Retrospective analysis of mode survival, reliability of atrial sensing and incidence of atrial tachyarrhythmias in 307 single-lead VDD pacemaker patients

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Aims The aim of this retrospective analysis was to investigate VDD mode survival, development of atrial tachyarrhythmias (AT), and long-term atrial sensing performance of VDD pacing systems.

Methods and results We implanted single-lead VDD pacemakers in patients with isolated atrioventricular block and performed a retrospective analysis of 307 patients who had their devices implanted between May 1994 and September 2001. In 39 patients (12.7%), the pacing mode had to be reprogrammed to a single-chamber ventricular pacing mode, mostly due to permanent AT. In 16 of these patients, the atrial sensing safety margin was less than 150%. The atrial sensing safety margin was insufficient, i.e. less than 100% in only seven patients. Although only 12 (3.9%) of the patients had a history of paroxysmal AT at the time of pacemaker implantation, 200 (65%) patients presented with AT during follow-up. The mean AT burden at the last follow-up was 2.5%.

Conclusion These data illustrate that single-lead VDD pacemakers can be applied without serious complications in a highly selected group of patients. Our main concern is the development of AT in a large part of our population. Over a 10-year period, two thirds of our patients presented with AT.

KEYWORDS
Single-lead VDD pacemaker; Long-term follow-up; Atrial tachyarrhythmia; Mode survival; Retrospective analysis

Introduction

The importance of the atrial contribution to cardiac output has long been recognized. Atrial synchronous ventricular pacing has both short and long term advantages over ventricular pacing. In patients with atrioventricular (AV) block and preserved sinus rhythm, a VDD pacing system would be sufficient to eliminate the ventricular bradycardia and to provide AV synchrony and chronotropic response. The presence of paroxysms of atrial fibrillation does not prohibit the use of single-lead VDD pacemakers if the pacemaker features mode switching and a rate-response sensor (mode switch to VDIR pacing mode). Atrial bradycardia or sinus pauses are a contra-indication to VDD pacing systems, because they lack the ability to pace the atrium under these circumstances. Sensing of atrial depolarization in VDD mode is achieved through electrodes that are in physical contact with the atrial wall (dual-lead systems) or through floating electrodes (single-lead systems). Floating electrodes can be placed on the lead body of the ventricular lead at the atrial level. Such a system is referred to as a single-lead VDD pacing system. The single-lead VDD pacemaker concept was proposed as early as 1973 but became commercially available in the late 1980s.

We have been implanting single-lead VDD pacing systems since the early 1990s according to the strict indication of preserved sinus rhythm in combination with AV block. Primary reasons for this policy are less foreign material in the body, shorter implantation times and radiation exposure, and fewer post implantation complications with lower follow-up costs.

We performed this retrospective analysis to investigate VDD mode survival, development of AT, and long term atrial sensing performance of these pacing systems.

Methods

All patients were implanted with a single-lead VDD pacing system, consisting of a Saphir or Saphir II VDDR pacemaker and a Brilliant or Brilliant+ quadripolar lead (Vitatron, Arnhem, Netherlands). Between May 1994 and September 2001, we implanted and followed 441 patients with such pacing systems. Patient follow-ups were...
included in this analysis until September 2004. We included 307 patients in our analysis (mean age 75 ± 13 years; 56% male; mean follow-up 5.98 ± 1.59 years). We excluded patients from the analysis that were considered ‘lost to follow-up’ either because they did not have any follow-up visits in the last 18 months or they died and did not have a single follow-up visit.

We assessed sinus node function prior to pacemaker implant according to our local practice (long-term ECG, carotid sinus massage, adenosine, stress testing). For the mode survival analysis, we accepted only the VDD or VDDR mode. Patients were considered to have atrial tachyarrhythmia (AT), if this was noted in the patient’s file by the physician and/or if the AT burden indicated 1% or higher during one or more of the follow-up visits. AT burden was defined as the percentage of the time that the atrial rhythm was classified as AT by the implanted pacemaker.

The Saphir VDD pacemakers include a P-wave amplitude histogram, showing the distribution of P-waves and AT signals over the entire follow-up period. The atrial sensing safety margin was defined as a quotient of the smallest amplitude in the P-wave amplitude histogram and the programmed atrial sensitivity. Values above 100% indicate reliable sensing.

Statistical analysis
Descriptive statistics (mean ± standard deviation) were calculated for most of the data sets. VDD mode survival and incidence of AT were evaluated using Kaplan–Meier cumulative survival curve. Independent variables were dichotomized and one or two-tailed Mann–Whitney was applied to assess differences between the groups for dependent variables. A P value of less than 0.05 was considered statistically significant.

Results
A total of 249 patients had at least one follow-up visit in the last 18 months and 58 patients died and had at least one follow-up visit.

The indication for pacing was AV block (91.7%), bundle branch block (6.3%), sick sinus syndrome (SSS) (1%), and other (1%). The atrial rhythm at the time of implantation was sinus rhythm (94.8%), paroxysmal atrial fibrillation (AF) (3.9%), SSS (1%), and missing (0.3%). The AV conduction status at the time of implantation was normal (3.6%), second-degree AV block (29%), complete (third degree) AV block (65.5%), and missing (2%).

VDD mode survival
Figure 1 shows the Kaplan–Meier cumulative survival curve for the VDD pacing mode. In the cohort of 307 patients, 39 (12.7%) patients had their pacing mode reprogrammed to a single-chamber ventricular pacing mode. In almost all (36) these patients, AT was the primary reason for mode reprogramming and atrial undersensing accounted for the remainder. The atrial sensing safety margin was less than 150% in 16 of the patients in whom the mode was reprogrammed. The atrial sensitivity was programmed to its lowest value (0.1 mV) in 14 of these patients (0.18 mV and 0.25 mV in the two other patients). The mean atrial sensing safety margin was higher in patients who remained in the VDD pacing mode compared with patients in whom the pacing mode was reprogrammed (223 ± 156% vs. 165 ± 106%; P < 0.05).

Incidence and burden of atrial tachyarrhythmias
Figure 2 shows the Kaplan–Meier cumulative survival curve for AT free patients. Only 3.9% of the patients had a history of paroxysmal AT at the time of pacemaker implantation. Figure 3 illustrates the AT burden at the last follow-up visit (n = 191). The mean AT burden was 2.5 ± 8.6% and 104 (54.5%) of the patients were free of AT burden.
Aspects related to AT

In our patient cohort, the incidence of right ventricular apical pacing was high (92.1 ± 15.1%) as the vast majority of patients had their pacemaker implanted because of high-degree AV block. The incidence of ventricular pacing did not differ significantly between the AT-free patients and patients with AT.

The percentage of the time during which the device operated in an AV synchronous mode was significantly higher in patients that were free of AT (87.2 ± 18.0% for patients free of AT vs. 75.0 ± 22.6% for patients with AT; \( P < 0.001 \)).

P-wave sensing

The P-wave amplitude was measured during a follow-up visit using the pacemaker programmer. Figure 4 shows the mean value of these measurements, illustrating that in most patients a sufficient atrial sensing safety margin is available with respect to the highest programmable sensitivity of 0.1 mV.

The lowest P-waves in the P-wave amplitude histogram were 0.32 ± 0.21 mV for patients free of AT and 0.27 ± 0.28 mV for patients with AT (\( P = 0.005 \)). Using the lowest amplitude in the P-wave amplitude histogram, we found that the atrial sensing safety margin was less than 100% in seven patients. In these patients, the atrial sensitivity was programmed to 0.1 mV (\( n = 2 \)) and 0.18 mV or 0.25 mV (\( n = 5 \)) and therefore could have been improved in the majority of these patients. Atrial undersensing can cause intermittent AV asynchrony and more ventricular events may be classified as premature ventricular complex (PVC) by the pacemaker. The incidence of PVCs in the seven patients with a sensing safety margin of less than 100% was 8.0 ± 18.8% vs. 1.2 ± 4.2% in patients with a sensing safety margin of more than 100% (\( P < 0.05 \)). AV synchrony was significantly higher in patients with a sensing safety margin of more than 100% (79.2 ± 21.4% vs. 66.5 ± 25.7%; \( P < 0.05 \)).

Other results

Atrioventricular delay programming had no significant influence on the incidence of ventricular pacing because of the high-degree AV block in most patients.

Discussion

One of the appealing characteristics of single-lead VDD pacemakers is their simplicity: the implantation of a single lead allows the physician to obtain dual-chamber function. Several studies have shown that the rate of complications requiring surgical intervention, the implantation time, and the fluoroscopic time of these systems are comparable with that of VVI pacemakers and significantly lower than that of DDD pacing systems.\(^{10,11}\)

There are several mechanisms in patients with single-lead VDD pacemakers that potentially affect the development of AT. A disadvantage of VDD pacing systems is the inability to pace the atrium and thus to prevent long atrial intervals e.g. as a result of sino-atrial block or sinus bradycardia.\(^{12}\) In contrast, single-lead VDD pacemakers do not injure the atrial wall nor do the atrial electrodes pose a mechanical stress on the atrial wall, factors that may facilitate development of AT.

In our study, we have found that 65.1% of our patients revealed AT during follow-up. We used the pacemaker arrhythmia counters to access the presence of AT. Because the leads that we used all had an atrial inter-electrode distance of 10 mm, we feel that far field R-wave sensing, and thus false positive AT counting and over-estimation of AT burden, is not significantly affecting the results.\(^{13}\)

Our results are not consonant with the results published by Kong et al.\(^{14}\) and Folino et al.\(^{15}\) An important difference between their methodology and ours is the determination whether AT is present in a given patient. Their retrospective analysis relied on documented AT in the ECG during follow-up or in 24 h Holter ECG recordings. This may have influenced their results as AF is a rather random phenomenon that may occur in 'storms'.\(^{16}\) Using the pacemaker diagnostics to diagnose the presence of AT avoids under-reporting whereas over-reporting, e.g. due to far field
sensing, is expected to be limited. This may explain why our results show a higher proportion of patients with AT. Schuchert et al. used pacemaker diagnostic data to study the incidence of AT in patients with no prior history of them. They concluded that AT was detected within one year in 50% of patients with a single-lead VDD pacemaker. Other studies that used pacemaker diagnostics to monitor the incidence of AT have shown similar results. These results are more in line with ours.

Paroxysms of AT are usually not a contraindication for single-lead VDD pacemakers if these devices feature mode switching to a non-tracking pacing mode upon detection of AT. If patients with single-lead VDD pacemakers require replacement of their pacemaker and they have AT, then upgrading to a DDDR system should be seriously considered, as atrial pacing may reduce the AT burden.

Several recent studies have shown that a high percentage of right ventricular apical pacing is associated with a higher incidence of AF. However, the incidence of ventricular pacing in our group did not differ significantly between the AT-free patients and patients with AT. With respect to mode survival, our results are in line with other long-term follow-up studies with single-lead VDD pacemakers. Sassara et al. reported a mode survival of 94.6% for a follow-up period of almost 4 years (90.6% after 4 years in our study) and Rey et al. reported 95%, whereas Chamberlain-Webber et al. reported 88.6% for a 2 year follow-up period (94.8% after 2 years in our study).

The initial concern about single-lead VDD pacemakers was the reliability of atrial sensing using a floating dipole. Long-term atrial sensing of single-lead VDD pacing systems is reliable although the floating atrial electrodes in VDD pacing systems yield smaller P-waves when compared with dual-lead pacing systems. The P-wave amplitude decreases during the immediate post-implantation phase and afterwards remains relatively constant. The high atrial sensitivity that can be programmed in these devices allows the programming of an adequate sensing safety margin.

Conclusions

Our study shows that single-lead VDD pacemakers can be applied without major technical difficulties in a highly selected group of patients. Over a follow-up period of 10 years, only 12.7% of the patients required mode reprogramming to a single-chamber ventricular pacing mode (Kaplan-Meier), the primary reason being the development of AT.

Long-term atrial sensing is reliable and, in the vast majority of patients (97.7%), an adequate sensing safety margin was sustained over a long period of time, even for patients with AT.

Our main concern is the development of AT in a large part of our population. During the follow-up period, two-thirds of our patients presented with AT.

Therefore, we suggest that single-lead VDD pacemakers should be implanted in carefully selected patients and that patients with these devices should be monitored closely for the development of AT.

References