase of ventricular activation time that exceeds a predefined threshold, wherein the predefined threshold is either an absolute time interval or a percentage of previous ventricular activation time average.

[0024] The foregoing and other objectives, advantages and novel features of the present invention can be understood and appreciated by reference to the following detailed description of the invention, taken in conjunction the accompanying drawings, in which:

Fig. 1 is an overview over a patient monitoring system including an implantable heart stimulator;

Fig. 2 illustrates a heart stimulator connected to electrode leads that are placed in a heart;

Fig. 3 depicts a schematic block diagram of some components of the heart stimulator of Fig. 1;

Fig. 4 is a schematic illustration of VAT measurement; and

Fig. 5 is a schematic illustration of VAT trending analysis.

[0025] In Fig. 1, a remote monitoring system including an implantable heart stimulator 10, an external device 90 and a central data server 92 of a central service center is displayed. Such system allows data communication between the implantable heart stimulator 10 and central server 92 via the external device 90. External device 90 is configured to communicate wirelessly with implantable heart stimulator 10.

[0026] From Fig. 2 it is apparent that stimulator 10 comprises a housing or case 12 and a header 14.

[0027] The heart stimulator 10 is connected to three electrode leads, namely a right ventricular electrode lead for 16, a right atrial electrode lead 18 and a left ventricular electrode lead 20.

[0028] Fig. 2 and Fig. 3 illustrate the pacing system that includes a heart stimulator and the connected leads. The right atrial electrode lead 18 has a distal right atrial tip electrode 26 (RA-tip) at the distal end of right atrial electrode lead 18 and a proximal right atrial ring electrode 28 (RA-ring), as well as a superior vena cava coil electrode 36 (SVC-coil) that has large surface area.

[0029] The right ventricular electrode lead 16 has a distal right ventricular tip electrode 22 (RV-tip) at the distal end of right ventricular electrode lead 16 and a proximal right ventricular ring electrode 24 (RV-ring), as well as a right ventricular defibrillation coil electrode 34 (RV-coil) that has large surface area.

[0030] Similarly, the left ventricular (LV) lead has a distal left ventricular tip electrode 30 (LV-tip) and a proximal left ventricular ring electrode 32 (LV-ring), as well as a defibrillation coil electrode 38 (LV-coil) that has large surface area. The left ventricular electrode lead 20 is designed to pass trough the coronary sinus of heart 40. A typical electrode suitable for use with heart stimulator 10 is the electrode lead Corox+ UP/BB by the applicant.

[0031] Each electrode and shock coil of electrode leads 16 to 20 is separately connected to an electric circuit enclosed by case 12 of heart stimulator 10 by way of electrical contacts of a plug (not shown) at the proximal end of each electrode lead 16 to 20 and corresponding contacts (not shown) in header 14 of heart stimulator 10.

[0032] Now refer to Fig. 3. SVC shock coil 36 is connected to right atrial shock generator 68 that is controlled by a control unit 54 of heart stimulator 10.

[0033] Similarly, right ventricular shock coil 34 is connected to a right ventricular shock generator 52 that is connected to control unit 54 and left ventricular shock coil 38 is connected to a left ventricular shock generator 50 that is also connected to control unit 54.

[0034] Right atrial tip electrode 26 and right atrial ring

electrode 28 are both connected to a right atrial stimulation pulse generator 60 and a right atrial sensing stage 62 that internal both connected to control unit 54.

[0035] Right atrial stimulation pulse generator 60 is adapted to generate atrial stimulation pulses of sufficient strength to cause an excitation of atrial myocardium by an electrical pulse delivered via right atrial tip electrode 26 and right atrial ring electrode 28. Preferably, means are provided to adapt the right atrial stimulation pulse strength to the stimulation threshold in the right atrium.

[0036] Right atrial sensing stage 58 is adapted to pick up myocardial potentials indicating an intrinsic atrial excitation that corresponds to a natural atrial contraction. By way of right atrial sensing stage 58, it is possible to stimulate the right atrium 44 of heart 40 in a demand mode wherein a right atrial stimulation pulse is inhibited if an intrinsic atrial event (intrinsic atrial excitation) is sensed by right atrial sensing stage 58 prior to expiration of an atrial escape interval.

[0037] In a similar manner, right ventricular ring electrode 24 and right ventricular tip electrode 22 are connected to right ventricular stimulation pulse generator 56 and to a right ventricular sensing stage 58 that in turn are connected to control unit 54. By way of right ventricular tip electrode 22, right ventricular ring electrode 24, right ventricular stimulation generator 56 and right ventricular sensing stage 58, right ventricular stimulation pulses can be delivered in a demand mode to the right ventricle 42 of heart 40.

[0038] In the same way left ventricular tip electrode 30 and left ventricular ring electrode 32 are connected to the left ventricular stimulation pulse generator 64 and the left ventricular sensing stage 66 that internal connected to control unit 52 and that allow for stimulating a left ventricle 46 of heart 40.

[0039] Triggering and inhibition of delivery of stimulation pulses to the right atrium, the right ventricle or the left ventricle is controlled by control unit 54, in a manner known to the man skilled in the art. The timing that schedules delivery of stimulation pulses if needed is controlled by a number of intervals that at least partly may depend on a hemodynamic demand of a patient that is sensed by means of an activity sensor 72 that is connected to control unit 54. Activity sensor 72 allows for rate adaptive pacing wherein a pacing rate depends on a physiological demand of a patient that is sensed by a way of activity sensor 72. A clock 82 allows recording of events and signals in association with time stamps that enable a synchronous evaluation of signals at a later point of time.

[0040] For the purpose of composition of a far-field right ventricular electrogram (RV EGM) and a far-field left-ventricular electrogram (LV EGM) a far-field right ventricular electrogram recording unit 74 and a far-field left ventricular recording unit 76, respectively, are provided. The far-field right ventricular electrogram recording unit 74 is connected to a case electrode that is formed by at least an electrically conducting part of case 12 of the heart stimulator 10 and to the RV coil electrode 34. The far-field left ventricular recording unit 76 is also connected to the case electrode formed by a case 12 of heart stimulator 10 and to the left ventricular coil electrode 38.

[0041] The right ventricular sensing stage 58 for picking up near-field right ventricular electrogram and the far-field right ventricular recording unit 74 are connected to a right ventricular activation time assessing unit 96.

[0042] The left ventricular sensing stage 66 for generating near-field left ventricular electrogram signals and the far-field left ventricular recording unit 76 for picking up far-field left ventricular electrogram and generating far-field left ventricular electrogram signals are connected to a left ventricular activation time assessing unit 98. Left ventricular sensing stage 66 and left ventricular far-field recording unit 76 are configured to feed near-field left ventricular electrogram signals and far-field left ventricular electrogram signals, respectively, to the left ventricular activation time assessing unit 98.

[0043] The near-field electrogram in the right ventricle 42 is measured between the RV-tip electrode 22 and RV-ring electrode 24. Preferably, the far-field electrogram in the right ventricle 38 is measured between the RV-coil electrode 34 and the device can 12. Alternatively, the far-field electrogram in the right ventricle 38 can be measured between the RV-ring electrode 24 and the device can 12.

[0044] Likewise, the near-field electrogram in the left ventricle 48 is measured between the LV-tip electrode 30 and LV-ring electrode 32. Preferably, the far-field electrogram in left ventricle is measured between the LV-coil electrode 38 and the device can 12. Alternatively, the far-field electrogram in the left ventricle 48 can be measured between the LV-ring electrode 32 and the device can 12.

[0045] Preferably, the far-field electrogram in the right ventricle and the left ventricle are minimally filtered and have wide bandwidth, e.g., with lower corner frequency 4Hz and high corner frequency 128Hz, whereas the near-field electrogram in the right ventricle and the left ventricle are filtered with narrower bandwidth, e.g., with lower corner frequency 18Hz and high corner frequency 40Hz. Accordingly, right and left far-field ventricular recording units 74 and 76 comprise each a band pass filter with lower corner frequency 4Hz and high corner frequency 128Hz. Right ventricular sensing stage 58 and left ventricular sensing stage 66 for picking up near-field electrogram in the right ventricle and the left ventricle each comprise band pass filters with narrower bandwidth, e.g., with lower corner frequency 18Hz and high corner frequency 40Hz.

[0046] Simultaneous unipolar (containing far-field signals) and bipolar electrogram (EGM) recordings from a single electrode catheter has been used to assess the prematurity of local activation during ablation of focal arrhythmias (Delacretaz et al., PACE 2001; 24: 441-449). Similar concept has been recently used to measure the local activation time from EGM, which is used to explain the success or failure of antitachycardia pacing in termination of ventricular tachycardia in some patients (Lim

et al., PACE 2010; 33: 549-552).

[0047] The apparatus and method illustrated herein use a similar concept for continuous measurement of ventricular activation time (VAT). A trending analysis of VAT allows chronic monitoring of LBBB/RBBB progression and aids clinical diagnosis and early intervention. Accordingly, right and left ventricular activation time assessing units 96 and 98 are configured to determine a respective ventricular activation time (RV VAT or LV VAT, respectively) as pointed out hereinafter.

[0048] Fig. 4 illustrates the measurement of ventricular activation time (VAT). The VAT in a ventricular chamber can be determined after each intrinsic ventricular depolarization (i.e. ventricular sense), while atrial rhythm can be either paced or sensed. The VAT in the right ventricle is derived from simultaneous measurement of near-field right ventricular electrogram and far-field right ventricular electrogram, and the VAT in left ventricle is derived from simultaneous measurement of near-field left ventricular electrogram and far-field left ventricular electrogram. A first peak of the negative deflection on the near-field electrogram (t2) corresponds to a depolarization of the local myocardial tissue surrounding the tip electrode. An initial positive deflection on the far-field electrogram (t1) represents a far-field signal generated by the activation wavefront moving toward the recording electrode. During intrinsic ventricular conduction, this far-field activation first appears after the conduction wave completes the AV nodal conduction and enters the right and left bundle branches. Therefore, the time difference between t1 and t2 represents the time delay of ventricular conduction from the distal end of AV junction to the recording ventricular tip electrode. In other words, the VAT in the right ventricle correlates with the right ventricular conduction time, and the VAT in left ventricle correlates with the left ventricular conduction time.

[0049] According to one typical embodiment, the VAT is continuously measured in the right ventricle and/or the left ventricle after each ventricular sensed event. In another embodiment, the VAT can be measured periodically or at predefined time of the day when ventricular senses are encouraged to occur (e.g. by temporarily prolonging the device AV delay). This latter application is particularly useful for cardiac resynchronization therapy (CRT) because its normal operation usually prefers continuous ventricular capture by ventricular paces.

[0050] Preferably, the device measured VAT is stored in a device memory 80 and used for trending analysis. The time resolution of VAT trend is preferably programmable by the user. For example, user could interrogate the device using programmer and show the daily, or hourly, or minute-by-minute VAT (averaged over the time interval) in the right ventricle and/or the left ventricle.

[0051] Right and left ventricular activation time assessing units 96 and 98 and/or memory 80 are connected to a ventricular activation time trend analyzing unit 1000 that is adapted to analyze a trend in ventricular activation time by comparing most recently measured ventricular activation time values with a moving average of the previously measured ventricular activation time values, and to trigger a warning signal when an increase in ventricular activation time values is detected that exceeds a predefined threshold.

[0052] The trend of increasing VAT in the right ventricle suggests the development or progression of RBBB, and the trend of increasing VAT in the left ventricle suggests the development or progression of LBBB. As well known in the art, the trend of increasing VAT can be detected by comparing the most recently measured VAT value with the moving average of the previously measured VAT values, and a warning signal is generated when the increase in VAT exceeds a predefined threshold (either an absolute time interval or a percentage of previous VAT average).

[0053] Preferably, the device stored VAT trend data are also transmitted to the remote service center 94 by means of a telemetry unit 84 for trending analysis through the wired or wireless Home Monitoring network. According to one embodiment, the transmission of VAT trend data is programmed at predetermined time of day or predetermined time interval. According to another embodiment, the VAT trend data are transmitted to the remote service center upon device detection of sudden increase of VAT that exceeds a predefined threshold, which can be either an absolute time interval or a percentage of previous VAT average.

[0054] As illustrated in Fig. 5, the abrupt increase of VAT in a specific ventricle may suggest the sudden development of ventricular bundle branch block, which often occurs as a result of exercise-induced myocardial ischemia. Therefore, continuous monitoring of VAT combined with real-time alarm for increasing VAT can also provide a useful means for early detection of acute myocardial infarction and facilitate early intervention.

[0055] The apparatus and the method disclosed herein provide a novel device feature to continuously measure the RV and LV conduction times, which could be used for long term monitoring of development and progression of LBBB/RBBB.

[0056] The apparatus further provides a novel device feature for real-time detection of ischemia-induced ventricular conduction abnormality, thus offering a novel means for early detection and prevention of myocardial infarction.

Claims

1. An implantable heart stimulator having a housing and electronic circuitry, wherein the housing encloses said electronic circuitry and has an at least partially electrically conducting outer surface and wherein said electronic circuitry is connected or can be connected to at least one electrode lead, said at least one electrode lead carrying at least two electrodes,

wherein said electronic circuitry comprises a far-field electrogram recording unit that is electrically connected or can be connected to said at least partially electrically conducting outer surface and to first one of said at least two electrodes,
said electronic circuitry further comprises a near-field electrogram recording unit that is electrically connected or can be connected to at least two electrodes carried by said electrode lead,
said electronic circuitry further comprises a ventricular activation time assessing unit that is operatively connected to said far-field electrogram recording unit and said near-field electrogram recording unit,
said ventricular activation time assessing unit being configured to determine a point in time t1 of an initial positive deflection on a far-field electrogram and a point in time t2 of a first peak of the negative deflection on a near-field electrogram of a same heart cycle said ventricular activation time assessing unit being further configured to determine a time difference between points in time t1 and t2 said time difference representing a ventricular activation time.

2. The implantable heart stimulator of claim 1, wherein said first electrode is a defibrillation electrode.

3. The implantable heart stimulator according to claim 1, wherein said electrode lead is a ventricular electrode lead.

4. The implantable heart stimulator of claim 1, wherein said near-field electrogram recording unit is a ventricular sensing unit.

5. The implantable heart stimulator of claim 1, said heart stimulator being configured to continuously measure the ventricular activation time in a right ventricle and/or a left ventricle after each ventricular sensed event.

6. The implantable heart stimulator of claim 1, said heart stimulator being configured to continuously measure the ventricular activation time periodically or at predefined time of the day when ventricular senses are encouraged to occur.

7. The implantable heart stimulator of claim 1 said heart stimulator comprising a device memory and being configured to store measured ventricular activation times in a device memory in such way that they can be used for trending analysis.

8. The implantable heart stimulator of claim 1 comprising a ventricular activation time trend analyzing unit that is at least indirectly connected to said ventricular activation time assessing unit and that is adapted to analyze a trend in ventricular activation time by comparing most recently measured ventricular activation time values with a moving average of the previously measured ventricular activation time values, and to trigger a warning signal when an increase in ventricular activation time values is detected that exceeds a predefined threshold.

9. The implantable heart stimulator of claim 7 said heart stimulator comprising a telemetry unit and being configured to transmit stored ventricular activation time values and/or ventricular activation time trend data to a remote service center.

10. The implantable heart stimulator of claim 9 wherein said implantable heart stimulator is configured to transmit ventricular activation time trend data at predetermined time of day or predetermined time interval.

11. The implantable heart stimulator of claim 9 wherein said implantable heart stimulator is configured to transmit ventricular activation time trend data to a remote service center upon device detection of sudden increase of ventricular activation time that exceeds a predefined threshold, which can be either an absolute time interval or a percentage of a previous ventricular activation time average.

12. A method for assessing a ventricular activation time said method comprising the steps of:

determining a point in time t1 of an initial positive deflection on a far-field electrogram and a point in time t2 of a first peak of the negative deflection on a near-field electrogram of a same heart cycle
determining a time difference between points in time t1 and t2 said time difference representing the ventricular activation time.

13. The method of claim 12, said method including repeated measurement of ventricular activation time in a right ventricle and/or a left ventricle activation time after each ventricular sensed event.

14. The method of claim 12, said method comprising storing measured ventricular activation time values in such way that they can be used for trending analysis.

15. The method of claim 12, said method comprising analyzing a trend in ventricular activation time by comparing most recently measured ventricular activation time values with a moving average of the previously measured ventricular activation time values, and triggering a warning signal when an increase in ventricular activation time values is detected that exceeds a predefined threshold.

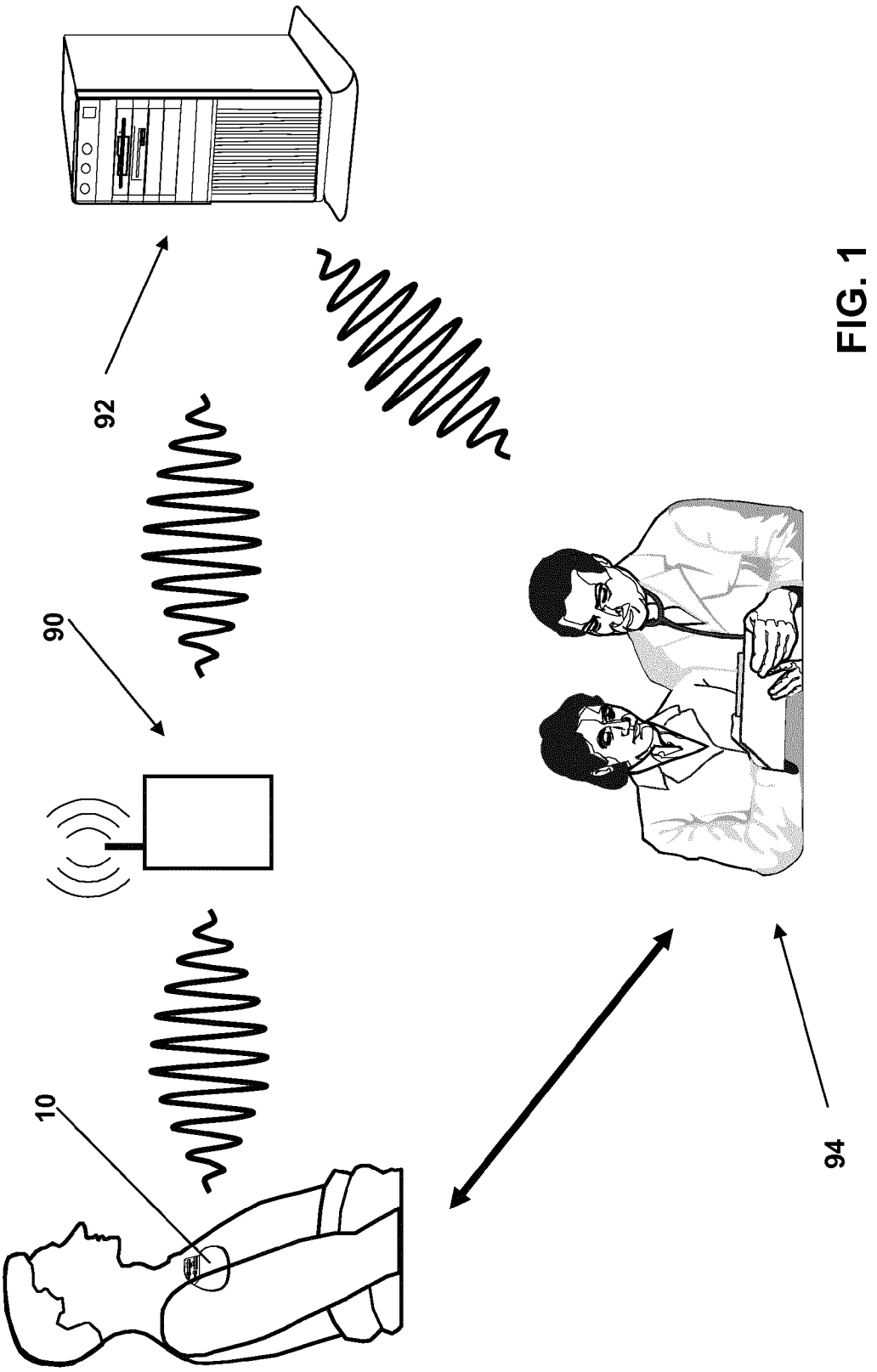


FIG. 1

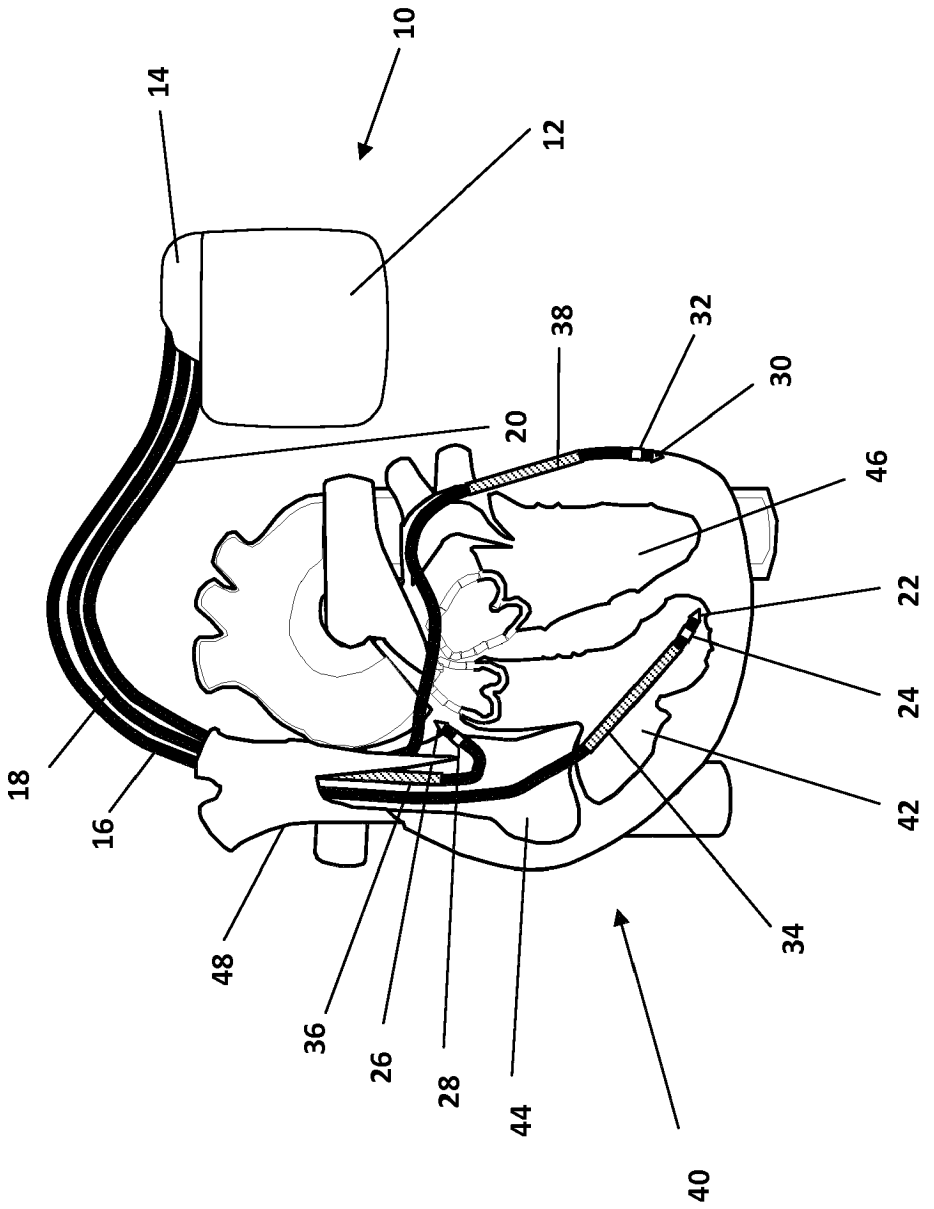
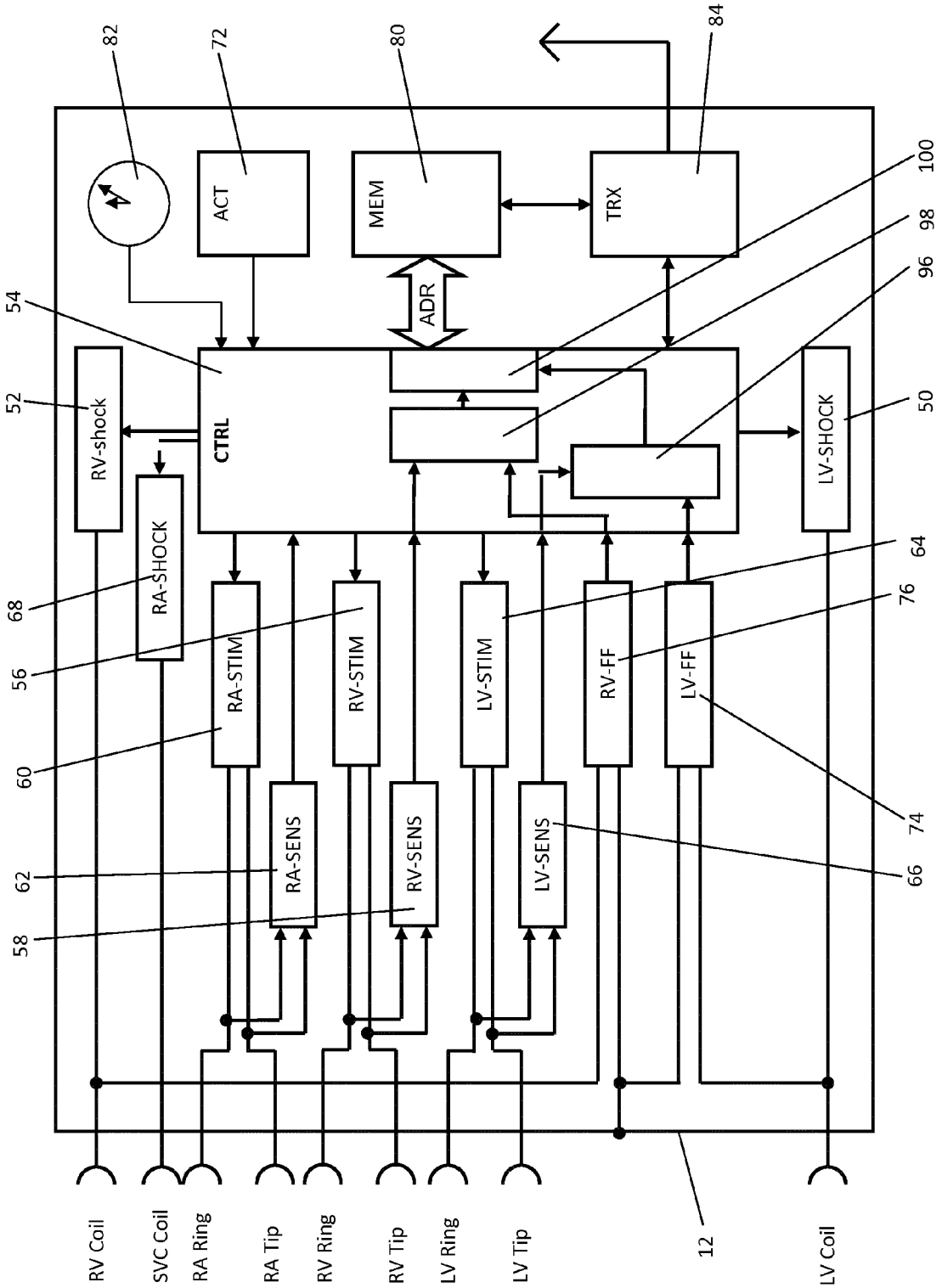


FIG. 2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74
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66
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FIG. 3

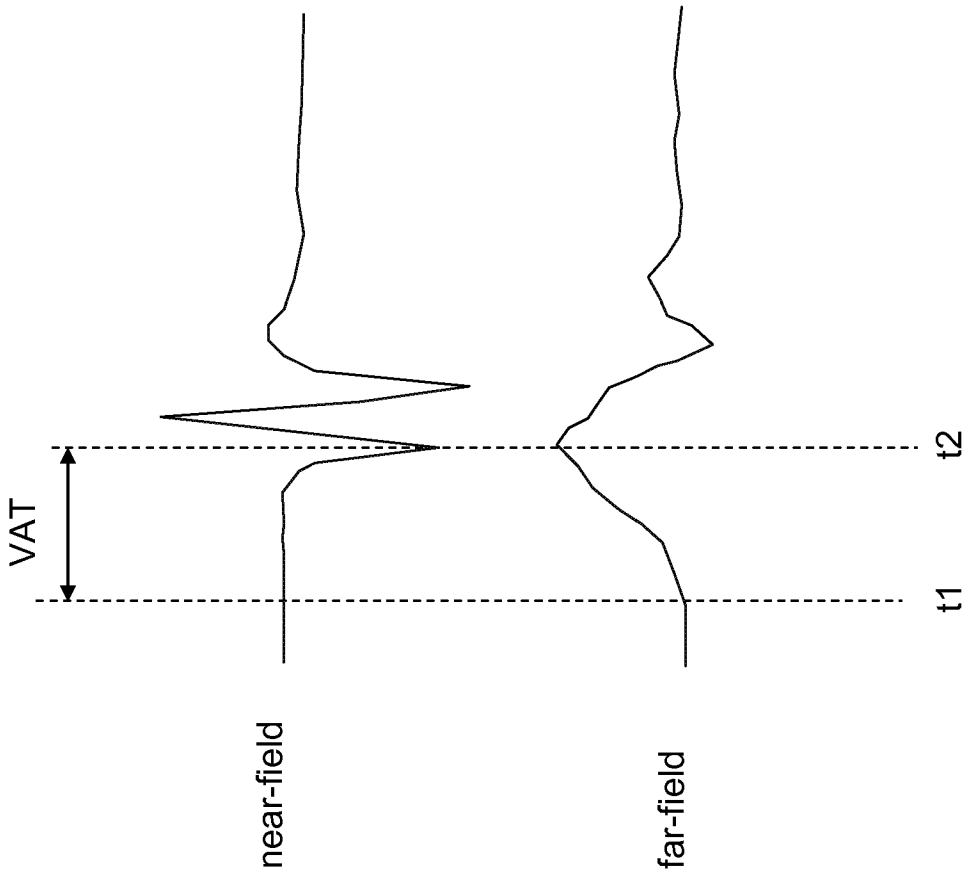

FIG. 4

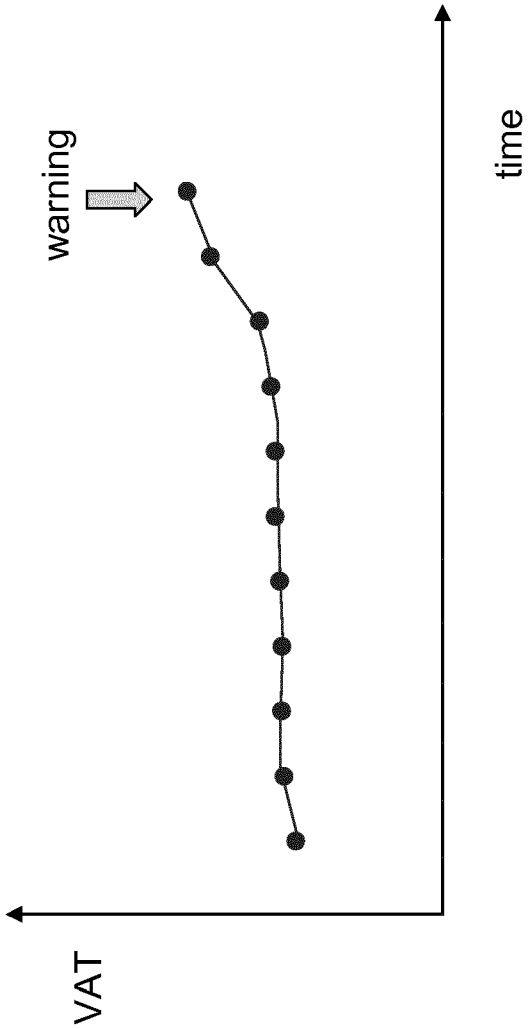

FIG.5

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EUROPEAN SEARCH REPORT

Application Number
EP 12 16 6541

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

A61N
A61B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	5 September 2012	Ließmann, Frank

CATEGORY OF CITED DOCUMENTS

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05-09-2012

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

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	植入式心脏刺激器和心室激动时间趋势分析方法		
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摘要(译)

本发明涉及一种用于通过确定远场电描记图上的初始正偏转的时间点t1和近端的负偏转的第一峰值的时间点t2来评估心室激动时间的方法和装置。相同心脏周期的场电描记图和确定时间点t1和t2之间的时间差表示心室激动时间的所述时间差。

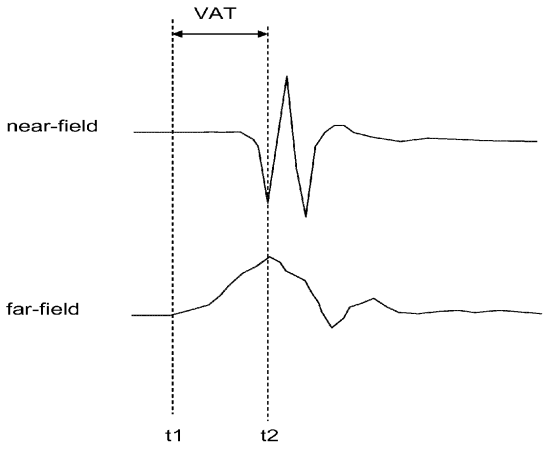

FIG. 4