Selecting Patients for Single-Lead DDD Pacing: Usefulness of Right Atrial and Ventricular Dimensions Assessed by Echocardiography

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Summary

Single-lead DDD pacing has been demonstrated to be a feasible alternative to conventional DDD pacing in properly selected patients. Recently, this technique has improved through the use of overlapping biphasic impulse (OLBI) stimulation; however, the percentage of loss of atrial capture is still relatively high, related to the distance of the free-floating electrodes to the right atrial wall. Since right atrial and right ventricular volumes and dimensions may be directly related to the distance between the free-floating electrodes and the right atrial wall, we studied the value of these echocardiographically assessed parameters to identify patients with low atrial pacing thresholds. In 16 patients with symptomatic third-degree (n = 11) and second-degree atrioventricular block (n = 5), a single-lead DDD pacing system was implanted. Lead lengths between tip and floating electrodes of 130 mm (n = 9) and 150 mm (n = 7) distance were selected using a standardized protocol. Patients were divided into two groups with respect to atrial OLBI pacing threshold during implantation: high (> 2 V, group A, n = 6) or low (≤ 2 V, group B, n = 9). Whereas group B patients had no significantly different ventricular and atrial dimensions as compared to group A patients, after correction for the leadlength, group B patients had significantly lower right atrial and right ventricular dimensions. Our findings suggest that pre-implantation echocardiography can identify patients suitable for single-lead DDD pacing. Consequently, there is the potential to define a predictor from echocardiography measurements and lead lengths for an optimal pacing threshold, and, thus for OLBI responders.

Key Words

Single-lead DDD pacing, overlapping biphasic impulse (OLBI) , echocardiography

Introduction

Single-lead DDD pacing offers potential benefits over conventional DDD pacing with respect to lower costs, ease of implantation, and reduction in complication rate, related to the absence of an additional atrial lead [1-5]. Recent studies have demonstrated that single-pass DDD pacing using overlapping biphasic impulse (OLBI) stimulation results in lower atrial pacing thresholds, although values are still relatively high [4,5]. Inability to achieve chronic atrial capture is reported to range from 19% to 24% [6-11]. Since the ability to pace the atrium is directly related to the distance from the free-floating electrodes to the right atrial wall, we studied the value of echocardiographically derived right atrial and right ventricular (RV) dimensions and volumes on atrial pacing thresholds in patients with single-lead DDD pacing using OLBI stimulation.

Materials and Methods

Patients

All 16 included patients (13 male, mean age 72 ± 9 years) had symptomatic third-degree (11 patients) and second-degree atrioventricular (AV) block (five patients) and normal sinoatrial function as assessed by intravenous atropine. Seven patients had known coronary artery disease. Informed consent was obtained from all patients before the procedure.

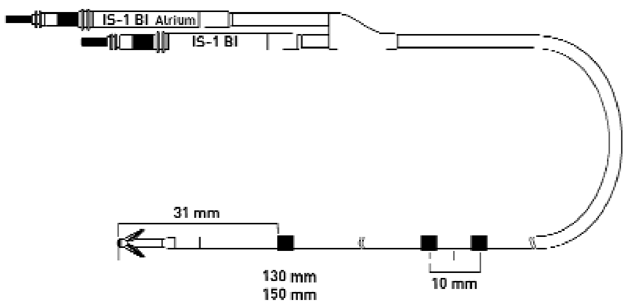

Figure 1. Single-lead SL 60/13-BP with 130 mm and SL 60/15-BP with 150 mm distance from the tip of the lead to the floating electrodes (Biotronik, Germany).

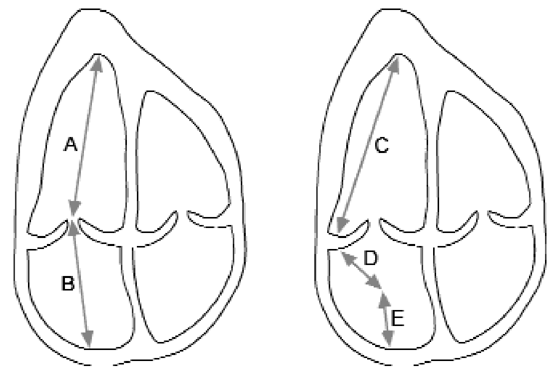

Figure 2. Definition of echocardiographic measured lengths of the right ventricle (RV) and the right atrium (RA). RA_{conv} = RA conventional, RA_{new} = roof to middle of the RA plus middle RA to lateral tricuspid valve origin, RV_{conv} = RV conventional, RV_{new} = distance of the apex of the RV to the lateral tricuspid valve origin.

Implantation of an OLBI Pacing System

A single-lead DDD pacing system (Eikos SLD, Biotronik, Germany) and bipolar leads (Figure 1, SL 60/13-BP or SL 60/15-BP, Biotronik, Germany) were used in all patients. The lead was positioned in the right ventricular apex under fluoroscopy. The ventricular pacing threshold, pacing impedance, and R-wave amplitude were routinely measured using a pacing system analyzer (ERA 300, Biotronik). The optimal position of the atrial dipole was verified by repeated measurements of the P-wave amplitudes [10]. A minimal amplitude of the unfiltered bipolar atrial electrocardiogram of ≥ 0.3 mV was required for the permanent lead position before OLBI pacing thresholds were determined.

Lead lengths between tip and floating electrodes of 130 mm (n = 9) and 150 mm (n = 7) distance were selected by two implanting physicians using a standardized protocol [12]. A threshold for OLBI pacing over 3.0 V was considered an unsuccessful implantation. One patient in whom no Echo data could be acquired was excluded. The remaining 15 patients were included in the further investigation. Patients were divided into two groups with respect to atrial OLBI pacing threshold during implantation: high (> 2 V, group A, n = 6) or low (≤ 2 V, group B, n = 9). The cut-off value of 2 V was chosen on an empirical basis; for free-floating electrodes it is considered acceptable.

Echocardiographic Study

Echocardiographic measurements were performed the day before pacemaker implantation. An ultrasound imaging system Sonos 2500 model 77020, with a 3.5 mHz continuous wave transducer (Hewlett Packard, USA), was used for all echocardiographic and Doppler studies. Measurements of end-systolic and end-diastolic dimensions and volumes of the right atrium and the right ventricle were performed offline by the use of a computer-assisted digitalization system (Nova Microsonics, USA) [13]. Excursions of the tricuspid annulus were measured in the apical four-chamber view [14]. The right-sided heart length was determined in different ways from calculations in the apical four-chamber view (Figures 2). The RV and atrial length was determined in two ways each:

- RV_{conv} = length from the RV apex to the middle of the tricuspid valve annulus;
- RV_{new} = length from the RV apex to the ventricular side of the lateral tricuspid valve origin;
- RA_{conv} = length from the roof of the RA to the middle of the tricuspid valve annulus;
- RA_{new} = length from the roof to the middle of the RA, added to the middle of the right atrium to the atrial side of the lateral tricuspid valve origin.

The atrial and ventricular lengths were calculated in four different ways to find the best correlation with OLBI threshold values:

- $(RA_{conv} + RV_{conv})$
- $(RA_{conv} + RV_{new})$
- $(RA_{new} + RV_{conv})$
- $(RA_{new} + RV_{new})$

Measurements were made at end systole and end diastole. All right-sided lengths were corrected for the lead length used by subtracting the actual dimension by the lead length selected. The accuracy should be ± 35%.

Statistics

All values are expressed as mean ± standard deviation. Groups were compared using the two-sided t-test for unpaired data. Linear regression was used for determining correlations between the corrected lead lengths and OLBI pacing.

Results

None of the implanted patients suffered from phrenic nerve stimulation in the supine position at 4.8 V OLBI stimulation (the maximum programmable value). Group A had a mean atrial pacing threshold (2.5 ± 0.3 V) statistically significant higher as in group B (1.7 ± 0.3 V). In sensing, no significant differences were found in the two groups (2.0 ± 1.0 mV in group A versus 2.1 ± 1.3 mV in group B).

Table 1 shows the end-diastolic and end-systolic volumes and dimensions of the RA and RV in relation to the pacing threshold, which are not statistically significant different between both groups. Table 2 shows the end-diastolic and end-systolic right-sided dimensions before and after correction for lead length. End-diastolic dimensions were not different between groups with low or high pacing thresholds.

Without correction for lead length (L), two parameters proved to be of value for discriminating between these groups. However, after correction for lead length, all end-systolic dimensions were significantly lower in the group with low pacing thresholds as compared to the group with a high pacing pacing threshold. After linear regression analysis of the corrected end-systolic dimensions, $RA_{conv} + RV_{new} - L$ proved to be the best single predictor for low atrial pacing thresholds (Figures 3a-d, dimensions in cm, OLBI threshold values in V):

- $RA_{conv} + RV_{new} - L = 1.90$ threshold – 7.31, $R^2 = 0.50$, $p = 0.003$
- $RA_{conv} + RV_{conv} - L = 1.41$ threshold – 6.79, $R^2 = 0.39$, $p = 0.012$
- $RA_{new} + sRV_{new} - L = 1.57$ threshold – 6.07, $R^2 = 0.38$, $p = 0.015$
- $RA_{new} + RV_{conv} - L = 0.90$ threshold – 3.60, $R^2 = 0.23$, $p = 0.068$

	Group A (n = 6) threshold > 2 V	Group B (n = 9) threshold ≤ 2 V	p-value
RV-EDV	58.2 ± 19.0	43.9 ± 10.8	ns
RV-ESV	15.8 ± 9.0	19.8 ± 8.8	ns
RA-EDV	59.5 ± 20.6	55.0 ± 22.3	ns
RA-ESV	39.5 ± 13.8	35.8 ± 12.7	ns
RA_{conv} (diastolic)	5.51 ± 0.35	5.13 ± 0.60	ns
RA_{conv} (systolic)	4.63 ± 0.42	4.05 ± 0.64	ns
RA_{new} (diastolic)	5.62 ± 0.50	5.16 ± 0.44	ns
RA_{new} (systolic)	5.13 ± 0.46	4.72 ± 0.65	ns
RV_{conv} (diastolic)	7.34 ± 0.71	6.99 ± 0.93	ns
RV_{conv} (systolic)	5.84 ± 0.49	5.44 ± 0.86	ns
RV_{new} (diastolic)	8.88 ± 1.46	7.88 ± 0.95	ns
RV_{new} (systolic)	6.53 ± 0.61	5.76 ± 0.73	ns

Table 1. Echocardiographic volumes in cm^3 and dimensions in cm of the right atrium (RA) and the right ventricle (RV). ns = not significant. See text for detailed information.

	Group A (n = 6) threshold > 2 V	Group B (n = 9) threshold ≤ 2 V	p-value
$RA_{conv} + RV_{conv}$ (d)	12.8 ± 1.0	12.1 ± 1.2	ns
$RA_{conv} + RV_{conv}$ (s)	10.5 ± 0.8	9.5 ± 1.4	ns
$RA_{conv} + RV_{new}$ (d)	14.4 ± 1.7	13.0 ± 1.5	ns
$RA_{conv} + RV_{new}$ (s)	11.2 ± 0.8	9.8 ± 1.2	0.0477
$RA_{new} + RV_{conv}$ (d)	13.0 ± 1.0	12.2 ± 1.1	ns
$RA_{new} + RV_{conv}$ (s)	11.0 ± 0.6	10.2 ± 1.3	ns
$RA_{new} + RV_{new}$ (d)	14.5 ± 1.7	13.0 ± 1.3	ns
$RA_{new} + RV_{new}$ (s)	11.7 ± 0.3	10.5 ± 1.2	0.0503
$RA_{conv} + RV_{conv}$-L (s)	-3.2 ± 0.8	-4.4 ± 0.9	0.028
$RA_{conv} + RV_{new}$-L (s)	-2.5 ± 1.1	-4.1 ± 0.9	0.015
$RA_{new} + RV_{conv}$-L (s)	-2.7 ± 0.5	-3.7 ± 0.9	0.033
$RA_{new} + RV_{new}$-L (s)	-2.0 ± 0.8	-3.4 ± 1.0	0.022

Table 2. Comparison of the echocardiographic dimensions in cm of the right atrium (RA) and the right ventricle (RV). L = lead length, ns = not significant, d = diastolic, s = systolic. See text for detailed information.

Discussion

Several studies have documented that single-lead VDD pacing may offer an advantageous alternative to conventional DDD pacing systems [2-7]. Single-lead

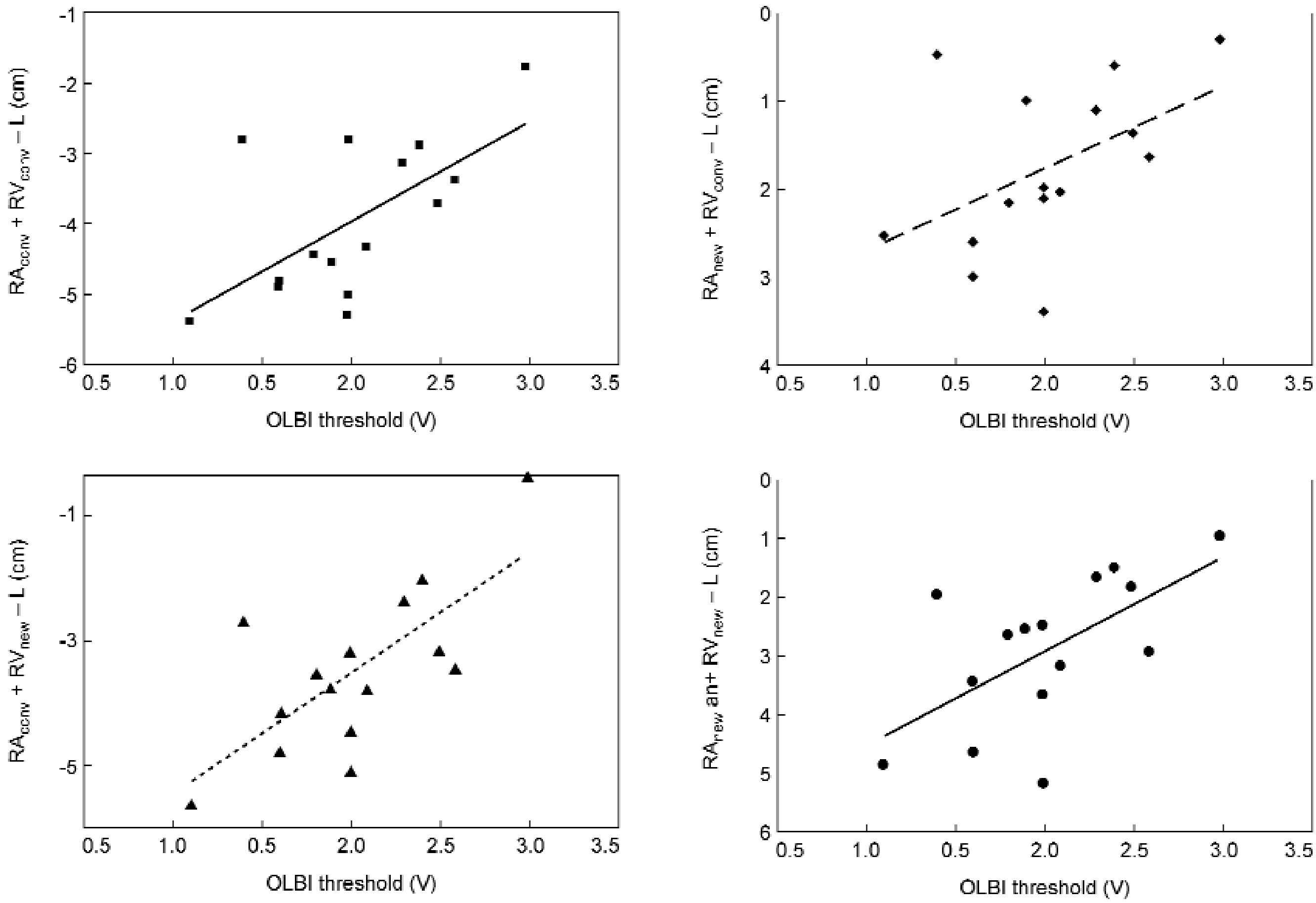

Figure 3. Linear regression of the systolic dimensions corrected by the lead length (L) versus OLBI pacing threshold measured by conventional and new echocardiographic methods. See Figure 2 and corresponding text for detailed information.

DDD pacing may provide a major advantage by eliminating the introduction of a second lead. Recently, Clarke, et al. demonstrated an almost threefold increase in perioperative complications in patients randomized to DDD pacing (9.0%) versus VVI pacing (3.8%, $p < 0.001$) [15]. Others have also demonstrated that single-chamber pacing in properly selected patients is associated with substantial benefits, including a significant reduction in costs. In single-lead DDD pacing, most studies reported the use of intraoperative telemetered sensing and pacing characteristics to guide lead selection and implantation techniques.

Long-term follow-up studies, however, demonstrated that acute atrial pacing thresholds may not reflect appropriate long-term pacing. Lucchese, et al. reported a mean single atrial pacing threshold of 1.6 V at implantation and 3.4 V before discharge [5]. Tse, et al. showed a mean acute single impulse atrial capture threshold of 3.9 ± 2.2 V at the 0.5 ms pulse width and 3.2 ± 1.3 V at the 0.5 ms pulse width during the pre-discharge test [16]. Rey, et al. extended the follow-up to 3 months and reported loss of atrial capture at maximal output in 4 of the 26 investigated patients, whereas in the other 22 patients the mean single capture threshold was 2.5 ± 0.8 V at the 1.0 ms pulse width [4]. Naegeli, et al., who also used intraoperative threshold measurements, observed an atrial pacing threshold ≤ 2.5 V for a 0.5 ms pulse duration in only 43% of patients [17]. Thus, intraoperative measurements of the atrial pacing threshold may not be adequate for patient selection.

Since the distance of the floating dipole is crucial for adequate pacing (and sensing) properties, selection of patients on the basis of echocardiographic measurements can provide clinically relevant information for long-term pacing thresholds in single-lead DDD pacing. De Cock, et al. demonstrated the usefulness of pre-implantation echocardiography to identify patients with adequate sensing during single-lead VDD pacing [13]. Using right atrial end-diastolic volumes, sensitivity and specificity of inappropriate atrial sensing (< 95% correct atrial synchronization on 24-hour Holter ECG monitoring) were 100% and 92% respectively. Other methods have been described to optimize lead selection in patients selected for VDD pacing. Nowak, et al. used chest X-ray images to select lead length to optimize atrial sensing [12]. They used test leads of different lengths that were positioned over a chest X-ray, and estimates of optimal lead lengths were made based on the position of the dipole in the mid-to-high right atrium for optimal atrial sensing. However, acute atrial sensing has been demonstrated to have a poor correlation with optimal pacing properties [16].

The present study demonstrates that echocardiographic variables may guide proper selection for patients selected for single-lead DDD pacing. Although right atrial volumes were reported to be slightly better in predicting atrial sensing than right atrial dimensions, the present study shows that right atrial in combination with right ventricular dimensions can accurately predict atrial capture thresholds during single-lead DDD pacing. Among a number of echocardiographic variables that could discriminate between patients with low or high atrial capture thresholds, the corrected right atrial dimension with ventricular apex to lateral tricuspid valve length proved to be the best predictor of adequate atrial pacing. Thus, pre-implantation echocardiographic measurements can be of value to select patients suitable for single-lead DDD pacing using OLBI stimulation.

Limitations

A number of limitations must be acknowledged. The procedure described in this paper assesses the optimal atrial dipole position when the patient is in the supine position. Anatomical changes in heart position at different postural conditions were not evaluated. The study population is small and retrospective, but despite this fact, we found the described difference in echocardiographic measurements. Since accurate echocardiographic measurements require good quality images in multiple views, only patients with a good or moderate echocardiographic window were included. Roughly a third of the patients have images whose quality is too poor to reliably perform right-sided measurements. In addition, only atrial pacing thresholds during implantation were studied, and no data were measured during extended follow-ups. However, recent studies reported a low variation in atrial capture threshold during follow-up as compared to values during implantation [4].

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