Atrial pacing and sensing characteristics in heart failure patients undergoing cardiac resynchronization therapy

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Abstract Patients with heart failure and sinus rhythm undergoing cardiac resynchronization therapy (CRT) require the proper detection of atrial signals and reliable atrial pacing for AV-synchronous ventricular pacing. The study aim was to compare atrial pacing and sensing characteristics in patients with transvenous CRT and patients with standard pacing indications.

Methods The study group consisted of 31 heart failure patients with depressed left ventricular function and bundle branch block, and the control group of 124 patients with dual-chamber pacemakers because of standard pacing indications. The bipolar steroid-eluting atrial screw-in lead Tendril DX 1388 T (St. Jude Medical) was implanted and connected to pulse generators that provide similar diagnostic features. The unipolar pacing threshold at 0.4 ms duration, bipolar sensing threshold, and unipolar pacing impedance were determined at implantation and after 1, 3, and 6 months.

Results At implantation, the atrial pacing threshold was significantly higher in the CRT group than in the control group, 1.07 ± 0.99 V versus 0.74 ± 0.36 V (P < 0.01). Similar pacing thresholds were recorded after 1 month. The pacing threshold in the CRT group was significantly higher at 1.46 ± 0.92 V after 3 and 1.50 ± 0.94 V after 6 months (control group: 0.96 ± 0.25 V at month 3; 0.98 ± 0.32 V at month 6; P < 0.05). Sensing threshold was similar at implantation with 2.36 ± 1.87 mV in the CRT and 2.54 ± 0.78 mV in the control group. The sensing threshold in the CRT group decreased to 1.64 ± 0.86 mV after 3 and to 1.71 ± 0.71 mV after 6 months

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and was significantly lower compared with the control group (2.16 ± 0.57 mV at month 3; 2.27 ± 0.98 mV at month 6; \( P < 0.05 \)). At implant, the atrial pacing impedance was not different between the two groups with 443 ± 156 ohms in the CRT and 416 ± 116 ohms in the control group. During follow-up, the impedance became significantly lower in the CRT group compared with the control group (404 ± 84 ohms versus 452 ± 101 ohms at month 3; \( P < 0.05 \)).

**Conclusions** Compared with patients with standard pacing indications, CRT recipients have less good electrical characteristics in the atrium. Atrial pacing and sensing function should be closely monitored in CRT patients.

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### Introduction

A specific finding in heart failure patients with impaired left ventricular function and bundle branch block is electrical and mechanical asynchrony [1,2]. Treatment for these patients is cardiac resynchronization therapy (CRT) usually realized by transvenous left ventricular or bi-ventricular pacing. Transvenous CRT significantly improves the well-being and prolongs exercise tolerance in these patients [3,4].

Effective transvenous CRT requires, in patients with sinus rhythm, the proper detection of atrial signals and reliable atrial pacing, which is mandatory for AV-synchronous ventricular pacing. Until now, pacing and sensing thresholds of atrial leads were mainly studied in patients who received an atrial pacing lead for standard pacing indications [5–8]. In patients undergoing CRT the impaired left ventricular function may influence left ventricular pacing threshold [9].

The aim of the study was to assess the atrial pacing and sensing function in patients undergoing transvenous CRT and to compare these findings with patients who had received a dual-chamber pacemaker for bradycardia.

### Methods

#### Patients

The study group consisted of 31 heart failure patients in New York Heart Association (NYHA) functional class III or IV who had depressed left ventricular systolic function with an ejection fraction < 35% and bundle branch block with QRS duration of 154 ± 18 ms. Their mean age was 61 ± 13 years and 20 (65%) patients were male. The target site for the left ventricular pacing lead was a lateral or postero-lateral tributary of the coronary sinus. The coronary sinus lead was connected to the dual-chamber pacemaker Affinity DR (St. Jude Medical (SJM), Sylmar, USA) in eight and to the bi-ventricular pacing device Frontier 3 × 2 Model 5510 (SJM) in 23 patients. At discharge, atrial sensitivity was programmed to a bipolar configuration at 0.5 mV.

The control group consisted of 124 patients who received the dual-chamber Affinity D/DR because of standard pacing indications and no evidence of severe symptomatic heart failure. The patients were enrolled in a multi-centre clinical study for the evaluation of a steerable stylet. Mean age was 69 ± 14 years and 68 (55%) patients were male. Indications for permanent pacing were sinus node disease or sinus and atrioventricular (AV) disease in 82, advanced AV-block in 39, and other indications in three patients.

#### Atrial pacing lead

All patients received the bipolar atrial screw-in pacing lead Tendril DX 1388 T (SJM). The lead uses a 2-mm long screw for active fixation. The electrode surface material consists of titanium—nitride alloy with an electrode surface area of 8.5 mm² for the tip and of 34 mm² for the ring electrode. There is 1 mg dexamethasone in the electrode tip, which elutes after lead implantation. The distance between the two electrodes is 10 mm. All leads were implanted in the right atrial appendage.

#### Measurements

All pacemaker models provided the same features for the measurement of pacing and sensing thresholds, and pacing impedance. Measurements were performed at implantation and after 1, 3, and 6 months. At each visit, unipolar pacing threshold was determined at 0.4 ms duration, bipolar sensing threshold, and unipolar pacing impedance. The first two parameters were measured using semi-automatic function tests and the pacemaker
calculated the pacing impedance itself on interrogation. The findings of the CRT patients were compared with the patients with standard pacing indications.

Statistics

Continuous variables are expressed as mean ± 1 standard deviation. Statistical comparisons were performed with the two-tailed paired or unpaired student’s t-test as indicated. P values <0.05 were considered to be statistically significant.

Results

Atrial pacing threshold

The atrial pacing threshold was in the CRT patients at implantation with 1.04 ± 0.99 V significantly higher than in the control group with 0.74 ± 0.36 V (P < 0.01; Fig. 1). Similar pacing thresholds were recorded after 1 month with a mean value of 1.29 V in the two groups. The pacing threshold in the control group decreased at the 3- and 6-month follow-up to 0.96 ± 0.25 and 0.98 ± 0.32 V, respectively. The pacing threshold in the CRT group increased to 1.46 ± 0.92 V after 3 and 1.71 ± 0.71 V after 6 months. The differences between the two groups became statistically significant again at months 3 and 6 (P < 0.05).

Atrial sensing threshold

Sensing threshold was similar at implantation with 2.36 ± 1.87 mV in the CRT and with 2.54 ± 0.78 mV in the control group (Fig. 2). The sensing threshold in the CRT group decreased to 1.64 ± 0.86 mV after 3 and to 1.71 ± 0.71 mV after 6 months and was significantly lower compared with the control group (P < 0.05). No CRT patient revealed during the follow-up visits any evidence of atrial undersensing.

Atrial pacing impedance

Atrial pacing impedance, at implantation in the two groups, was not different with 443 ± 156 ohms in the CRT and 416 ± 116 ohms in the control group (Fig. 3). During subsequent follow-up, impedance was significantly lower in the CRT group compared with the control group e.g. with 404 ± 84 ohms versus 452 ± 101 ohms after 3 months.

Discussion

Issues in transvenous CRT are the identification of patients who will respond to this therapy, the fixation of the pacing lead in a lateral tributary of the coronary sinus, and the correct pacing and sensing of the atrial lead [10,11]. The latter is mandatory for the vast majority of patients in sinus rhythm who only benefit from bi-ventricular pacing if the atrial signals are properly detected.
and are used to trigger the ventricular pacing pulse (VDD pacing mode).

In the present study the electrical atrial characteristics were assessed in CRT patients and compared with patients who had standard pacing indications. Both groups received the same steroid-eluting lead with active fixation. At implantation, pacing threshold was significantly higher in the CRT than the control group. Pacings thresholds in the CRT group remained elevated over the 6-month follow-up period. At the same time, CRT patients had lower sensing thresholds and lower pacing impedance. The results of the present study showed that CRT patients have worse electrical characteristics in the atrium compared with patients with standard pacing indications.

Pacing thresholds in the group with standard pacing indications were, in the present study, similar to the findings of previous investigators [5,12]. In addition, mean sensing threshold and atrial pacing impedance were, in the present study, in the range of other reports [7,12,13]. The higher pacing threshold in the CRT group was similar to the findings in patients with conventional pacing indications who had received pacing leads without steroid elution. For example, Wiegand et al. reported, in 68 patients with non-steroid-eluting pacing leads, chronic atrial pacing thresholds of 1.58 ± 0.71 V [12].

The exact mechanism of the less good atrial electrical characteristics in CRT patients remains unknown. Pacemaker patients with conventional pacing indications have lower atrial pacing impedance compared with that in the ventricle [14]. Moreover, lower ventricular pacing impedance was observed in pacemaker patients with severe cardiac diseases [15]. Secondly, a different electrode tissue interface and right atrial geometry in CRT patients may account for the lower atrial pacing impedance in combination with higher pacing and lower sensing thresholds.

After implantation of a left or biventricular pacing system the diagnostic pacemaker counters showed, in most CRT patients, dominant atrial sensing and little atrial pacing indicating that atrial sensitivity should be carefully programmed to avoid atrial undersensing [16]. The lower sensing threshold did not result in any adverse events in the present study, because the programmed setting of the bipolar atrial sensitivity still provided a sufficient safety margin. The atrial sensitivity was adjusted to detect also new onset of atrial fibrillation [12,17,18]. With respect to the pacing threshold, pacing with 2.5 V output at 0.4 ms pulse duration was feasible in most patients.

As a limitation, the present study only evaluated an atrial lead with active fixation and with local steroid elution. Previous studies demonstrated in patients with standard pacing indications that local steroid elution improves the electrical characteristics of screw-in pacing leads [5,6]. As a consequence, present-day screw-in pacing leads have similar atrial pacing and sensing thresholds compared with J-shaped tined pacing leads [8].

The clinical implications are that the patients with depressed left ventricular function and bundle branch block who undergo CRT may have higher atrial pacing thresholds at implantation and worse atrial electrical characteristics during follow-up compared with patients who have standard pacing indications. Atrial pacing and sensing function should be closely monitored in CRT patients. The pacemaker settings should be adjusted to take into account these findings so as to avoid potential malfunction.

Participants in the study group: Israel, Frankfur, Geiger, Hospital Oststadt Hannover, Kolditz, St. Elisabeth Hospital Essen, Runkel, Marien Hospital Bonn Schuchert, Ali Aydin and Gaby, Hamburg and Paul, Harefield.

References

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