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Atrial electrogram quality in single-pass defibrillator leads with floating atrial bipole in patients with permanent atrial fibrillation and cardiac resynchronization therapy

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ABSTRACT

Many patients receiving cardiac resynchronization therapy (CRT) suffer from permanent atrial fibrillation (AF). Knowledge of the atrial rhythm is important to direct pharmacological or interventional treatment as well as maintaining AV-synchronous biventricular pacing if sinus rhythm can be restored. A single pass single-coil defibrillator lead with a floating atrial bipole has been shown to obtain reliable information about the atrial rhythm but has never been employed in a CRT-system. The purpose of this study was to assess the feasibility of implanting a single coil right ventricular ICD lead with a floating atrial bipole and the signal quality of atrial electrograms (AEGM) in CRT-defibrillator recipients with permanent AF.

Methods and results: Seventeen patients (16 males, mean age 73 ± 6 years, mean EF $25 \pm 5\%$) with permanent AF and an indication for CRT-defibrillator placement were implanted with a designated CRT-D system comprising a single pass defibrillator lead with a floating atrial bipole. They were followed-up for 103 ± 22 days using remote monitoring for AEGM transmission. All patients had at least one AEGM suitable for atrial rhythm diagnosis and of 100 AEGM 99% were suitable for visual atrial rhythm assessment. Four patients were discharged in sinus rhythm and one reverted to AF during follow-up.

Conclusion: Atrial electrograms retrieved from a single-pass defibrillator lead with a floating atrial bipole can be reliably used for atrial rhythm diagnosis in CRT recipients with permanent AF. Hence, a single pass ventricular defibrillator lead with a floating bipole can be considered in this population.

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1. Background

Cardiac resynchronization therapy (CRT) has been shown to reduce morbidity and mortality in symptomatic heart failure patients on optimal medical therapy with left bundle branch block and a left ventricular ejection fraction $\leq 35\%$ [1,2]. The bulk of evidence has been generated in patients in sinus rhythm.

Up to one third of heart failure patients are in persistent or permanent atrial fibrillation (AF). There is evidence that these

patients do benefit from CRT if intrinsic atrioventricular (AV) nodal conduction is completely blocked by AV-node ablation [3,4] and therefore most CRT candidates with permanent AF receive CRT today [5,6].

Since atrial stimulation is not possible in permanent AF, many operators only implant a right and a left ventricular lead, thereby evading the risk of atrial lead placement like dislodgements. Knowledge of the atrial rhythm may be nonetheless important, since some patient will revert to sinus rhythm under CRT [7]. Any sort of atrial sensing then allows for AV-synchronous biventricular pacing. Furthermore, with regular remote monitoring transmission of atrial intracardiac electrograms (AEGM), an early appreciation of sinus rhythm may be facilitated [8].

Recently, a single-pass single-coil defibrillator lead with a

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floating atrial bipole has been shown to obtain reliable information of the atrial rhythm in patients receiving a single chamber ICD without CRT [9].

The purpose of this study was to assess the signal quality of AEGM in CRT-D recipients with permanent AF implanted with a single coil right ventricular ICD lead with a floating atrial bipole. AEGMs were analysed both as received from the programming device and as transmitted by remote monitoring.

2. Methods

2.1. Study population

Between August 2013 and June 2014 17 patients with permanent atrial fibrillation, heart failure NYHA class III/IV, QRS width ≥ 120 ms and a mean ventricular rate ≤ 60 bpm at rest or ≤ 90 bpm at exercise or pacemaker dependency as a result of planned AV junction ablation [5,10], and left ventricular ejection fraction $\leq 35\%$ were implanted with a CRT-D in 3 sites in Germany and Switzerland. Local ethics review committees at each center approved the study and informed consent was obtained from all participants. The trial was funded by Biotronik SE (Berlin/Germany) and registered at [ClinicalTrial.gov](https://clinicaltrials.gov) number, NCT01930605.

2.2. Device specification

Patients received a designated CRT-D device (Biotronik Lumax 640/740 DX, Biotronik SE, Berlin, Germany) with a specific 4-fold preamplifier for the atrial sensing signal and no atrial pacing capability. This device was connected to a single-coil right ventricular defibrillation lead with two floating atrial ring electrodes 15 or 17 cm proximal to the RV tip (Biotronik Linx Smart S DX, Biotronik SE, Berlin, Germany). The devices were equipped with remote monitoring (Biotronik Home Monitoring[®]) with the ability to transmit one three-channel IEGM per day either scheduled by programming or if a spontaneous episode of arrhythmia occurred. The devices record the “atrial burden” (AB) as the percentage of the time in which the atrial rate is above 200 beats per minute, and transmit the result of the last 24 h by Home Monitoring. AB figures were imported from the HM service center and averaged for the periods from implantation to the 1 month follow-up, and from the 1 month to the 3 months follow-ups.

2.3. Implantation and follow-up

Implantations were performed according to institutional standards. All patients received the Linx Smart S DX right ventricular lead and a transvenous left-ventricular lead, but no separate atrial lead. Leads were connected to a designated CRT defibrillator with optimized filter settings for atrial signal processing. The devices were programmed to the VVI or VVIR (for patients with bradycardic AF) pacing mode but atrial IEGM acquisition and transmission was activated in all patients. Study participants were followed-up for three months.

AEGMs were retrieved by device interrogation at implantation, discharge, after 1 month and after 3 months. Furthermore, periodic transmission of AEGMs by Home Monitoring was scheduled on days 3 and 20 after discharge from hospital, and every 20 days after the one-month follow-up. AEGMs were also analysed when an event triggered transmission was available (theoretically numerous, but the maximal real number was 3 during the three-month study period). Biotronik Home Monitoring[®] does allow for the transmission of periodic AEGMs only when the patient is near the transmission station at the time of EGM recording, as no memory possibility is available in the system. This explains why

these periodic EGMs are not available in all the patients all of the time points. For all AEGMs, whether retrieved by programmer or transmitted by Home Monitoring, two investigators independently decided whether or not it was possible to judge the atrial rhythm, and which atrial rhythm was present. These investigators were blinded to other potentially available ECG or electrogram tracings of the respective patients.

2.4. Endpoints

The first endpoint was the percentage of patients with at least one AEGM suitable for atrial diagnosis within the study period of three months. The second endpoint was the proportion of AEGM suitable for atrial diagnosis and the third the number of patients found in sinus rhythm based on the AEGM. During follow-up visits, the AEGM diagnosis was confirmed by 12-lead ECGs.

3. Results

The study population consisted of 17 patients, predominantly male (94%), with a mean age of 73 ± 6 years, and a mean EF of $25 \pm 5\%$. They were followed for 103 ± 22 days. The mean duration of AF before implantation was 43 ± 40 months and 5 patients underwent scheduled AV-node ablation (Table 1). During the follow-up no antitachycardia therapies for ventricular tachyarrhythmias were delivered by the ICD.

3.1. Atrial EGM

In the 17 remaining patients, 100 AEGM (2–11 per patient) were analysed. All patients had at least one AEGM that was suitable for atrial diagnosis. 99 out of 100 (99%) AEGM allowed for rhythm diagnosis (Figs. 1 and 2).

Four patients (patients 1/3/4/15, 23%) were discharged in sinus rhythm after cardioversion during defibrillation threshold testing. All of them had sinus rhythm confirmed in a first scheduled Home Monitoring transmission 3 days after discharge. After one month, 3 of these patients were still in sinus rhythm and another converted spontaneously to sinus rhythm. The rhythm diagnosis of the AEGM was congruent with the rhythm found during FU using a 12 lead ECG in all cases. However, signal amplitudes in some patients were too low and variable to be used for automated algorithms. This explains why the burden is not 100% in certain patients who were always in AF on every single documented ECG or AEGM.

Table 1
Patient demographics.

Patient characteristic	
Male	16 (94%)
Age (years)	73 ± 6
LVEF (%)	25 ± 5
AF duration (months)	43 ± 40
Mean heart rate (bpm)	79 ± 23
QRS duration (ms)	160 ± 27
Left bundle branch block (n)	13 (76%)
NYHA class II/III/IV	0/16/1
AV-node ablation	5 (29%)
Ischemic cardiomyopathy	7 (41%)
Primary preventive indication	17 (100%)
Hypertension	16 (94%)
Oral anticoagulation	15 (88%)
Amiodarone	4 (24%)
Beta-Blocker	14 (82%)

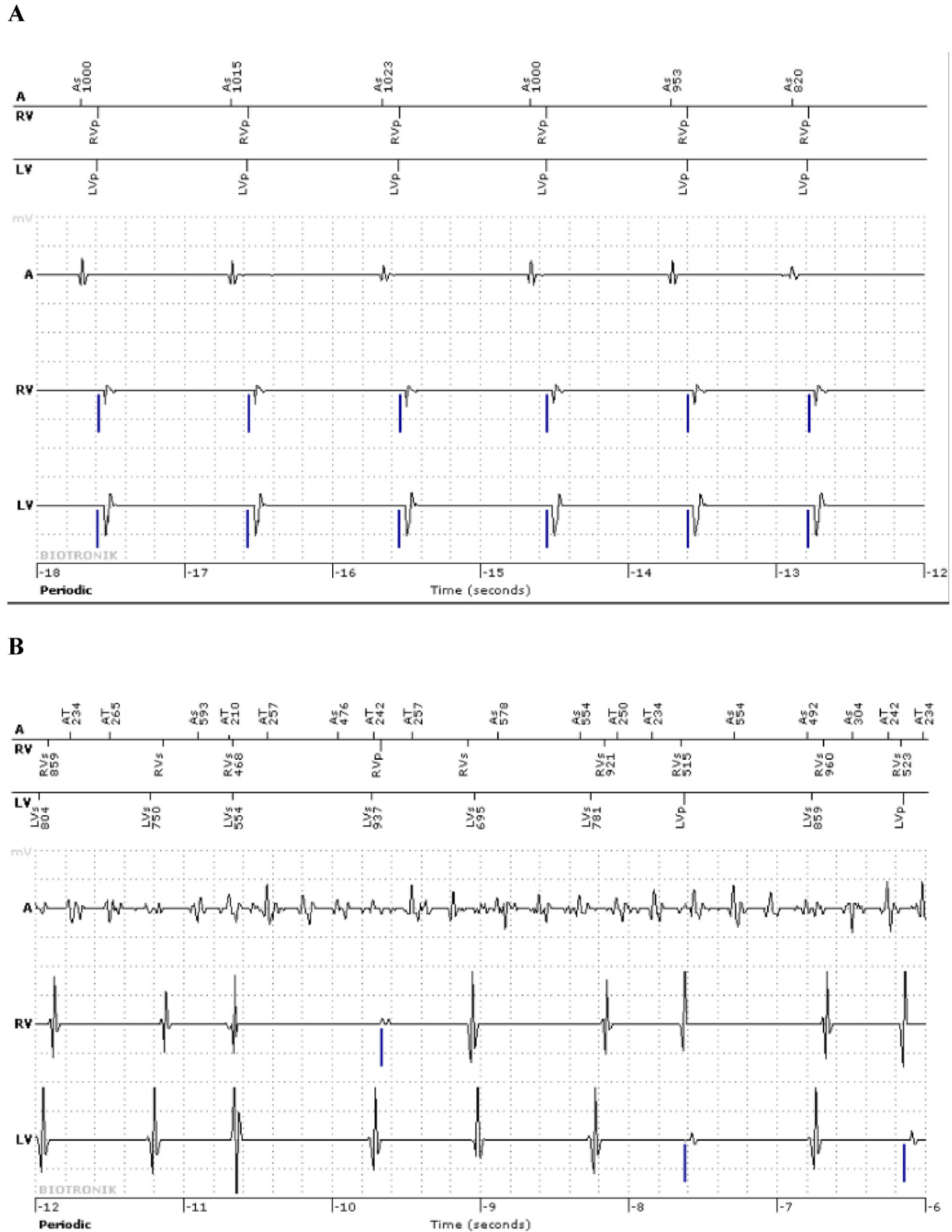


Fig. 1. Examples of three channel EGMs transmitted by Home Monitoring in a patient at 63 days (A) and 83 days (B) after implantation. A: correct atrial sensing of sinus rhythm and AV sequential biventricular pacing, B: The same patient 20 days later, in atrial fibrillation with loss of biventricular pacing and the need for intervention.

4. Discussion

The main finding of this study is that a single-pass defibrillator

lead with a floating atrial bipole can be safely implanted and used for visual diagnosis of the atrial rhythm in patients receiving a CRT defibrillator system. AEGM quality allowed for adequate rhythm

diagnosis in 99% of episodes. The study for the first time collected data on atrial sensing capabilities of single-pass defibrillator leads connected to a dedicated CRT defibrillator.

Previously, it has been shown that atrial rhythm detection via a floating atrial bipole can be safely employed in patients receiving a VDD defibrillator [9,11]. Furthermore, it was demonstrated that the sensitivity and specificity for detection of ventricular tachyarrhythmias and discrimination of supraventricular tachyarrhythmias were not different from a conventional dual chamber ICD [9]. The present study investigated its performance in a CRT heart failure population with pre-existing permanent AF. In our study, the AEGM retrieved from the atrium were used for visual diagnosis of the atrial rhythm only. It is important to point out that the atrial EGM could not be reliably used for correct annotation in the device's marker channel in the studied cohort of patients with advanced atrial remodelling due to long-lasting AF. This may be due to the fact that changing activation wave fronts during atrial fibrillation together with the slightly different location of the floating atrial bipole during cardiac contraction and different filling states cause greater differences in the atrial signal and accounts for more over- or undersensing. Whether the signals from the floating atrial bipole can be used for automated diagnosis or for detection enhancement algorithms with modified signal processing capabilities, needs to be further studied. Currently, the atrial channel should not be used for automated detection enhancement algorithms.

Many patients who require CRT are in long-standing AF and a significant proportion later requires ablation of the atrioventricular node in order to achieve sufficient biventricular pacing [12]. Many operators will not implant an atrial lead since there is a risk of dislodgement and atrial pacing or AV-synchronization is impossible in this population. Our study shows that the use of the studied lead allows for atrial rhythm diagnosis without an additional atrial lead. In fact, after a one month follow-up 4 of the patients with perceived permanent AF were in sinus rhythm and AV-synchronous pacing based on the atrial signal in sinus rhythm was possible. In these patients, remote monitoring may be particularly helpful as recurrence of atrial fibrillation may prevent effective biventricular stimulation and mandate antiarrhythmic therapy or AV-node ablation [8].

It is important to point out that the system used in this study contains an amplifier for the atrial channel to compensate for the smaller signal amplitudes of floating ring leads. We did not test whether atrial sensing would be possible without the amplifier, but experience from VDD pacemakers suggests that a more sensitive input stage is essential.

AV sequential pacing with floating ring VDD-electrodes has become less popular in the field of bradycardia pacing since atrial pacing is not possible in case of sinus node disease. However, it has been shown, that in a population with different degrees of AV-block less than 5% need to receive an additional atrial lead after a mean follow-up of 3.8 years [13].

Many operators will not implant any atrial lead in patients receiving a CRT-D system who are in permanent atrial fibrillation. Since the single-pass "DX" lead is not thicker than a comparable standard lead and single coil defibrillator leads are the current gold-standard, there is no obvious medical disadvantage compared to a conventional system without atrial lead. On the other hand it gives the few patients who may revert back to sinus rhythm the benefit of AV-sequential biventricular pacing.

Atrial pacing will not be possible with the investigated system. However, atrial pacing may be disadvantageous and is suggested to be avoided in the CRT population since it increases intraatrial and consequently AV dyssynchrony [14].

5. Limitations

One limitation of our study is the small sample size of only 17 patients. In terms of the actual implantation procedure there were no signs of specific problems with the novel system.

Furthermore, all atrial EGM were analysed visually and were not used for automated annotation. This carries a certain risk of subjective interpretation of the electrograms.

6. Conclusion

Atrial electrograms retrieved from a single-pass defibrillator lead combined with a dedicated CRT defibrillator can be reliably used for atrial rhythm diagnosis, e.g. after transmission through a remote monitoring system. The system can be used for monitoring the atrial rhythm in CRT recipients with long-standing atrial fibrillation without the need for an atrial lead.

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Conflicts of interest

Dr. Sticherling has received lecture honoraria/travel support from Biotronik, Boston Scientific, Medtronic, LivaNova, and St. Jude Medical; has been a consultant to Biotronik, Boston Scientific, and Medtronic; and has performed clinical studies supported by Biotronik, Medtronic, Boston Scientific, and St. Jude Medical.

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