Long-term Outcome of Atrial Synchronous Mode Pacing in Patients With Atrioventricular Block Using a Single Lead

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ABSTRACT

Background: Current guidelines suggest the use of atrial synchronous mode (VDD) pacemakers in patients with atrioventricular (AV) block and normal sinus node function. However VDD mode is being used much less than expected. The objectives of our study were to evaluate the efficacy of VDD pacing in long-term follow-up and to find risk factors for VDD loss.

Methods: We retrospectively evaluated all patients with VDD pacemakers who were implanted in our center between 1995 and 2007.

Results: During the study period, 123 consecutive patients with AV block (51% men, age 62 ± 17.8 years) received a VDD pacemaker. Mean follow up duration was 4.5 ± 3.2 years. At the last follow up visit, 21 patients (21.6%) lost their original VDD mode and were programmed to ventricular-based pacing (VVIR) (undersensing, 11; chronic AF, 7; SND, 3). In 28 patients, VDD mode was restored or maintained by increasing atrial sensitivity. No episodes of atrial oversensing were observed. In multivariate analysis history of paroxysmal AF ($p = 0.007$, odds ratio 36.6, 95% confidence interval 2.7–493.7) and p wave lower than 1 mv during the follow up ($p = 0.021$, odds ratio 7, 95% confidence interval 1.3–36.7), were found risk factors to VDD loss.

Conclusions: VDD pacing has good long-term performance. Absence of paroxysmal AF history predicts maintenance of VDD pacing mode. Taking into account that no atrial oversensing was observed, our recommendation is to increase atrial sensitivity when *P* wave amplitude declines to less than 1 mv.

Introduction

High degree atrioventricular (AV) block represents approximately half of permanent pacing indications. Hemodynamic advantages, reduction in the development of atrial fibrillation, and better quality of life are gained by a mode of pacing which preserves AV synchrony compared with ventricular demand pacing.[1–4] Advantages of single lead atrial synchronous mode (VDD) over regular DDD pacing are: it is a less complex implant procedure, and has lower implantation and follow-up costs.[5,6] VDD pacing utilizing a single-pass lead with far-field atrial sensing bipoles is a potentially simpler approach to provide the physiological benefits of AV synchronous pacing with a single-lead system. Despite this, VDD pacing is utilized in only 1% to 11%, 1% to 16%, and 2% to 20% of patients receiving pacemakers in America, Asia, and Europe, respectively.[7] This may be related to concern regarding stability of atrial sensing or development of sinus node disease. Most of the previous studies evaluated VDD pacing during a relatively short follow-up.[8–12] Although some risk factors for losing VDD mode pacing such as old age, low *P* value, high right-atrial dimension, and atrial dipole placement in low atria were found,[13,14] criteria to optimize atrial sensitivity and VDD pacing have not been completely defined. The aim of our study was to evaluate the efficacy and stability of VDD pacing in long-term follow-up and to find risk factors for VDD loss.

Methods

Study Population

Data from pacemaker implantation and pacemaker follow-up visits of all patients who had a VDD pacemaker implanted at our center between January 1995 and October 2007 were analyzed. In general, the indication for the implantation of a VDD pacemaker was based on a history of symptomatic AV block. Intact sinus node function and paroxysmal atrial fibrillation prior to implantation were determined clinically by means of the patient's history. Left ventricular function, presence of valvular disease, and left atrial size were determined by echocardiographic examination. An E to A ratio above 1 in the presence of atrial enlargement was defined as diastolic dysfunction.

Implantation Technique and Devices

Pacemakers were implanted under local anesthesia using a standard implantation technique. The single-pass 9 French VDD lead was inserted under fluoroscopy via the cephalic or subclavian vein. *P* wave amplitude at implantation was measured. Devices used were specific VDD pacemakers.

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Follow-up

Follow-up visits with clinical evaluation, recording of a standard electrocardiogram (ECG), pacemaker interrogation, and testing were arranged 3 months after implantation followed by intervals of 9 to 12 months, or earlier, if patients developed symptoms. Pacemaker reprogramming and reasons for pacing mode changes were documented.

Statistical Analysis

Data are presented as mean ± 1 standard deviation. Categorical variables were compared with an χ^2 test or Fischer exact test. Not–normally-distributed continuous variables were compared using the Mann-Whitney and Wilcoxon signed ranks test. A P value <0.05 was considered statistically significant. Multivariate logistic regression analysis was performed to determine the relationship between various risk factors and VDD mode pacing failure. All data analyses were performed using SPSS version 15 (SPSS, Chicago, IL).

Results

Implantation and Follow-up

Between 1995 and 2007, 1294 consecutive patients underwent pacemaker implantation at our institution. Of those, 135 patients (10.4%) received a VDD pacemaker. A total of 12 patients were lost to follow-up and were excluded from the analysis (8.8%). The remaining 123 patients represent the study population. Clinical characteristics of the patients are shown in Table 1. Indication for pacemaker implantation was either a permanent or an intermittent AV block: a third-degree AV block was present in 77 patients (63%), a second-degree AV block in 42 patients (34%), and a first-degree AV block in 4 patients (3%). Implanted pacemakers and leads are shown in Table 2. The lead was inserted via a transvenous route using the left cephalic in 67 patients (58%) and via the left subclavian in the remaining 49 patients (42%). The sensing dipole was positioned at the middle third of the right atrium in 47 patients (52%), at the upper third of the right atrium in 25 patients (27%), and at the lower third of the right atrium in 19 patients (21%). Mean P wave at implantation was 2.5 ± 1.4 mV and mean impedance was 642.5 ± 182 ohms. There were 4 (3.3%) implant complications, 1 pneumothorax, 1 hematoma, 1 wound infection, and 1 subclavian vein thrombosis. All complications were treated successfully. Follow-up duration was 4.5 ± 3.2 years (range, 1 mo–13 yrs). Elective pacemaker replacement for battery depletion was performed in 15 patients (12.1%), in 13 of them (86.6%) to a VDD pacemaker. A total of 22 patients (17.8%) died during the follow-up.

A total of 97 patients had information about their last follow-up. At the last follow-up visit, among paced patients, 76 pacemakers (78.4%) remained in VDD mode. A total of 21 patients (21.6%) lost their original VDD mode and were programmed to VVIR. The reasons for VDD loss are shown in Table 3. VDD mode was restored in 4 of 11 patients that had an undersensed P wave, after increasing atrial sensitivity. Permanent VDD loss occurred in 17 patients (17.5%). One patient (1%) underwent upgrading to DDD mode due to pacemaker syndrome. During

Table 1. Clinical Characteristics of the Study Population, n = 123

Variable	
Age	62 ± 17.8
Men	51%
Hypertension	60%
Diabetes mellitus	27%
Ischemic heart disease	18%
Past heart surgery	20%
History of atrial fibrillation	7%
Valvular heart disease	45%
Left ventricle systolic dysfunction	13%
Left ventricle diastolic dysfunction	23%
Left atrial enlargement	44%
Degenerative disease in conduction system	80%

Data are expressed as mean ± SD or as percentages.

Table 2. VDD Pacing System and Leads in 123 Patients with Symptomatic AV Block

Manufacturer	Pulse Generator	n
Medtronic	Sigma	75
Medtronic	Prodigy	13
Sorin	Miniswing	12
Biotronic	Axios	8
Biotronic	Actros	6
St Jude	Affinity	4
	Other	5
Manufacturer	**Lead Type**	**n**
Medtronic	5038	97
Medtronic	5032	10
Sorin	S-84	8
Sorin	S-83	4
	Other	4

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Table 4. Reasons for Reprogramming or Upgrading the VDD Pacing System During the Follow-up (n = 97)

Reason for VDD Loss	No. of Patients (Percentage)	Months After Implantation (Median)
Atrial undersensing[a]	11 (11.3%)	12
Chronic atrial fibrillation	7 (7.2%)	8
Sinus dysfunction	3 (3%)	16

[a] In 4 patients, VDD was restored after increasing sensitivity.

the follow-up, undersensing and chronic atrial fibrillation occurred earlier than sinus dysfunction (Table 3). Mean *P* wave amplitude decreased by 60% during follow-up (from 2.5 ± 1.4 mV at implantation to 1 ± 0.79 mV at the end of the study, $P < 0.001$). In 24 patients with low P wave amplitude (mean 0.58 ± 0.3 mV, range, 0.2–1.4 mV), increasing atrial sensitivity resulted in the preservation of VDD mode pacing. Atrial sensitivity was increased from 0.25 ± 0.07 mV at the implantation to 0.21 ± 0.07 mV during the follow-up. No atrial oversensing was observed. Table 4 displays the results of univariate analysis examining the relationship between selected risk factors and VDD mode pacing loss. In the multivariate model, history of atrial fibrillation and P wave amplitude <1 mV during follow-up were independent predictors of VDD pacing loss.

Discussion

VDD systems which allow normal AV synchrony, have been shown to shorten the implantation time, overall cost, time of fluoroscopy, and tend to have less short-term and long-term complications.[5,6] However, the gradual decrease in the *P* wave amplitude and the potential development of sinus node dysfunction during the follow-up period, especially among the elderly, make this mode of pacing less attractive than DDD mode pacing.

Table 3. Factors Predictive of VDD Loss

Variable	VDD Lost, n = 21	VDD Not Lost, n = 76	*P* Value
Age >75, n (%)	8 (38%)	15 (19.7%)	0.09
Male, n (%)	9 (42.8%)	40 (52.6%)	0.42
Past history of atrial fibrillation, n (%)	5 (23.8%)	1 (1.3%)	0.002
Hypertension, n (%)	13 (61.9%)	46 (60.5%)	0.9
Diabetes mellitus, n (%)	5 (23.8%)	21 (27.6%)	0.72
IHD, n (%)	4 (19%)	12 (15.7%)	0.65
Degenerative etiology for AV block, n (%)	13 (61.9%)	61 (80.2%)	0.148
Valvular disease, n (%; moderate or severe)	7 (33.3%)	%16 (21%)	0.65
EF <50%, n (%)	3 (14.2%)	6 (7.8%)	0.5
Left atrium diameter >4 cm, n (%)	7 (33.3%)	17 (22.3%)	0.5
CAVB, n (%)	5 (23.8%)	29 (38.1%)	0.24
Medtronic, n (%)	12 (57.1%)	58 (76.3%)	0.1
Lead 3038, n (%)	14 (66.6%)	59 (77.6%)	0.47
Ventricular bipolarity, n (%)	7 (33.3%)	34 (44.7%)	0.349
Atrial dipole placement in lower third, n (%)	3 (14.2%)	13 (17.1%)	0.92
P amplitude at implantation <1 mV, n (%)	2 (9.5%)	8 (10.5%)	0.91
P amplitude during follow-up <1 mV, n (%)	10 (47.6%)	28 (36.8%)	0.032
Diastolic dysfunction, n (%)	2 (9.5%)	6 (7.8%)	0.4
Duration of follow-up in months, median	59	48	0.14

Abbreviations: AV, atrioventricular; CAVB, complete atrioventricular block; EF, ejection fraction; IHD, ischemic heart disease.

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Table 5. Multivariate Model for Predicting VDD Loss

Variable	Odds Ratio	95% Confidence Interval	*P* Value
Age >75	0.7	0.09–5.1	0.7
Past history of atrial fibrillation	86	5.2–1411	0.002
P amplitude during follow-up <1 mV	8.1	1.3–47	0.02
Duration of follow-up in months	1	1.001–1.041	0.042

We performed a retrospective analysis of 123 patients with VDD pacing to determine the clinical long-term performance of this mode in daily practice and to characterize patients that would maintain VDD pacing mode. At the last follow-up visit, 78.4% of patients were in VDD mode, and in an additional 4%, VDD mode pacing was restored after increasing atrial sensitivity.

The rates of VDD mode maintenance in several studies were 80.5% to 99%[8–12] with a mean follow-up of 1 to 3 years. Atrial sensing plays a central role in single lead VDD pacemakers. Previous studies have demonstrated a gradual decrease in the *P* wave amplitude during the follow-up period.[15,16] Our study also demonstrated that atrial signal measurements decreased by 60% in the period between implantation and last visit. Many factors may affect the quality and the characteristic of the *P* wave signals. These include the position of the atrial dipole, distance between the electrode and the atrial wall, and aging or scarring of cardiac muscle.

Sustained atrial undersensing developed in 7.2% of patients, which is higher than previous reports.[5,10] This finding could be explained by the fact that we have not routinely programmed the atrial sensitivity to the most sensitive values. Increasing the atrial sensitivity during follow-up in 24 patients (25%), most likely had prevented the loss of VDD mode pacing, emphasizing the importance of close routine *P* wave amplitude evaluation. Clinically relevant sinus node dysfunction developed in 3.1% of patients. In other reports, the incidence of symptomatic sinus node dysfunction ranged from 0.2% to 0.6% in 2.5 to 3.1 years.[5,10] Our finding suggests that longer follow-up increases the incidence of late sinus node dysfunction development and that clinical evaluation of sinus function prior to implantation may not be enough.

In a multivariate analysis we found that prior history of atrial fibrillation and *P* wave <1 mV during follow-up were independent predictors of VDD loss. Patients with a history of paroxysmal atrial fibrillation are at increased risk for recurrence, development of atrial fibrosis, and sinus dysfunction. Although age above 75 years is an established risk factor for atrial fibrillation and could potentially contribute to VDD loss, older age was not an independent predictor of VDD loss in the multivariate analysis. We found that a *P* wave value less than 1 mV during follow-up, but not *P* wave value at implantation, is an independent predictor of VDD loss. This could be explained by changes in the sensed atrial signal with physical activity, patient position, and methods used to measure the *P* wave value (pacing system analyzer vs the device).[11] There was no statistically significant difference in duration of follow-up between patients that lost and did not lose VDD mode pacing. Left atrial enlargement, atrial dipole placement, and decreased left ventricular systolic function were not found to be independent predictors of VDD mode loss.

Conclusions

In daily clinical practice, VDD pacing has good long-term performance. According to our data, absence of paroxysmal atrial fibrillation history prior to implantation predicts long-term maintenance of VDD pacing mode. Consideration should be given to evaluate sinus node function by additional modalities prior to implantation. Routine *P* wave amplitude should be monitored closely and atrial sensitivity increased once *P* wave amplitude is below 1 mV. This practice seems to be safe and effective given the fact that no atrial oversensing was observed.

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