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(71) Applicant *(for all designated States except US)*: **KONINKLIJKE PHILIPS ELECTRONICS, N.V.** [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(71) Applicant *(for AE only)*: **U.S. PHILIPS CORPORATION** [US/US]; 1251 Avenue Of The Americas, New York, New York 10020 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **BREDNO, Joerg** [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL). **ECK, Kai** [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(74) Common Representative: **KONINKLIJKE PHILIPS ELECTRONICS, N.V.**; C/o David Barnes P.o. Box 3001 345, Scarborough Road, Briarcliff Manor, New York 10510-8001 (US).

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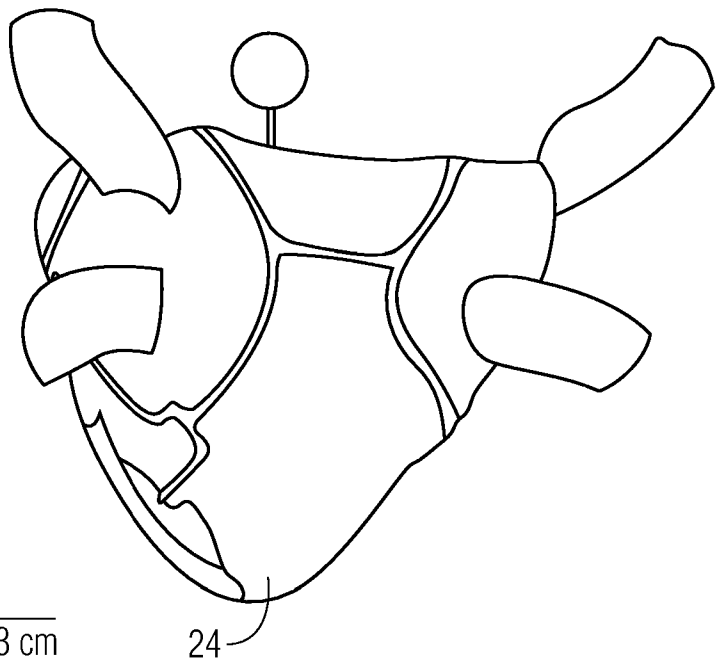

(57) Abstract: An apparatus and method for ablating tissue in a heart (24) of a subject (25) during an ablation procedure is disclosed. The method includes contacting an ablation catheter tip (48) to tissue of the heart (24) at a plurality of sites designated for ablation; sensing at each respective site a feedback signal from the ablation catheter indicative of success of the intended local ablation; storing any available data defining a current position of the ablation catheter tip (48) relative to the heart (24) at a moment of sensing the feedback signal indicative of a failed intended ablation for later re-visit; displaying a map (60) of a region of interest of the heart (24); and designating, on the map display (60), indications of the sites corresponding to when the required electrical current is above the threshold current value indicative of a gap in an ablation line or ring.

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SYSTEM AND METHOD FOR ELECTROPHYSIOLOGY REGAINING SUPPORT TO CONTINUE LINE AND RING ABLATIONS

The present disclosure relates generally to a system and method for repositioning an ablation catheter to points on the cardiac tissue where contact with the catheter was lost, in order to continue line or ring ablations in the treatment of tachycardia.

Tachycardia can be caused by abnormal conduction of the electric pulse, where the pulse doesn't follow its physiological pathway but creates feedback loops, e.g. from one of the ventricles back to the atrium (reentry tachycardia) or by non-physiologic circular conduction pathways in one of the ventricles e.g. around scar tissue or in one of the atria, resulting in a high heart rate. A ring or line ablation is required to block reentry tachycardia or abnormal conduction pathways, and there must be no gaps in the ablation path.

Electrophyisologic (EP) diagnosis and treatment of cardiac arrhythmia receives more and more clinical attention. Tachycardia (irregular increases of the pulse rate with irregular heart beat configuration) requires treatment because it has been identified as a major source for small blood coagulations that induce a high risk of stroke or cardiac infarction. Sources of tachycardia can be either ectotopic (local diseased heart tissue that creates false impulses) or due to reentry conduction where the electric pulse does not follow its physiologic pathways but creates parasitic feedback loops that result in a pathologically high heart rate.

Cardiac mapping is used to locate aberrant electrical pathways and currents within the heart, as well as to diagnose mechanical and other aspects of cardiac activity. Various methods and devices have been described for mapping the heart. Radiofrequency (RF) ablation is used to treat cardiac arrhythmia by ablating and killing cardiac tissue in order to create non-conducting lesions that disrupt the abnormal electrical pathway causing the arrhythmia. In RF ablation, heat is induced at the tip of an ablation catheter to create lesions in the myocardium. Such ablated scar tissue can no longer create or transport electric impulses. Local ablation destroys irregular local sources, whereas a ring or line ablation is required to block reentry tachycardia. Figure 1 depicts what is commonly referred to as a cartoon image of localizer information relating to an ablation procedure in the left atrium of a patient's heart. The line traversing and forming rings about the heart tissue indicate positions where an ablation-induced block was intended by the physician.

Line and ring ablations are extremely time-intense, lasting hours because any gap in the disabled tissue can cause a continued reentry tachycardia. It is desired that the intervention allow for a fast revisit of candidate positions where the ablation catheter was not in sufficient contact with the heart tissue when ablation was intended by the interventionalist.

The present disclosure provides a method for ablating tissue in a heart (24) of a subject (25) during an ablation procedure. The method includes: contacting an ablation catheter tip (48) to tissue of the heart (24) at a plurality of sites designated for ablation; sensing at each respective site a feedback signal from the ablation catheter indicative of success of the intended local ablation; storing any available data defining a current position of the ablation catheter tip (48) relative to the heart (24) at a moment of sensing the feedback signal indicative of a failed intended ablation for later re-visit; displaying a map (60) of a region of interest of the heart (24); and designating, on the map display (60), indications of the sites corresponding to when the required electrical current is above the threshold current value indicative of a gap in an ablation line or ring.

The present disclosure also provides an apparatus for ablating tissue in a heart (24) of a subject (25) during an ablation procedure. The apparatus includes: an ablation catheter tip (48) contacting tissue of the heart (24) at a plurality of sites designated for ablation; a sensor means for sensing at each respective site electrical current required to maintain the tip (48) at a target temperature; a storage means for storing any available data defining a current position of the ablation catheter tip (48) relative to the heart (24) at a moment of sensing the required electrical current above a threshold current value for later re-visit; and a display means (60) for displaying a map of a region of interest of the heart (24), wherein indications of the sites corresponding to when the required electrical current is above the threshold current value indicative of a gap in an ablation line or ring are designated on the display means.

The present disclosure also provides a computer software product (100) for ablating tissue in a heart (24) of a subject (25) during an ablation procedure. The product includes a computer-readable medium, in which program instructions are stored, which instructions, when read by a computer, cause the computer (50) to: sense electrical current required to maintain an ablation catheter tip (48) at a target temperature at a plurality of sites designated for ablation during an ablation procedure; store any available data defining a

current position of the ablation catheter tip (48) relative to the heart (24) at a moment of sensing the required electrical current above a threshold current value for later re-visit; display a map (60) of a region of interest of the heart (24); and designate, on the map display (60), indications of the sites corresponding to when the required electrical current is above the threshold current value indicative of a gap in an ablation line or ring.

Additional features, functions and advantages associated with the disclosed system and method will be apparent from the detailed description which follows, particularly when reviewed in conjunction with the figures appended hereto.

To assist those of ordinary skill in the art in making and using the disclosed system and method, reference is made to the appended figures, wherein:

FIGURE 1 depicts an intended ablation path indicated as dots on a so-called cartoon image of the left atrium illustrating where an ablation-induced block is intended by the physician;

FIGURE 2 is a schematic, pictorial illustration of a system for real-time mapping of cardiac ablation treatment in the heart, in accordance with an exemplary embodiment of the present disclosure;

FIGURE 3 is a schematic, pictorial illustration of a distal portion of a catheter used in the system of FIG. 2, in accordance with an exemplary embodiment of the present disclosure;

FIGURE 4 is a flow chart that schematically illustrates a method for indicating gaps formed during line or ring ablation in a cardiac chamber for immediate or later re-visit, in accordance with an exemplary embodiment of the present disclosure;

FIGURE 5 illustrates a fluoroscopy x-ray image that is automatically acquired and displayed or stored upon detection of a gap in the line or ring ablation procedure indicative of a catheter tip losing contact with the heart tissue, in accordance with an exemplary embodiment of the present disclosure.

As set forth herein, the present disclosure advantageously facilitates detection of the loss of contact between the catheter tip and heart tissue using an automated navigation support to revisit those parts of the ablation line or ring where gaps are possible. The present disclosure may be advantageously employed in cardio applications including automated acquisition and storage of position information at the moment where ablation contact to the heart tissue is lost serving to massively reduce the amount of time that is

spent in trial and error corrections of incomplete ring and line ablations to treat reentry tachycardia.

Figure 2 is a schematic, pictorial illustration of a mapping system 10, for real-time mapping of cardiac ablation treatment in a heart 24 of a subject 25, in accordance with an exemplary embodiment of the present disclosure. System 10 comprises an elongated mapping probe, preferably a catheter 30, which is inserted by a user 22 through a vein or artery of the subject into a chamber of the heart, which can be the right or left ventricle or atrium.

Figure 3 is a schematic, pictorial illustration showing a distal portion of catheter 30, which is inserted into heart 24. Catheter 30 preferably comprises at least one position sensor 40, a tip electrode 48, and one or more temperature sensors 49, all of which are preferably fixed at or near a distal tip 44 of the catheter. Temperature sensors 49 may comprise, for example, thermocouples and/or thermistors. Position sensor 40 generates or receives signals used to determine the position and orientation of catheter 40 within the chamber of the heart. Tip electrode 48 is preferably configured to apply electrical signals to heart 24 for ablating cardiac tissue, and is preferably further configured for diagnostic purposes such as cardiac mapping. Alternatively, separate electrodes are provided for diagnostic purposes and for ablating cardiac tissue. There is preferably a fixed positional and orientational relationship of position sensor 40, distal tip 44 and tip electrode 48. Optionally, catheter 30 further comprises at least one additional position sensor (not shown) and radio-opaque markers to identify individual catheters and to determine their location and orientation on x-ray projection images.

Reference is again made to Figure 2. In a preferred embodiment of the present invention, mapping system 10 comprises a display monitor 52, an imaging system 39 and a console 20, which preferably comprises a location system control unit 36, an ablation power generator 38, a junction box 32, an electrocardiogram (ECG) recording and/or monitoring system 34 and a computer 50, which preferably comprises appropriate signal processing circuits that are typically contained inside a housing of the computer. Computer 50 is preferably programmed in software and/or hardware to carry out the functions described herein. This software may be downloaded to the computer in electronic form, over a network, for example, or it may alternatively be provided on tangible media, such as

magnetic or optical media or other non-volatile memory. In some embodiments, computer 50 comprises a general-purpose computer.

Junction box 32 preferably routes (a) conducting wires and temperature sensor signals from catheter 30 to ablation power generator 38, (b) location sensor information from sensor 40 of catheter 30 to location system control unit 36, and (c) the diagnostic electrode signals generated by tip electrode 48 to ECG monitor 34. Alternatively or additionally, junction box 32 routes one or more of these signals directly to computer 50. ECG monitor 34 is preferably also coupled to receive signals from one or more body surface electrodes, so as to provide an ECG synchronization signal to computer 50.

The imaging system 39 is further operably connected to computer 50 for control and receipt of images from the imaging system 39. In an exemplary embodiment, imaging system is a fluoroscopy x-ray system. However, other imaging modalities are contemplated including, but not limited to, MRI, echocardiography, CT, or any other modality suitable to provide an instantaneous image that captures the current position of the catheter together with heart tissue.

A location system 11 preferably comprises a set of external radiators 28, position sensor 40 of catheter 30 and any additional position sensors, and location system control unit 36. External radiators 28 are preferably adapted to be located at respective positions external to subject 25 and to generate fields, such as electromagnetic fields, towards position sensor 40, which is adapted to detect the fields and facilitate a calculation of its position coordinates by location system control unit 36 responsive to the fields. Alternatively, position sensor 40 generates fields, which are detected by external radiators 28. For some applications, a reference position sensor, typically either on an externally-applied reference patch attached to the exterior of the body of the subject, or on an internally-placed catheter, is maintained in a generally fixed position relative to heart 24. By comparing the position of catheter 30 to that of the reference catheter, the coordinates of catheter 30 are accurately determined relative to the heart, irrespective of motion of the subject. In an exemplary embodiment, ECG 34 and an additional respiration sensor are used to provide heartbeat and respiration motion compensation discussed further below.

Location system control unit 36 receives signals from position sensor 40 (or from external radiators 28 when position sensor 40 generates the energy fields), calculates the location of sensor 40 and catheter 30, and transmits to computer 50 the location

information and energy dose information (received from ablation power generator 38, as described below) which relates to the location information. The location system control unit preferably generates and transmits location information essentially continuously.

Ablation power generator 38 preferably generates power used by tip electrode 48 to perform ablation. Preferably, the ablation power generator generates RF power for performing RF ablation. Alternatively or additionally, the ablation power generator induces ablation by means of other ablation techniques, such as laser ablation or ultrasound ablation, for example. Preferably, suitable feedback techniques are applied to facilitate identifying less than suitable ablated regions on the cardiac map, as discussed more fully below.

Ablation power generator 38 measures the current needed to maintain the tip at a constant temperature of between about 50 °C to about 65 °C. The ablation power generator 38 transmits electrical current information related to the current needed to maintain a constant tip temperature and preferably over a serial communications line, to computer 50. The technical means of transportation over a "serial communications line" are not relevant. What is important is that the signal feed is synchronous and real-time capable such that ECG(t), depth of respiration(t), ablation feedback(t) and position(t) are all available close to the time (t) when they have been acquired, which is mentioned later as "essentially continuously". The ablation power generator preferably measures and transmits the electrical current needed to sustain the tip at a constant temperature essentially continuously.

Alternatively, a cardiac map generated during a previous cardiac procedure is used. In an exemplary embodiment, a cardiac map adapted to the patient heart's anatomy is acquired from another source, such as an imaging modality (e.g., fluoroscopy, MRI, echocardiography, CT, single-photon computed tomography (SPECT), or positron emission tomography (PET)), and the location of the catheter is visualized on this map for at least sites of ablation that are not successful because of lack of contact between the tip and tissue of the heart. In this case, computer 50 marks the intended ablation lesion locations on this map as gaps in a line or ring ablation. Alternatively, for some applications, a cardiac map adapted to the anatomy of the patient's heart is not acquired, in which case only a map indicative of a proximate location of where the catheter ablation tip was located is acquired when lack of contact between the tip and tissue is detected.

Figure 4 is a flow chart 200 that schematically illustrates a method for indicating a gap in a line or ring ablation, and thus an incomplete ablation formed in a cardiac chamber, in accordance with an exemplary embodiment of the present disclosure. After a geometric and electrical map of the cardiac chamber has been generated, user 22 advances catheter 30 to the area of the surface of the cardiac chamber on which ablation is to be performed at block 202. As ablation energy is applied to the cardiac surface, ablation power generator 38 measures, preferably continuously, the amount of electrical current that is needed to maintain the tip at a constant temperature at block 204, as described above. Current ablation catheters are controlled to keep a constant temperature at their tip of about 50 °C to about 65°C. The ablation power generator 38 senses the amount of current that is required to heat the catheter tip. A simple threshold decision or other means of signal classification applied to this feedback information at block 206 then allows distinguishing between contact of the catheter tip with cardiac tissue (e.g., low current required) and the catheter tip that is only in contact with the blood flow (e.g., high current required). If the measured feedback signal is classified as "not in contact" with the heart tissue, then block 202. If the measured current is greater than the threshold current value indicative of a lack of tip contact with the heart tissue, then block 208. A system and method according to the intervention automatically detects lost contact between the tip and cardiac tissue based on this control parameter (e.g., sensed electrical current). The system and method includes acquiring and storing any relevant available data available defining the current catheter position at block 208. At block 210, the user 22 or interventionalist revisits any gaps in the ablation path using the data acquired at block 208 defining the current position of the catheter tip when the measured current is above the threshold current value indicative of lost contact between the tip and heart tissue.

In exemplary embodiments, the data includes current localizer information and x-ray images (Figure 5) of the catheter acquired and stored at the moment that lost contact is detected (e.g., current above a threshold value). Acquisition of these images at the moment of lost contact will indicate the catheter tip proximate to a position where the ablation must be continued or completed to avoid gaps in a line or ring ablation. Figure 5 is a fluoroscopic image 300 acquired when the measured current required to maintain a constant tip temperature rises above the threshold current value. Image 300 illustrates three ECG leads 302 proximate heart 24 attached to the patient's skin. The reference EP

catheter 304 in one of the atria is the middle one of the three visible catheters 306, i.e. the dark bend structures. This catheter 304 is positioned at an anatomical landmark, e.g. the coronary sinus. The lower EP catheter 306 appears to lay in the left ventricle close to the apex. On this catheter, radio-opaque marker rings 308 are easily visible. The upper catheter 306 is located in one of the atrial chambers of the heart. The diaphragm 310 separating the lung from abdominal organs is visible in the lower right of the image 300 and is a possible source to determine the depth of respiration intake. Image 300 illustrates the arc-shaped transition from bright lung tissue to darker abdominal tissue. Furthermore, image 300 depicts the spine and some ribs, but these are not of interest.

Two modes of operation are supported using data defining a current position of the catheter tip corresponding with a moment that lost contact between the cardiac tissue and tip is detected. The modes of operation relate to the point in time when the interventionalist makes use of this information, either as soon as the gap candidate has been identified or the ablation is continued as normal and the interventionalist navigates back if and only if the ablation was not successful. By use of mask overlays, i.e. a mixing of live images and images acquired when contact was lost, the current position of the catheter and the position where contact was lost can be presented such that a revisit of the lost position is guided by an image or by localizer geometry and, therefore, easily achievable. In a second mode, a list of candidate positions can be displayed when a finished line or ring ablation has not been successful, which is easily detectable on the ECG 34 as soon as the ablation is considered finished. In this manner, corrections need only be applied to these candidate positions and it is not necessary to retrace the complete ablation procedure.

One proposed embodiment of the invention consists of a software module that is integrated into an EP workstation or console 20 depicted generally at 100 within computer 50. Such an EP workstation is the central control and display unit of an EP procedure and combines the EP-specific ECG signals, x-ray and localizer information. The software module 100 receives data corresponding to the sensed electrical current that is required to heat the ablation catheter tip to the target temperature. When the electrical current rises above a threshold, lost contact between the tip and heart tissue is detected. The software module 100 then instructs computer 50 to automatically store any and all available data that defines the current catheter position together with available information on the

patient's status, namely the current cardiac phase determined from ECG and the depth of respiration intake determined from an external sensor or the optionally acquired image.

For example, when localizers are used, then the available data defining current position of the catheter tip includes storing localizer geometry. For ablations under x-ray surveillance, a current fluoroscopy image is stored (FIG. 5). In an extended embodiment of this intervention, the acquisition of one fluoroscopy frame can be automatically triggered (e.g., imager switched on for one frame), even if the fluoroscopy is currently in an off state. The current phase in the heart and respiration motion cycle is acquired using ECG 34 and one of the described means to determine depth of respiration and stored as well to allow for respective motion compensations that are required to position the catheter at the same position with respect to the cardiac tissue independent of motion due to respiration and heart beat.

This information indicative of position of the catheter tip when contact is lost with the heart tissue can be used either in an immediate mode in a revisit mode discussed above. To start the ablation immediately after the contact was lost as close as possible to the previous position, a respiration and heart motion compensated mask overlay of the automatically stored image or the position of the localizers and their distance to the target position are displayed to the interventionalist 22 on monitor 52 such that the user 22 can easily reposition the catheter to continue with the interrupted ablation.

The revisit mode is used when the EP ablation procedure is finished, but the reentry tachycardia is not blocked. It will be recognized that immediate treatment results are obtained once the ablation is complete using ECG 34. Then, the interventionalist 22 is provided with a list of candidate positions where insufficient contact between the catheter and heart tissue was present during ablation and can successively use the navigation support provided in the immediate mode via monitor 52, as described above, for these candidate positions until success of the intervention is obtained.

The offer of advanced dedicated EP lab equipment incorporating the software module 100 as described above offers the assignee of the current application a tremendous opportunity in this growing market . The automated acquisition and storage of position information at the moment when ablation contact to the heart tissue is lost serves as a unique selling proposition for such an EP lab. One advantage includes the massive

reduction in the amount of time that is spent in trial and error corrections of incomplete ring and line ablations to treat reentry tachycardia.

All dedicated EP labs may incorporate the EP workstation according to the exemplary embodiments described herein, e.g. a target hardware that controls and combines the various hardware (e.g., x-ray imager, EP ECG acquisition, ablation catheter control, and localizer system). The invention is easily included in a software package for such a workstation.

In sum, the disclosed, apparatus, method, computer software product provide significant benefits to users of EP workstations, particularly physicians desiring a reduction in the amount of time to complete line and ring ablations to treat reentry tachycardia. The handling of possible gaps in an incomplete line or ring ablation includes automated creation and display of an image of the current catheter tip position or the storage of the current position image for later re-visit, which is necessary if the treatment goal is not reached at the end of the ablation path. Further, the immediate or later re-visit of a gap candidate in the path is simplified when heartbeat and/or respiration motion compensation is provided using an ECG and information on depth of respiration. In this manner, the re-visit can be image-guided using interventional imaging devices or based on localizer information. In contrast to the current use of the localizer information in daily clinical routine and the above described exemplary embodiments, it is proposed to use the localizer information for targeted navigation support. For example, the indication of current position information is replaced with information indicative of where the catheter should be disposed. For example, the localizer information would give the distance and direction to gap candidates from the current position of the tip, rather than information pertaining to only the current position of the ablation tip, and in so doing, applying heartbeat and respiraton motion compensation. For this, the comparison between the position of the gap candidate and the current position of the catheter is corrected for heart and respiration motion using the synchronously acquired ECG and depth of respiration together with information how the catheter moves locally due to heart beat and respiration. The latter information can be extracted by observing the position of the catheter tip over a heart cycle and an independent observation of the motion of the heart in the rib cage due to respiration.

Advantageously, embodiments of the present disclosure enable a user of the apparatus, method and computer software product to visually determine, in real-time

during a procedure, which areas of the surface of the cardiac chamber have not been ablated and which require application or re-application of the ablating electrode. As a result, a more complete non-conducting lesion is typically formed, without unnecessary ablation of excess cardiac tissue and in less time than before possible.

Although the method, apparatus and software product of the present disclosure have been described with reference to exemplary embodiments thereof, the present disclosure is not limited to such exemplary embodiments. Rather, the method, apparatus and software product disclosed herein are susceptible to a variety of modifications, enhancements and/or variations, without departing from the spirit or scope hereof. Accordingly, the present disclosure embodies and encompasses such modifications, enhancements and/or variations within the scope of the claims appended hereto.

CLAIMS

1. A method for ablating tissue in a heart (24) of a subject (25) during an ablation procedure, the method comprising:

contacting an ablation catheter tip (48) to tissue of the heart (24) at a plurality of sites designated for ablation;

sensing at each respective site a feedback signal from the ablation catheter indicative of success of the intended local ablation;

storing any available data defining a current position of the ablation catheter tip (48) relative to the heart (24) at a moment of sensing the feedback signal indicative of a failed intended ablation for later re-visit;

displaying a map (60) of a region of interest of the heart (24); and

designating, on the map display (60), indications of the sites corresponding to when the required electrical current is above the threshold current value indicative of a gap in an ablation line or ring.

2. The method of claim 1, wherein the feedback signal includes electrical current required to maintain the tip (48) at a target temperature and the available data is stored defining a current position of the ablation catheter tip (48) relative to the heart (24) at a moment of sensing the required electrical current above a threshold current value for later re-visit.

3. The method of claim 1, further comprising:

re-visiting the sites corresponding to gaps in the ablation line or ring to ablate the gaps using at least one of an interventional imaging device and localizer information as navigation support for the ablation catheter tip (48).

4. The method of claim 3, wherein the re-visiting is one of immediate upon detection of a gap and when completion of the line or ring ablation procedure has not been successful.

5. The method of claim 4, wherein correction for incomplete ablation entails ablation of only sites corresponding to sites detecting the feedback signal indicative of failed intended local ablation.

6. The method of claim 3, wherein use of the localizer information provides relative distance and direction from a current position of the ablation catheter tip to the gaps.

7. The method of claim 1, wherein the available data includes localizer geometry when localizers are used.

8. The method of claim 1, wherein the available data includes fluoroscopy image data when under x-ray surveillance.

9. The method of claim 8, wherein the fluoroscopy image data is automatically acquired at least when triggered by sensing electrical current above the threshold current value.

10. The method of claim 1, wherein the available data includes a current phase of at least one of the heart(24) and respiratory motion cycle.

11. The method of claim 10, wherein recording the current phase of at least one of the heart (24) and respiratory motion cycle provides motion compensation upon immediate or later re-visit of a gap candidate in the ablation line or ring.

12. The method of claim 1, further comprising:

acquiring image data of the heart (24) at least at a moment of sensing the required electrical current above the threshold current value.

13. The method of claim 12, wherein the image data is displayed on the map (60) indicating a respective site corresponding to a location of the ablation catheter tip when contact between the tip and the tissue of the heart (24) is lost indicative of a gap in a line or ring ablation of the tissue.

14. The method of claim 12, wherein the image data includes x-ray image data overlaid on the map (60) of the heart (24).

15. The method of claim 14, wherein the image data includes live interventional images overlayed with a reference image that was acquired when the feedback signal from the ablation catheter indicated insufficient contact.

16. The method of claim 15, wherein the reference image is automatically transformed to correspond to the current and depth of respiration intake and phase in the cardiac cycle using information from an ECG and respiration sensor together with the feedback signal with respect to motion of the catheter tip due to heart beat and respiration.

17. The method of claim 1, further comprising:

one or more body surface electrodes (302), adapted to be coupled to a surface of a body of the subject 25), and an electrocardiogram (ECG) monitor (34), adapted to receive signals from the body surface electrodes (302) and to provide an ECG synchronization signal to a computer (50).

18. The method of claim 17, wherein the ECG synchronization signal provides at least one of heartbeat and respiratory motion compensation.

19. The method of claim 1, wherein the sensed current below the threshold current value is indicative of the ablation catheter tip in contact with the tissue and the sensed current above the threshold current value is indicative of the ablation catheter tip (48) losing contact with the tissue and in contact with a blood flow.

20. The method of claim 1, wherein the target temperature is about 65 ºC.

21. An apparatus for ablating tissue in a heart (24) of a subject (25) during an ablation procedure, the apparatus comprising:

an ablation catheter tip (48) contacting tissue of the heart (24) at a plurality of sites designated for ablation;

a sensor means for sensing at each respective site electrical current required to maintain the tip (48) at a target temperature;

a storage means for storing any available data defining a current position of the ablation catheter tip (48) relative to the heart (24) at a moment of sensing the required electrical current above a threshold current value for later re-visit; and

a display means (60) for displaying a map of a region of interest of the heart (24), wherein indications of the sites corresponding to when the required electrical current is above the threshold current value indicative of a gap in an ablation line or ring are designated on the display means.

22. The apparatus of claim 21, wherein an interventionalist steers the ablation catheter tip (48) to re-visit the sites corresponding to gaps in the ablation line or ring to ablate the gaps using at least one of an interventional imaging device (39) and localizer information as navigation support for the ablation catheter tip (48), the re-visiting is one of immediate upon detection of a gap and when completion of the line or ring ablation procedure has not been successful and entails ablation of only sites corresponding to sites detecting current above the threshold current value.

23. A computer software product (100) for ablating tissue in a heart (24) of a subject (25) during an ablation procedure, the product comprising a computer-readable medium, in which program instructions are stored, which instructions, when read by a computer, cause the computer (50) to:

sense electrical current required to maintain an ablation catheter tip (48) at a target temperature at a plurality of sites designated for ablation during an ablation procedure;

store any available data defining a current position of the ablation catheter tip (48) relative to the heart (24) at a moment of sensing the required electrical current above a threshold current value for later re-visit;

display a map (60) of a region of interest of the heart (24); and

designate, on the map display (60), indications of the sites corresponding to when the required electrical current is above the threshold current value indicative of a gap in an ablation line or ring.

24. The computer software product (100) of claim 21, wherein the ablation catheter tip(48) re-visits the sites corresponding to gaps in the ablation line or ring to ablate the gaps using at least one of an interventional imaging device (39) and localizer information as navigation support for the ablation catheter tip (48), the re-visiting is one of immediate upon detection of a gap and when completion of the line or ring ablation procedure has not been successful and entails ablation of only sites corresponding to sites detecting current above the threshold current value.

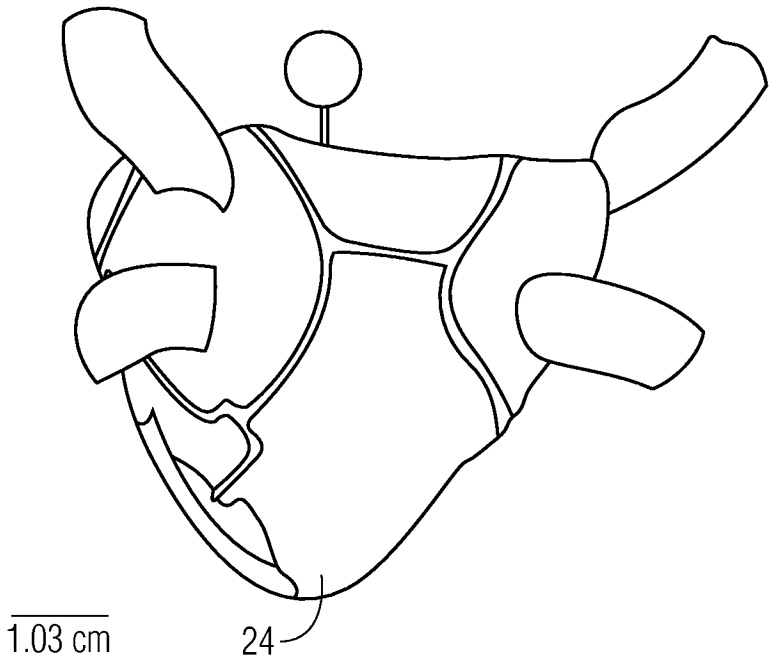

FIG. 1

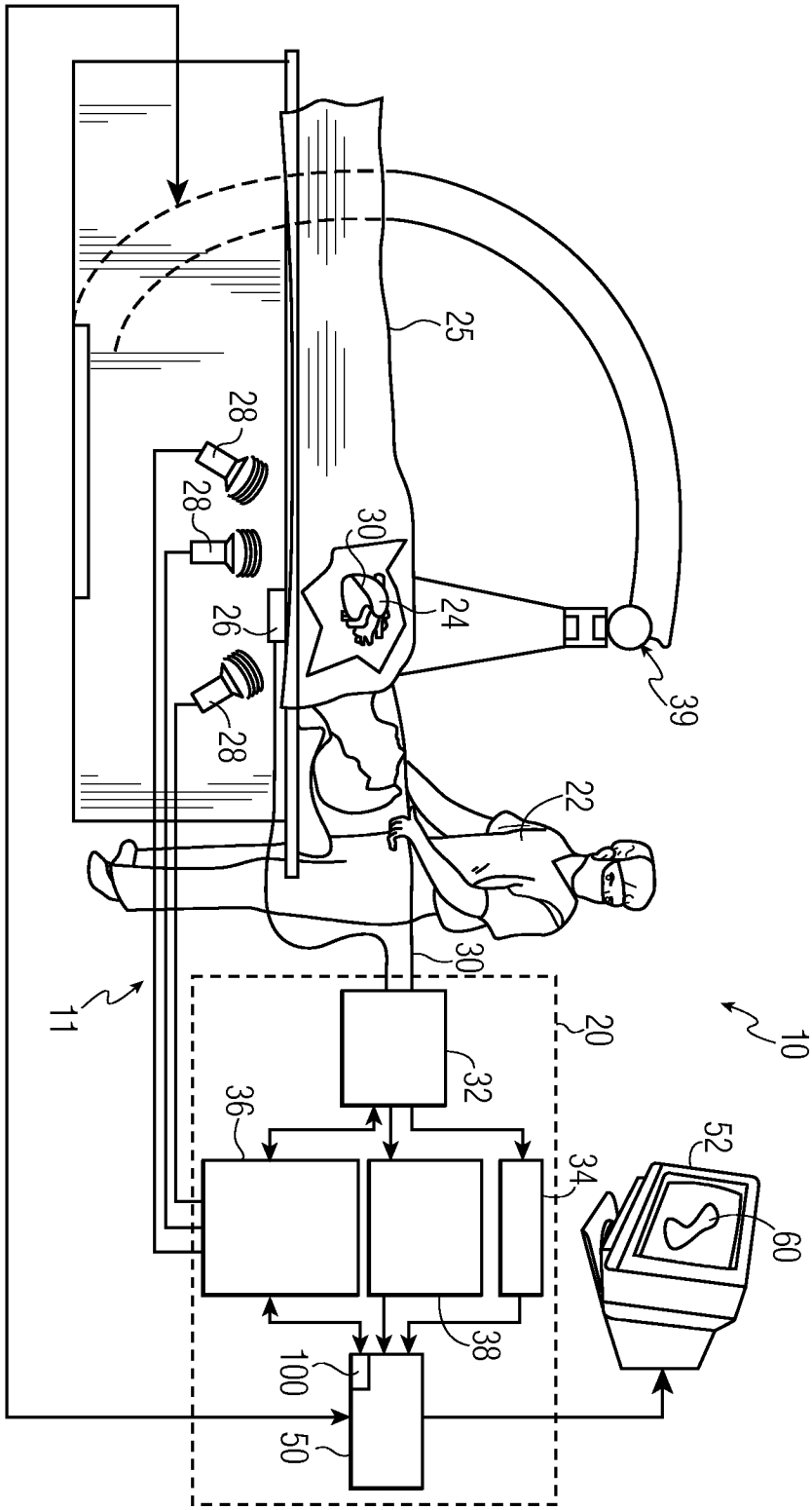

FIG. 2

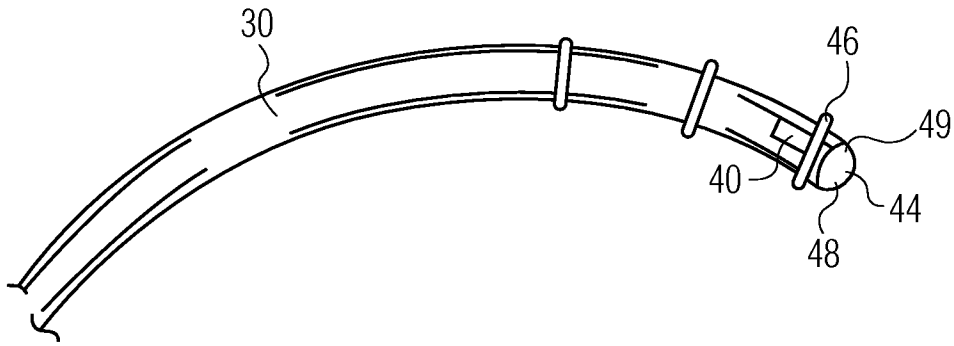

FIG. 3

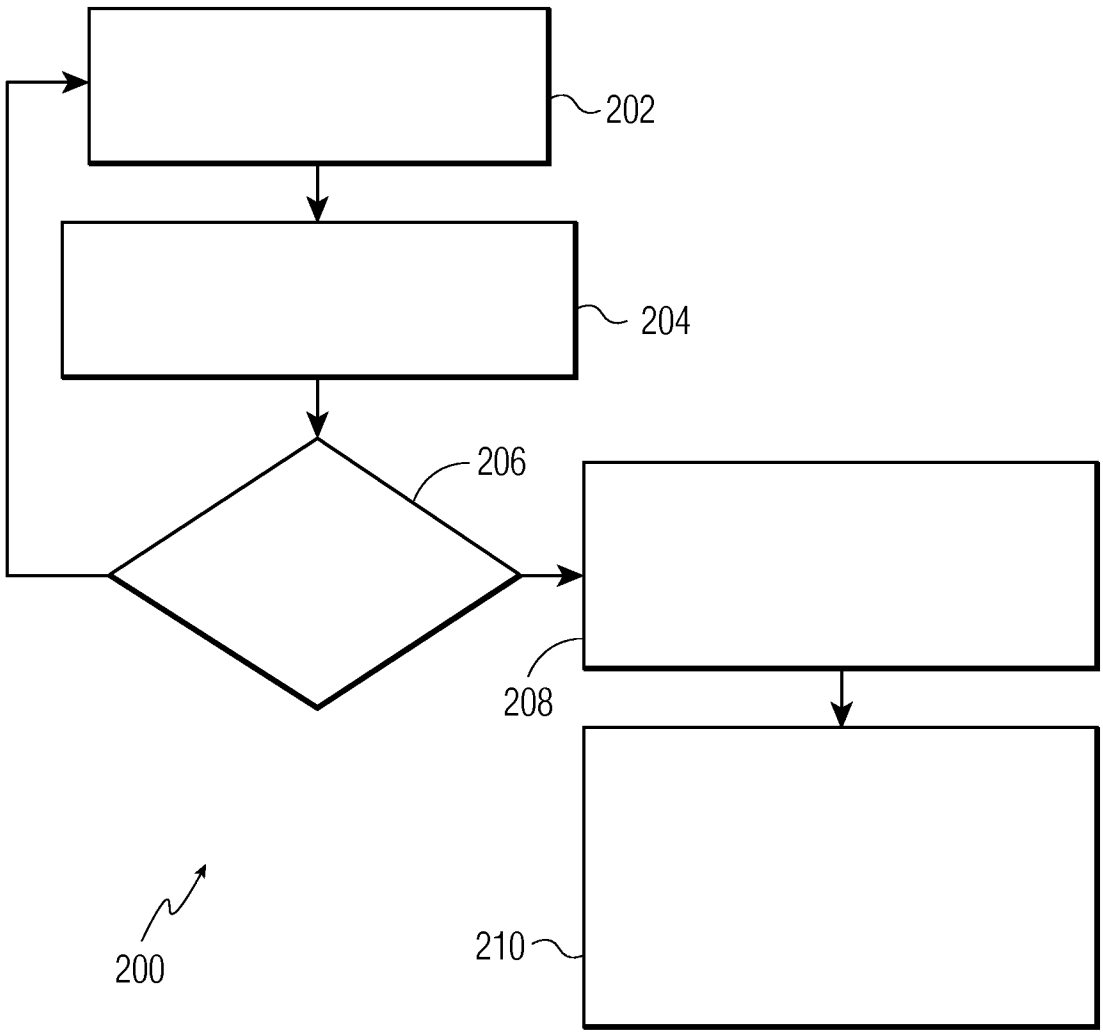

FIG. 4

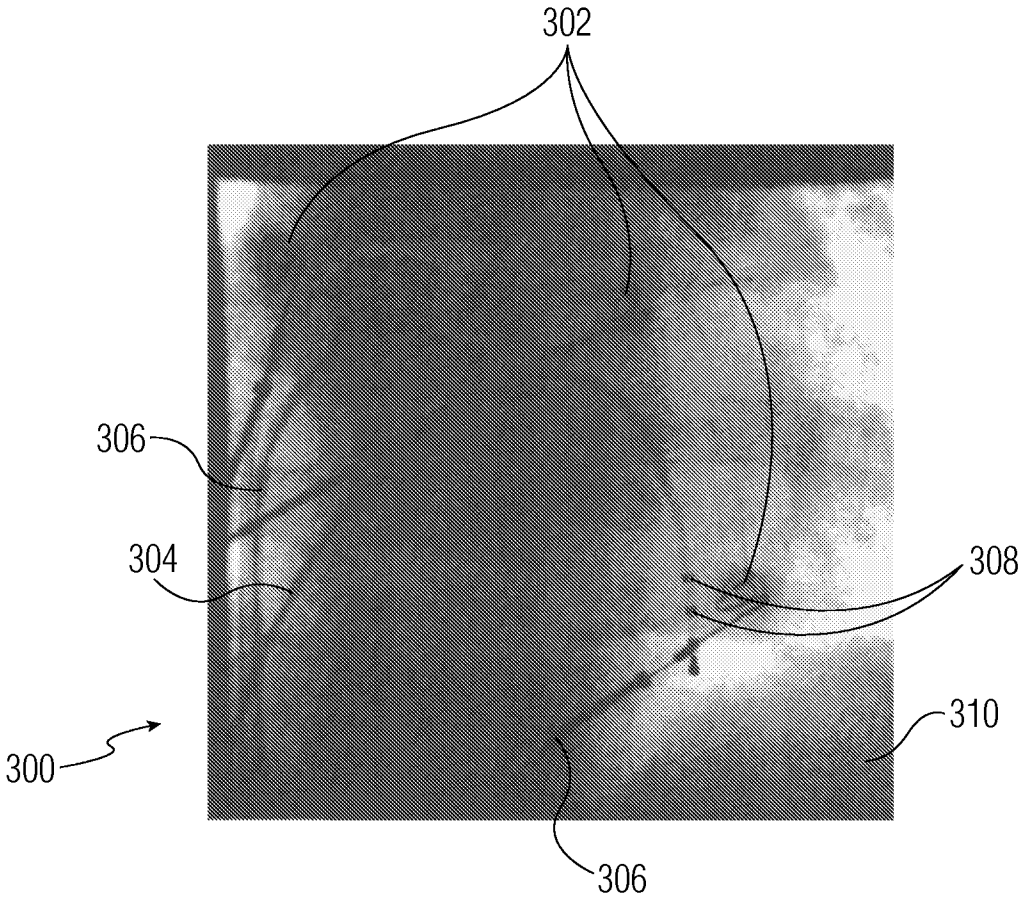

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/052756

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B18/00

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)
A61B

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 415 608 A2 (BIOSENSE INC [US]) 6 May 2004 (2004-05-06) abstract; figures 1-4 paragraphs [0020], [0028], [0040], [0048] - [0050]	21
X	US 2005/038333 A1 (SRA JASBIR S [US]) 17 February 2005 (2005-02-17) abstract; figure 7 paragraphs [0018], [0019], [0025], [0057], [0073], [0075]	21
X	US 5 588 432 A (CROWLEY ROBERT J [US]) 31 December 1996 (1996-12-31) abstract; figures 13,14,22 column 2, line 32 - line 47 column 3, line 61 - column 4, line 24 column 12, line 54 - column 13, line 4	21

☐ 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 document 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
8 January 2007	23/01/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Pereda Cubián, David

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2006/052756

Box 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. [X] Claims Nos.: 1-20,23,24
because they relate to subject matter not required to be searched by this Authority, namely:

Rule 39.1(iv) PCT - Method for treatment of the human or animal body by surgery

2. [X] Claims Nos.: 22
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:

see FURTHER INFORMATION sheet PCT/ISA/210

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 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.

[ ] No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.1

Claims Nos.: 1-20,23,24

Rule 39.1(iv) PCT - Method for treatment of the human or animal body by surgery

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Continuation of Box II.2

Claims Nos.: 22

Dependent claim 22 does not meet the requirements of Article 6 PCT as the category of the claim is ambiguous and not clearly defined. Claim 22 is defined in terms of product by process (see PCT Guidelines, IV-5.26).

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2006/052756

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1415608 A2	06-05-2004	AU 2003255201 A1	06-05-2004
		CA 2445360 A1	21-04-2004
		JP 2004160212 A	10-06-2004
		KR 20040036867 A	03-05-2004
		US 2004078036 A1	22-04-2004
		US 2004147920 A1	29-07-2004
US 2005038333 A1	17-02-2005	WO 2006020920 A2	23-02-2006
US 5588432 A	31-12-1996	NONE	