Heart rhythm model for the simulation of electric fields in transesophageal atrial pacing and cardiac resynchronization therapy

Abstract: Electric field of biventricular (BV) pacing, left ventricular (LV) electrode position and electrical interventricular desynchronization are important parameters for successful cardiac resynchronization therapy (CRT) in patients with heart failure, sinus rhythm and reduced LV ejection fraction. The aim of the study was to evaluate electric pacing field of transesophageal left atrial (LA) pacing and BV pacing with 3D heart rhythm simulation. Bipolar right atrial (RA), right ventricular (RV), LV electrodes and multipolar hemispherical esophageal LA electrodes were modeled with CST (Computer Simulation Technology, Darmstadt). Electric pacing field were simulated with bipolar RA and RV pacing with Solid S (Biotronik) electrode, bipolar LV pacing with Attain 4194 (Medtronic) electrode and bipolar LA pacing with TO8 (Osypka) esophageal electrode. 3D heart rhythm model with esophagus allowed electric pacing field simulation of 4-chamber pacing with bipolar intracardiac RA, RV, LV pacing and bipolar transesophageal LA pacing. The pacing amplitudes were 3V RA pacing amplitude, 50V LA pacing amplitude, 1.5V RV pacing amplitude and 3V LV pacing amplitude with 0.5ms pacing pulse duration. The atrioventricular delay between RA pacing and BV pacing was 140ms atrioventricular pacing delay and simultaneous RV and LV pacing. Electric pacing fields were simulated during the different pacing modes AAI, VVI, DDD, DDD0V and DDD0D pacing modes. Electric pacing field of RA, RV and LV pacing in combination with LA pacing may additional useful pacing mode in CRT non-responders.

Keywords: Cardiac resynchronization therapy, electrical field, biventricular stimulation, 3D modeling, computer simulation technology, esophageal electrode, transesophageal atrial pacing

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1 Introduction

The development of innovative types of electrodes and further development of existing products account for a large part of the resulting costs for a company. With the help of suitable software, changes of the constructions can be recorded and certain simulations, e.g. the occurrence of interactions in the electric field, can be carried out before the actual prototyping. The aim of the study was to model different pacing and ablation electrodes and to integrate them into the Offenburg heart rhythm model (HRM) [1] for the static and dynamic simulation of CRT with transesophageal atrial pacing using the CST STUDIO SUITE® (CST Computer Simulation Technology AG, Darmstadt) [2].
2 Methods

The modeling and simulation was performed with the simulation software CST (Computer Simulation Technology, Darmstadt). Based on the technical manuals of the pacemaker manufacturers Medtronic and Biotronik, bipolar electrodes (Solid S) [3] for the right atrium and the right ventricle likewise the bipolar electrode (ATTAIN OTW) [4] for the left ventricle were modeled. For the left atrium the bipolar eight-pole esophageal probe TO8 from Osypka [5] was modeled. The electrodes were integrated into the heart rhythm model for the simulation of the E-field during biventricular pacing (see Figure 1, 2, 3).

3 Results

The applied CRT with transesophageal atrial pacing at the right and left atrium were performed simultaneously with an amplitude of 3V at the right atrium electrode and with 50V at the esophageal probe with a pulse width of 0.5 ms. The right ventricular and left ventricular pacing were performed simultaneously with an amplitude of 3V at the left ventricular electrode and with 1.5V at the right ventricular electrode with a pulse width of 0.5ms. The intracardiac far-field pacing potentials measured with a distance of 1mm from the electrode tips were in RA electrode 1.104V, in RV electrode 0.703V and in LV electrode 1.32V. The transesophageal far-field pacing potential measured with a distance of 10mm from the esophageal electrode tip was in LA electrode 6.076V (see Figure 4).
4 Discussion

Costet and Co-workers evaluated the relationship between electrical and electromechanical activation mapping in all four heart chambers during sinus rhythm and LV pacing with EnSite cardiac mapping system [6].

The 3D heart rhythm and esophagus model with integrated RA, LA, RV and LV pacing electrodes allow the evaluation of electrical pacing and sensing fields in one, two, three and four heart chamber pacing with static and dynamic simulation of different pacing mode. The new heart rhythm and esophagus model offers new insights into the electrical cardiac propagation and activation mapping. Heart rhythm model simulation with transesophageal atrial pacing allows evaluation of electric pacing fields in AAI, VVI, DDD, DDD0V and DDD0D pacing modes. Electric pacing field of RA, RV and LV pacing in combination with LA pacing may additional useful temporary pacing mode in CRT non-responders.

Author Statement

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References