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(54) Title: CARDIAC STIMULATION SYSTEM WITH AUTOMATED OPTIMIZATION OF HIS BUNDLE PACING FOR CARDIAC RESYNCHRONIZATION THERAPY

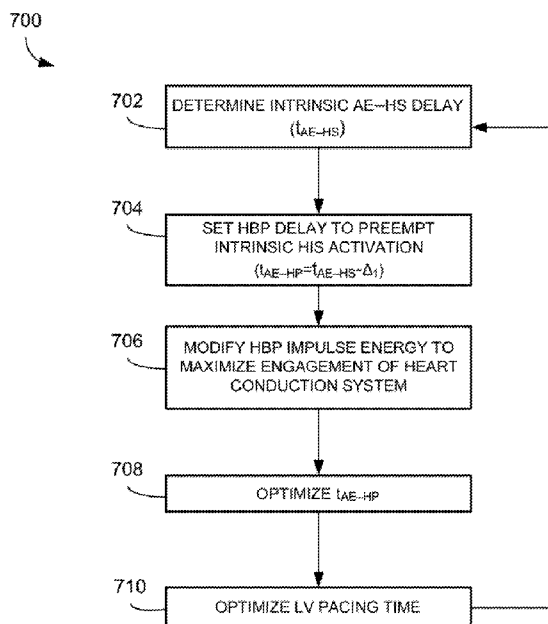


FIG. 7

(57) Abstract: Systems and methods of performing cardio resynchronization therapy (CRT) on a patient heart include the use of a stimulation system having at least one processor, at least one memory, a pulse generator, a stimulating electrode disposed in proximity to a His bundle of the patient heart, and a sensing electrode adapted to sense electrical activity of the left ventricle (LV) of the patient heart. CRT is provided by applying, using the pulse generator and through the stimulating electrode, a His bundle pacing (HBP) impulse having a first impulse energy. The sensing electrode is then used to measure an LV activation time in response to the HBP impulse. At least one setting of the pulse generator is modified based on the LV activation time such that a subsequent HBP impulse may be provided by the pulse generator via the stimulating electrode using a modified impulse energy.

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AMENDED CLAIMS

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1. A cardiac stimulation system adapted to provide cardiac resynchronization therapy (CRT) for a patient heart, the stimulation system comprising:
 - a pulse generator;
 - a stimulating electrode coupled to the pulse generator and configured to be disposed in proximity to a His bundle of the patient heart;
 - an implantable sensing electrode coupled to the pulse generator, adapted to be implanted proximate to the left ventricle (LV) of the patient heart, and adapted to sense electrical activity of the LV of the patient heart;
 - a processor communicatively coupled to the pulse generator; and
 - a memory communicatively coupled to the processor, the memory including instructions executable by the processor that, when executed by the processor, cause the processor to:
 - apply, using the pulse generator and through the stimulating electrode, a His bundle pacing (HBP) impulse having a first impulse energy;
 - measure, using the implantable sensing electrode, an LV activation time in response to the HBP impulse; and

automatically modify, based on the LV activation time, at least one setting of the pulse generator stored in the at least one memory such that a subsequent HBP impulse to be provided by the pulse generator via the stimulating electrode has a second impulse energy different from the first impulse energy.

2. The cardiac stimulation system of claim 1 further comprising a second implantable sensing electrode communicatively coupled to the processor and adapted to sense electrical activity of the His bundle, wherein the instructions further cause the processor to:

identify an atrial event, the atrial event being one of a pacing of the right atrium (RA) and a sensing of intrinsic RA activation;

identify, using the second implantable sensing electrode, an intrinsic His bundle activation corresponding to the atrial event;

determine a His bundle activation time, the His bundle activation time being a time between the atrial event and the intrinsic His bundle activation; and

automatically set an HBP impulse timing of the pulse generator to be less than the His bundle activation time such that HBP impulses applied using the stimulating electrode preempt intrinsic His bundle activation.

3. The cardiac stimulation system of one or more of claims 1 and 2, wherein the instructions further cause the processor to:

measure at least one hemodynamic response of the patient heart in response to application of HBP impulses; and

adjust an HBP impulse timing setting of the pulse generator to maximize a hemodynamic response corresponding to a subsequently applied impulse.

4. The cardiac stimulation system of one or more of claims 1 to 3, further comprising a left ventricle (LV) electrode coupled to the pulse generator and adapted to provide an LV impulse to the LV after an LV pacing delay (t_{HP-LVP}), t_{HP-LVP} corresponding to a time from application of the HBP impulse.

5. The cardiac stimulation system of one or more of claims 1 to 4 wherein the instructions further cause the processor to:

apply a plurality of LV timing impulses, each of the plurality of LV timing impulses being applied using a respective LV pacing delay;

for each LV timing impulse of the plurality of LV timing impulses, measure a QRS waveform generated in response to application of the LV timing impulse;

for each QRS waveform, determine a respective QRS duration;

identify a shortest QRS duration of the respective QRS durations; and

modify an LV pacing delay setting of the pulse generator such that t_{HP-LVP} equals the respective LV pacing delay of the LV timing impulse having the shortest QRS duration.

6. The cardiac stimulation system of one or more of claims 1 to 5, wherein the instructions further cause the processor to:

measure each of a first intrinsic delay (t_{HP-RVS}) between HBP and a response of a right ventricle (RV) of the patient heart, a second intrinsic delay (t_{HP-LVS}) between HBP and a response of the LV, and a third intrinsic delay ($t_{LVP-RVS}$) between pacing of the LV and a response of the RV; and

set t_{HP-LVP} based on each of t_{HP-VSR} , t_{HP-LVS} , and $t_{LVP-RVS}$.

7. The cardiac stimulation system of one or more of claims 1 to 6, wherein the at least one setting of the pulse generator includes at least one of an HBP impulse amplitude and an HBP impulse duration that is automatically modified by the processor.

8. The cardiac stimulation system of one or more of claims 1 to 7, further comprising: an impedance measuring circuit configured to collect dynamic impedance data corresponding to one or more cardiac functions in response to HBP impulses applied by the pulse generator, wherein the processor is configured to automatically modify the HBP impulse timing to maximize dynamic impedance with respect to the HBP impulses applied by the pulse generator.

9. The cardiac stimulation system of one or more of claims 1 to 8 wherein the instructions further cause the processor to apply, using the pulse generator, an LV impulse to the LV after an LV pacing delay (t_{HP-LVP}), t_{HP-LVP} corresponding to a time from application of the HBP impulse after which a pacing impulse is applied to the LV.

10. The cardiac stimulation system of one or more of claims 1 to 9, wherein t_{HP-LVP} results in a shortest QRS duration.

11. The cardiac stimulation system of one or more of claims 1 to 10, wherein t_{HP-LVP} is based on each of a first intrinsic delay (t_{HP-RVS}) between HBP and a response of a right ventricle (RV) of the patient heart, a second intrinsic delay (t_{HP-LVS}) between HBP and a response of the LV, and a third intrinsic delay ($t_{LVP-RVS}$) between pacing of the LV and a response of the RV.

12. The cardiac stimulation system of one or more of claims 1 to 11, wherein the instructions further cause the processor to:

- perform HBP by applying a first impulse to the His bundle;
- measure each of t_{HP-LVS} and t_{HP-RVS} in response to applying the first impulse;
- apply a second impulse to the LV; and
- measure $t_{LVP-RVS}$ in response to applying the second impulse.

13. The cardiac stimulation system of one or more of claims 1 to 12, further comprising a multipolar LV lead including a plurality of LV sensing electrodes, wherein the instructions further cause the process to:

- measure a plurality of LV activation delays, each of the plurality of LV activation delay measured using a respective LV sensing electrode of the plurality of LV sensing electrodes; and

- calculate a total LV activation time by subtracting a minimum LV activation delay of the plurality of LV activation delays from a maximum LV activation delay of the plurality of LV activation delays.

14. The cardiac stimulation system of one or more of claims 1 to 13, wherein the instructions further cause the processor to apply, in response to determining the total LV activation time is below a total LV activation time threshold, at least one second LV impulse to the LV.

15. The cardiac stimulation system of one or more of claims 1 to 14 wherein the total LV activation time threshold is equal to one half of the minimum LV activation delay.