Predictors of loss of atrioventricular synchrony in single lead VDD pacing

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Abstract

Objective—To evaluate maintenance of proper VDD function, defined as persistence of sinus rhythm with atrial synchronous ventricular pacing, and to define factors predicting failure of the VDD mode in patients with atrioventricular (AV) block and normal sinus function.

Design—Observational study in 86 consecutive patients (mean (SD) age 74 (12) years; 38 women, 48 men) with single lead VDD pacing systems (Intermedics Unity, n = 66, Medtronic Thera VDD, n = 20), implanted for high degree AV block with documented normal sinus node. Pacemaker function was assessed by event counters, telemetric measurements, and Holter recordings. Demographic, radiological, and pacing variables were correlated with loss of proper VDD function.

Results—During a mean (SD) follow up of 10 (10) months (range 1–37), sinus rhythm and atrial triggered ventricular pacing were maintained in 70 of 86 patients (81%). Atrial undersensing was observed in nine patients, lead migration in two, atrial fibrillation in three, and symptomatic sinus bradycardia in two. Univariate predictors of loss of proper VDD function were: low position of the atrial dipole relative to the carina (≥ 6 cm; $p < 0.01$) during fluoroscopy; and maximum programmable atrial sensitivity of the pacemaker ($p = 0.03$). In a multivariate analysis, only dipole position remained predictive of outcome ($p < 0.02$). Not predictive were sex, age, symptoms before pacemaker implantation, cardiothoracic ratio or dilatation of individual heart chambers on chest x ray, side of device implant, and P wave amplitude at implant.

Conclusions—To maintain proper VDD function in the long term, a low anatomical dipole position relative to the carina should be avoided. Electrical guidance of dipole positioning does not seem to influence long term outcome.

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Keywords: VDD pacing; atrioventricular synchrony; arrhythmias

In patients with high degree atrioventricular (AV) block, AV synchronous pacing offers several advantages over VVI pacing, including improved haemodynamics¹ and exercise tolerance and a lower incidence of atrial fibrillation, heart failure, and cerebral embolism, together

resulting in improved survival.^{2–4} These effects have been accomplished using VAT, VDD, and DDD pacemakers with two separate leads. Recently, atrial triggered ventricular pacing has also been achieved with single pass leads. Based on the excellent initial experience with such pacing systems in selected patients with documented normal sinus node function,⁵ single lead VDD pacing has started to replace the classic indication for DDD pacemakers in patients with pure AV block.

In this observational cohort study our aim was to evaluate the maintenance of proper VDD function in patients with AV block and a normal sinus node, and to identify factors that predict failure in the long term.

Methods

Indications for pacemaker implantation were high degree AV block with normal chronotropic function of the sinus node. Patients with a history of chronic or intermittent atrial fibrillation did not receive VDD pacemakers.

We implanted 66 Unity pacemakers (model No 292-07, Intermedics Inc, Angleton, Texas, USA) and 20 Thera VDD pacemakers (model No 8948, Medtronic Inc, Maastricht, the Netherlands). The characteristics of the patients are given in table 1. Lead types used for Unity pacemakers were models 425-04 (33 patients), 425-13 (32 patients), and 425-06L (one patient), with a distance from the ventricular tip to the atrial dipole of 11 cm, 13 cm, and 16 cm respectively. For Thera VDD pacemakers, the lead model 5032 was used in all patients. Pacemakers were inserted by the infraclavicular approach with cut down of the cephalic vein, and lead placement optimised by intraoperative fluoroscopy and by measurement of P

Table 1 Patient characteristics

Number	86
Male/female	48/38
Mean (SD) age (years)	74 (12) (range 18 to 92)
Indication for pacing	
AV block III	44
AV block II	35
Incomplete trifascicular block	7
Clinical diagnosis	
Degenerative AV nodal disease	72
Ischaemic heart disease	6
Myocarditis	1
Valvar heart disease	1
Surgical AV block	3
Pacemaker model	
Intermedics Unity	66
Medtronic Thera VDD	20
Distance from electrode tip to dipole	
13 cm	85
16 cm	1
Insertion side	
Right/left	76/10

AV, atrioventricular.

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Figure 1 Kaplan-Meier analysis showing proportion of patients remaining with correct VDD function over time. Note that there is a steady decline in atrial triggered ventricular pacing over the observation period.

and QRS wave amplitudes and ventricular pacing threshold.

Postoperatively, lead position was documented by upright chest x ray. To find the best landmark for determination of the atrial dipole position, the vertical distance between the dipole and carina was measured, and the dipole position relative to the right atrium determined. The cardiothoracic ratio was measured

Table 2 Predictors of loss of atrioventricular synchrony

	Univariate <i>p</i> value	Multivariate <i>p</i> value
Demographic variables		
Age	NS	—
Sex	NS	—
Indication for pacing	NS	—
Underlying heart disease	NS	—
Pacing variables		
Maximum programmable atrial sensitivity	0.03	NS
Electrode model and length	NS	—
Side of pacemaker insertion	NS	—
P wave amplitude during implant	NS	—
Sensing threshold at implant	NS	—
Ventricular sensing and pacing thresholds	NS	—
Radiological variables		
Atrial dipole position relative to carina	0.01	0.02
Dipole position relative to right atrium	NS	—
Transverse heart diameter	NS	—
Cardiothoracic ratio	NS	—
Position of electrode tip	NS	—
Electrode stretching	NS	—

Figure 2 In patients with later loss of atrial triggered ventricular pacing at follow up, the position of the atrial dipole relative to the carina was significantly lower than in patients with normal VDD function.

and the dimensions of the individual heart chambers estimated according to standard radiological criteria.

The pacemakers were programmed to a lower pacing rate of 40 beats/min and an AV interval of 50 ms. The atrial sensitivity was always set to the most sensitive level (0.10 mV for Unity; 0.25 mV for Thera VDD). Event counters were activated to document AV synchrony. The day after implant, sensing and pacing thresholds were determined. The atrial sensing threshold was defined as the most insensitive setting with reliable P wave detection during forced respiration manoeuvres. Similar tests were done at three and 12 months, and yearly thereafter, or if the patient became symptomatic.

Correct VDD function was defined as correct atrial sensing with > 90% atrial triggered ventricular pacing and documented persistence of sinus rhythm. Failure of atrial triggered ventricular pacing was defined as atrial undersensing (loss of atrial triggering in > 10% of all expected atrial triggered ventricular paced events) at the most sensitive pacemaker setting, or the clinical need to program to the VVI mode (for example, drug refractory atrial fibrillation, symptomatic sinus bradycardia). Suspected failure of VDD pacing was always confirmed by Holter.

Maintenance of proper VDD function was analysed by the Kaplan-Meier method; *t* tests, the Mann-Whitney U test, and Fisher's exact test were used where appropriate. Interactions between proper VDD function and demographic, radiological, or other variables were analysed by univariate and multiple regression methods. A probability (*p*) value of < 0.05 was considered statistically significant.

Results

Between 1992 and 1995, 86 consecutive VDD pacemakers were implanted in patients with pure AV block and normal sinus node function.

During a mean (SD) follow up of 10 (10) months (range 1–37), sinus rhythm with correct atrial sensing and atrial triggered ventricular pacing was maintained in 70 of 86 patients (81%). Atrial undersensing occurred in nine patients, lead displacement in two, atrial fibrillation in three, and symptomatic sinus bradycardia in two. Kaplan-Meier analysis (fig 1) showed a gradual decline in patients with proper VDD function during the first two years.

By univariate analysis, the parameters predictive of loss of atrioventricular synchrony (table 2) were low position of the atrial dipole relative to the carina ($p < 0.01$) and maximum programmable atrial sensitivity ($p = 0.03$). The best cut off point for prediction of loss of atrioventricular synchrony during follow up was an atrial dipole position ≥ 6 cm below the carina (fig 2; sensitivity 83%, specificity 63%). By univariate analysis, proper VDD function was also linked to the higher programmable atrial sensitivity of the Unity pacemaker (0.1 mV *v* 0.25 mV for Thera), but this association was no longer significant in multivariate analysis.

Discussion

Despite our excellent initial experience in highly selected patients,³ our current study showed a higher than expected failure rate of the VDD mode with single pass leads (19%) when they were in general use instead of a DDD pacemaker in patients with AV block. This finding was mainly related to atrial undersensing, which was predicted by a low atrial sensing dipole position relative to the carina. By univariate analysis, the maximum programmable sensitivity of the pacemaker was also predictive.

ATRIAL DIPOLE POSITION

A low radiological atrial dipole position (≥ 6 cm below the carina) was the main predictor of loss of AV synchrony. This may be explained by the anatomical fact that close to the entrance of the superior vena cava the cross sectional area of the right atrium is considerably smaller than at mid-atrium, resulting in a generally closer proximity of the dipole to the atrial wall than in other (lower) positions. In addition, the part of the electrode just extruding from the superior vena cava is less exposed to heart motion. A common problem of dipole positioning under fluoroscopic control is to find a stable anatomical landmark that is moving in parallel with the right atrium during breathing and changing body position (supine, upright). In that respect, the carina is an ideal landmark, as it is in direct contact with the roof of the right atrium. Other radiological indices of poor atrial wall contact may have failed owing to greater anatomical variation (for example, heart size and cardiothoracic ratio).

ATRIAL SENSING TECHNOLOGY

The second predictor of VDD failure in the univariate model was the maximum programmable atrial sensitivity of the pacemaker. Despite a shorter median observation time, we observed significantly more VDD failures with the Thera VDD pacemakers (maximum sensitivity 0.25 mV) than with the Unity system, with a maximum sensitivity of 0.10 mV. The recent experience in patients with Thera pacemakers and atrial undersensing showed that downloading of new software that allowed programming of a maximum atrial sensitivity of 0.18 mV could restore proper VDD function. These findings highlight the importance of optimising atrial dipole design and sensing circuit in future VDD pacemakers. Differences in the reported rate of malfunction in other studies^{6,7} may be explained by the different technologies used. New developments in electrode design⁸ and new pacemaker features such as continuous P wave amplitude measurement⁹

and automated adjustment of atrial sensing address these problems.

LIMITATIONS

Although the importance of the atrial dipole position has clearly been shown in this study, we still lack suitable radiological indices for selecting optimum electrode length. This should be the focus of further prospective studies.

It should be kept in mind that a more liberal use of VDD pacemakers, as in the present study, may be associated with higher rates of VDD failure compared with those found in short term studies on highly selected groups of patients.^{7,10-13} This is most probably related to less rigorous preoperative validation of normal sinus node function.

CONCLUSIONS AND CLINICAL IMPLICATIONS

Based on our experience, optimal anatomical dipole positioning with avoidance of low atrial positions (≥ 6 cm below the carina) is critical for the long term success of proper VDD function, whereas electrical guidance does not seem to influence the outcome. Atrial sensing technology of the selected system may influence the results, but probably to a lesser degree.

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