His-Optimized Cardiac Resynchronization Therapy (HOT-CRT) in a subcutaneous ICD patient: first-in-human case report

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Abstract

Recent developments in arrhythmology have enabled the use of new devices, such as subcutaneous implantable cardioverter-defibrillators (s-ICD), and the comeback of older strategies, such as His-Bundle pacing (HBP) in clinical practice, alongside the use of thoroughly proven therapies such as cardiac resynchronization therapy (CRT), e.g. with His-Optimized CRT (HOT-CRT). However, interplay between these new and older techniques is not always clear. We report the first-in-human case of biventricular pacemaker (CRT-P) implantation with HOT-CRT in an s-ICD patient. Paced QRS morphology was similar to the spontaneous morphology, albeit shorter. Correct QRS identification by the s-ICD was confirmed both intra-procedurally and post-procedurally.

Introduction

Recent developments in the field of cardiac arrhythmology have enabled the use of new devices, such as subcutaneous implantable cardioverter-defibrillators (s-ICD), which have proved to be non-inferior to transvenous ICDs[1], while potentially avoiding vascular and transvenous (TV) lead extraction-related complications. Furthermore, clinical practice has seen a comeback of older strategies, such as His-Bundle pacing (HBP), first described in 1970[2], which guarantees physiological stimulation of the ventricles by using the intrinsic cardiac conduction system. Recent meta-analyses have proven its safety and potential superiority to conventional right ventricular pacing (RVP)[3]. These novel techniques have been implemented in clinical practice alongside the use of thoroughly-corroborated electrical therapies, such as cardiac resynchronization therapy (CRT), which is a landmark therapy for heart failure (HF) with reduced left ventricular (LV) ejection fraction (LVEF)[4], i.e. HFrEF, particularly in the context of HF with a high expected percentage of RVP[5]. Lately, His-Optimized CRT (HOT-CRT), in which HBP is sequentially followed by LV pacing (LVP), has been used in order to optimize CRT by further narrowing the paced QRS (pQRS) duration in the case of intra-ventricular conduction delay (IVCD)[6].

However, the interplay between these newer and older therapeutic strategies is not always clear, especially between the use of s-ICD and pacing devices. Indeed, data from a sub-study of the Multicenter Automatic Defibrillator Implantation Trial (MADIT-II trial) suggest that only a fraction (i.e. 5.2%) of post-myocardial infarction patients with reduced LVEF develop the need for permanent pacemaker (PPM) or CRT implantation over a follow-up of 20 months, thus making them appropriate candidates for s-ICD implantation.[7]. However, considering the current prevalence of HFrEF[8] and the widespread use of s-ICDs[4], the correct pacing

approach in these patients is still debated. We report the first-in-human case of biventricular PPM (CRT-P) implantation with HOT-CRT in an s-ICD patient.

Case report

A 49-year-old male patient affected by ischemic heart disease leading to HFrEF and with a history of two episodes of out-of-hospital resuscitated sudden cardiac arrest (SCA) underwent s-ICD implantation by means of an EMBLEM MRI system (Boston Scientific, Massachusetts, United States). Eight months after s-ICD implantation, the patient complained of fatigue and inconstant dyspnea on moderate effort. Beta-blocker therapy had been withdrawn months earlier, owing to symptomatic sinus bradycardia. ECG showed profound sinus bradycardia with heart rate (HR) 38 bpm, PR interval of 200 msec and aspecific IVCD with spontaneous QRS (sQRS) 115 msec. Echocardiography revealed LVEF 35%, which was unaltered from 8 months before. Coronary angiography with intra-vascular ultrasound imaging excluded coronary lesions requiring invasive treatment. Continuous ECG monitoring confirmed profound sinus bradycardia with minimum HR 34 bpm and revealed episodes of II degree Mobitz type 2 AVB, requiring PPM implantation.

Considering the need for CRT[4], we chose to perform CRT-P with HOT-CRT implantation and preservation of the s-ICD, rather than biventricular ICD (CRT-D) implantation and subsequent s-ICD extraction. This approach was selected for three reasons: to reduce costs; to reduce generator size and therefore the risk of pocket-related complications, owing to the small amount of subcutaneous pectoral tissue present; and in accordance with patient preference. HBP with RVP lead implantation on the His Bundle was chosen in order to guarantee correct pQRS recognition by the s-ICD, with possible bail-out to ICD lead implantation in the case of unsatisfactory intraprocedural pQRS identification by the s-ICD.

After creation of a left pre-pectoral pocket and acquisition of left subclavian vein access, an active-fixation bipolar HBP lead (Ingevity MRI 7842 59 cm, Boston Scientific) was implanted by means of SSPC3 delivery (Boston Scientific) and a pace-mapping approach, obtaining non-selective capture. A quadripolar LV lead (Acuity X4 Straight, Boston Scientific) was then implanted, after coronary sinus (CS) angiography, in an antero-lateral branch of the CS (**Fig. 1**). Correct pQRS identification by the s-ICD was established by means of intraprocedural device interrogation, and was confirmed for HBP, LVP (LV1-LV2 configuration) and biventricular pacing (BiVP), i.e. HBP with sequential LVP after 20 msec. BiVP yielded a pQRS morphology similar to that of the sQRS, albeit shorter, i.e. pQRS 100 msec vs. sQRS 115 msec (**Fig 2, Fig. 3**). A passive-fixation right atrial lead (Fineline II Sterox Atrial J Model 4480 52 cm, Boston Scientific) was implanted and the leads were then fixed to the muscle plane with silk sutures. The leads were connected to the CRT-P generator, which was placed in the pocket. Vicryl 0 and 3-0 sutures were used to close the pocket. Electrical parameters were optimal, with capture thresholds below 1 V @ 0.4 msec. The device was programmed in DDD-R 60 bpm mode, with an AV interval 150 msec, and LVP configuration LV1-LV2 with a pacing delay of 20 msec after HBP, obtaining 100% BiVP. The bipolar-to-unipolar safety switch was turned off in order to avoid accidental activation of the unipolar configuration, which is contraindicated in the presence of an s-ICD. To avoid under-sensing of the CRT-P during ventricular arrhythmias (which could lead to inappropriate pacing and therefore suboptimal recognition of arrhythmias by the s-ICD), the autosensing algorithm (Automatic Gain Control) was activated. After the procedure, QRS recognition by the s-ICD was tested again, both by device interrogation and by the automated s-ICD screening tool (AST, Boston Scientific), both of which confirmed correct pQRS identification in both the supine and standing positions (**Fig. 3**).

Discussion

CRT remains a landmark therapy for HFrEF[4], particularly in the context of HF with a high expected percentage of RVP[5]. HOT-CRT was recently shown to be safe and potentially superior to conventional CRT

in the case of IVCD[6]. To our knowledge, ours is the first-in-human case of TV CRT-P implantation in an s-ICD patient, and also the first case of HOT-CRT in an s-ICD patient to be described in the literature. As already mentioned, this approach was chosen in order to reduce both costs and generator size, and to respect patient preferences, while ensuring possible bailout to conventional CRT-D during implantation in the event of suboptimal pQRS recognition by the s-ICD.

Many cases of the concomitant use of s-ICD and TV-PPM[9,10], epicardial PPM[11], epicardial CRT-P[12], and HBP devices[13] have been reported. In addition, there are numerous case-reports of the associated use of leadless PPM (LP) and s-ICD[14]. Indeed, Boston Scientific has developed a hybrid LP (EMPOWER) plus s-ICD (EMBLEM) system that is able to provide anti-bradycardia pacing and anti-tachycardia pacing together with shocks[15], and which is currently under investigation (Modular ATP trial, NCT04798768). In one case, a completely leadless CRT-D system was created by using an LP (Medtronic Micra TPS) combined with a WiSE-CRT system (EBR Systems, Sunnyvale, CA) and an s-ICD[16]. When conventional ICD lead implantation has proved impossible, other strategies have been adopted, such as the use of a hybrid subcutaneous and trans-venous CRT-D approach using the Medtronic 6996SQ Finger subcutaneous array lead[17], and ICD lead implantation in the coronary sinus in the context of CRT-D[18]. In one case, an s-ICD with a right parasternal electrode plus an AAI PPM was implanted[19], and in another case, owing to multiple ventricular lead fractures causing inappropriate shocks, an s-ICD was implanted and the existing TV-ICD was reprogrammed as an AAI pacemaker[20].

However, a few cases of device-device interaction between the s-ICD and both the TV[21] and epicardial PPM[22]have been described. To avoid this eventuality, we chose HOT-CRT as the pacing strategy; this yielded a pQRS which was similar to the sQRS, albeit shorter. Moreover, we ensured correct pQRS recognition by the s-ICD both intra-procedurally, with the possibility of bailout to conventional CRT-D during implantation, and post-procedurally, by means of both s-ICD interrogation and the AST in multiple body positions. Of note, screening by means of the AST has been tested in patients with PPM[23], HBP[13] and CRT[24] devices, with variable results. One group found an association between s-ICD screening and response to CRT[25], which may have been due to the fact that correct pQRS identification by the s-ICD might depend on the pQRS being narrow, therefore predicting better outcomes of CRT.

In conclusion, considering that potentially up to 5.2% of s-ICD patients develop a need for permanent pacing[7], we demonstrated that CRT-P, and particularly HOT-CRT implantation in an s-ICD patient, was both feasible and safe, yielding optimal electrical parameters and correct pQRS identification by the s-ICD both intra- and post-procedurally. In the event of suboptimal intra-procedural pQRS recognition by the s-ICD, bailout to conventional CRT-D is a possibility.

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Figures

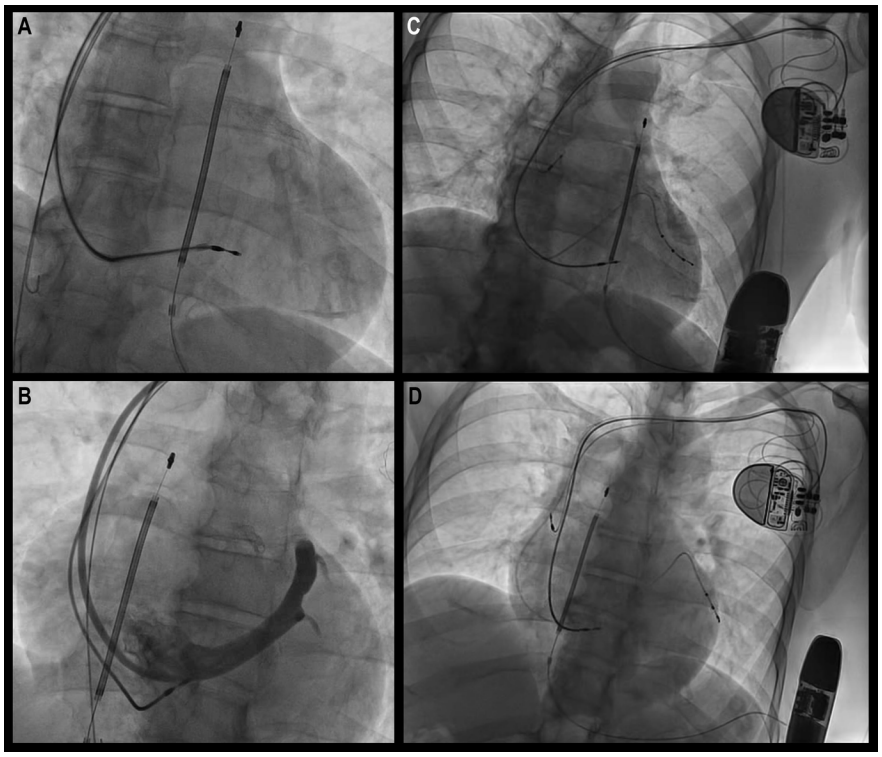

Figure 1 Biventricular pacemaker (CRT-P) with His-Optimized Cardiac Resynchronization Therapy, i.e. His Bundle Pacing (HBP) lead plus conventional left ventricular (LV) lead in coronary sinus (CS) in a subcutaneous implantable-cardioverter defibrillator patient. **A** : HBP lead implantation with SSPC3 delivery (Boston Scientific).**B** : CS angiography with selection of antero-lateral venous branch of CS as target vessel for LV lead implantation. **C** and**D** : Right anterior oblique and left anterior oblique views, respectively, of the whole CRT-P system implanted.

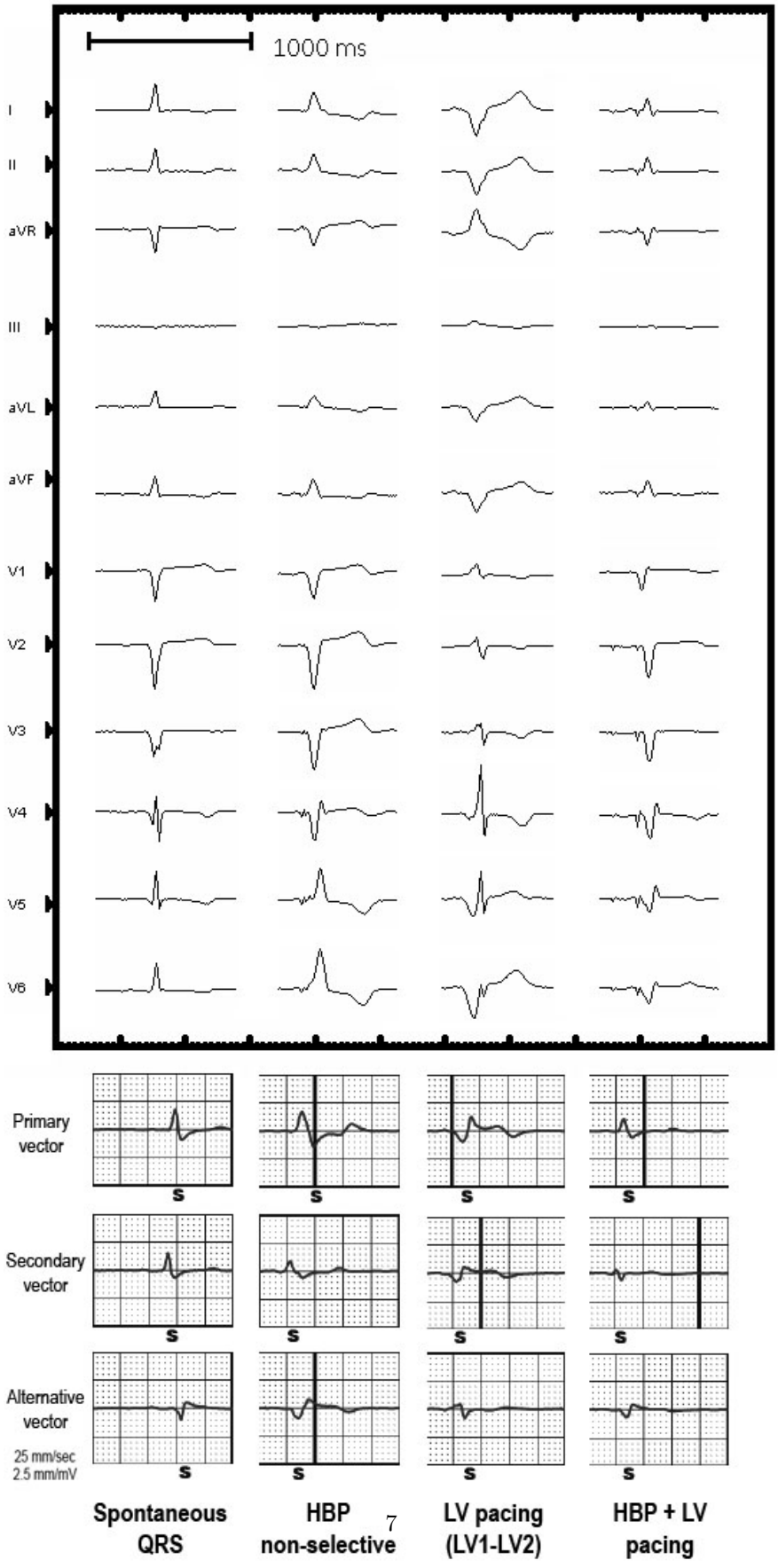

Figure 2 From the left to the right column, ECG strips (above) and subcutaneous implantable cardioverter-defibrillator (s-ICD) vector strips (below) of spontaneous QRS, non-selective His-Bundle-paced (HBP) QRS, left ventricular (LV)-paced QRS in the configuration LV1-LV2 (final configuration chosen for programming), and His-Optimized Cardiac Resynchronization Therapy, i.e. biventricular HBP + LV paced QRS (with a delay of 20 msec between HBP and LV pacing), respectively. As shown in the s-ICD vector strips below, the paced QRS complex was correctly identified by the s-ICD in all above-mentioned configurations.

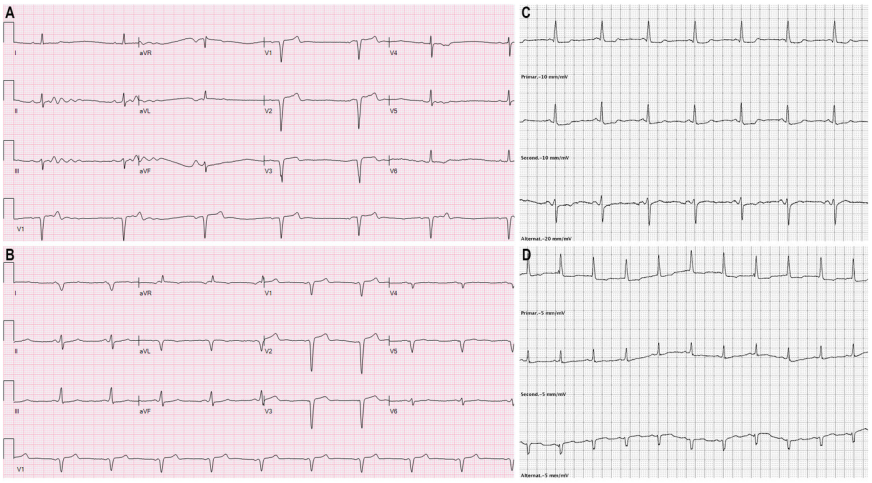

Figure 3 12-lead ECG strips at 25 mm/sec before (**A**) and after (**B**) biventricular pacemaker (CRT-P) implantation with His-Optimized Cardiac Resynchronization Therapy in a subcutaneous implantable cardioverter-defibrillator (s-ICD) patient. Paced QRS complexes were smaller (100 msec) than spontaneous ones (115 msec). Vector ECG strips (Primary, Secondary and Alternative) from the Automated Screening Tool for s-ICD (Boston Scientific) are shown in both the supine (**C**) and upright (**D**) positions, with correct paced QRS identification in both cases.