ATRIAL ARRHYTHMIAS

Efficacy and tolerability of continuous overdrive atrial pacing in atrial fibrillation


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Overdrive right atrial pacing has been used to prevent atrial fibrillation, but its efficacy in atrial fibrillation prevention and the patient tolerability and quality of life during high rate pacing remain uncertain. The objective of this study was to test the effects of a consistent atrial pacing algorithm that automatically paced the atrium at 30 ms shorter than the sinus P-P interval for atrial fibrillation prevention. Fifteen patients with sick sinus syndrome implanted with a Thera DR (model 7940 or 7960, Medtronic Inc.) were randomly programmed to rate adaptive dual chamber pacing (DDDR) or DDDR+consistent atrial pacing mode, each for an 8-week study period. The efficacy of consistent atrial pacing was assessed by the number of automatic mode switching and the number of premature atrial complexes. Symptoms and quality of life were assessed by the SF-36 quality of life questionnaire and an atrial fibrillation symptom checklist. The percentage of atrial pacing increased from 57±32% to 86±28%. Overall, there was no significant difference in the number of automatic mode switching episodes between DDDR and DDDR+consistent atrial pacing (47±90 vs 42±87, P>0.05), but a significant reduction in premature atrial complexes by 74-7%(P<0.001). There was no undue increase in atrial rate by the DDDR+consistent atrial pacing mode versus DDDR (63±13 vs 70±7 bpm). There was no significant difference in quality of life scores and symptom severity on frequency between the two modes of pacing, but a trend towards a lower frequency of symptoms in the DDDR+consistent atrial pacing mode compared with conventional pacing. The algorithm appears to be well-tolerated, but further studies are needed to address the clinical impact of this atrial fibrillation prevention algorithm.

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Key Words: Atrial fibrillation, consistent atrial pacing, prevention of premature atrial complexes.

Introduction

Atrial pacing has been shown to be superior to ventricular pacing in patients with sick sinus syndrome. The risk of developing atrial fibrillation is significantly more common among those with ventricular pacing than atrial pacing[1-6], and atrial pacing may lead to an improved survival[5]. Experimental and human atrial fibrillation can be caused either by a single source of very rapid impulse discharges or by multiple reentrant wavelets that travel randomly through the myocardium. Heterogeneity of atrial electrophysiology has also been reported with atrial fibrillation. All these factors may be modified by atrial pacing.

Single site atrial pacing has been utilized in the prevention of drug resistant paroxysmal, vagally mediated atrial arrhythmias[7]. It eliminates sinus bradycardia and accelerates atrial rates, making atrial repolarization more homogeneous. Atrial pacing is believed to reduce intra-atrial conduction delay by eliminating short long
sequences that can initiate atrial fibrillation. Overdrive atrial pacing also prevents premature atrial complexes and junctional escape beats which can initiate intratrial reentry. However, the role of pacing in atrial fibrillation prevention in patients without a clear vagal initiation is less certain. In a study of efficacy of conventional atrial pacing on atrial fibrillation, dual chamber pacing reduced the frequency of premature atrial complexes, without a significant reduction in the atrial fibrillation burden nor the time to the first atrial fibrillation recurrence compared with no pacing [8]. The use of either biatrial [9] (right atrial and coronary sinus) or dual site atrial pacing [10,11] (high right atrial and posterior right atrial) may have an incremental benefit in atrial fibrillation suppression. The complex implantation technique at present limits their widespread application.

To achieve potential benefits from single or dual site pacing, a prerequisite is to ensure a high percentage of atrial pacing. Most investigators have used a high lower rate limit and aggressive rate adaptive sensor settings in their patients. However, it is uncertain if these manoeuvres can achieve consistent overdrive pacing. In addition, any symptomatic benefit that may result from atrial fibrillation suppression might be counterbalanced by the high rate pacing. The aim of this study was to assess the use of an automatic algorithm, that ensured consistent atrial overdrive pacing, on the frequency of atrial fibrillation recurrence and to evaluate patient tolerability and quality of life when using this new algorithm.

**Materials and methods**

Fifteen consecutive patients with sick sinus syndrome who received DDDR pacemakers were included. Sick sinus syndrome was defined as syncope or near syncope with documented sinus bradycardia (<40 bpm) or sinus pauses >3 s. The atrial and ventricular leads were positioned in the conventional right atrial appendage and right ventricular apex, respectively. Each patient also had paroxysmal atrial fibrillation episodes documented either on echocardiogram or Holter recording before implant. All patients were paced for 4 weeks in the dual chamber mode with the lower and upper rate limits at 60 and 140 bpm, respectively. Then the pacemakers were programmed to the DDDR mode with the consistent atrial pacing function on and off for 2 months each in a randomized crossover fashion. Atrial sensitivity was set to at least three times the sensitivity level needed to detect sinus P waves. All medications were kept constant during the study period.

At baseline, a 12-lead electrocardiogram, 2-dimensional echocardiography, symptom checklist and a validated quality of life questionnaire based on the local version of SF-36 were performed. Pacemakers were interrogated monthly in each phase, whereas echocardiography, symptom checklist and quality of life assessment were performed at the end of each phase.

**Consistent atrial pacing**

Consistent atrial pacing is an injectable (downloadable) pacemaker software from Medtronic Inc. (Minnesota, USA) that can be used with Thera models 7940 and 7960. This algorithm can increase the pacing rate in response to a sensed atrial event. Both the magnitude of increase in rate and the maximum rate of pacing are programmable. When the pacemaker senses an atrial beat, it will pace the atrium at a programmable P-P interval shorter than that which has been sensed. In this study, we used a 30 ms decrement for every sensed atrial beat and a consistent overdrive rate limit of 120 bpm. For example, when the spontaneous sinus rate was 60 bpm, a programmed 20 ms overdrive produced a pacing rate of 61 bpm when the sensed sinus rate was 80 bpm (Fig. 1). To prevent an overly aggressive rate response during exercise, the sensor setting that resulted in a rate of 100 bpm during walking was chosen. Consistent atrial pacing was considered effective if the percentage of atrial paced events was ≥80% of all atrial events. Monthly interrogation of the data log was performed.

**Measurements**

Data available from the telemetry includes (1) number of sensed and paced atrial events, (2) number of premature atrial and ventricular beats, and (3) number of automatic mode switch episodes, up to a limit of 250 episodes. These data were collected on a monthly basis. A premature atrial complex was defined as an atrial activity falling within the atrial refractory period, and was the same for both atrial sensed and atrial paced situations.

Quality of life questionnaire was performed with SF-36 Standard version 1.0 (validated for the local population) and an atrial fibrillation symptom checklist. Inquiry was carried out at baseline, at the end of 2 months of DDDR pacing, as well as at the end of 2 months of DDDR+consistent atrial pacing.

Echocardiography was used to measure ejection fraction and left atrial size at baseline, and at the end of each study period.

Twenty-four hour ambulatory echocardiogram was performed at the end of each study period to determine the average heart rate over 24 h in each mode.

**Statistical analysis**

Data are presented as mean ± SD. As the data are not normally distributed, the differences between the two phases were compared using the Wilcoxon test. P values <0.05 were considered statistically significant.

**Results**

Fifteen patients (six males and nine females) with sick sinus syndrome and a mean age of 70 ± 9 years were
included in this study. Intermittent high degree atrio-
ventricular block was also present in two patients. Other
concomitant medical illnesses included ischaemic heart
disease in four, hypertension in two, diabetes mellitus in
one and a history of minor stroke in one. Cardioactive
medications used included diuretics (eight), beta
blockers (five) and nifedipine (three).

Percentage of atrial pacing and premature
atrial complexes

One patient was excluded from analysis because she developed persistent atrial flutter-fibrillation after
implantation and before the randomized part of the
study. The average percentage of atrial pacing, as calcu-
lated from the data log, increased from 57 ± 32% with
DDDR mode to 86 ± 28% during DDDR+consistent atrial pacing; P<0·05 (Fig. 2).

The number of premature atrial complexes decreased
from 23 450 ± 55 569 counts per month during DDDR
pacing to 5937 ± 8793 counts per month with atrial
overdrive pacing (74·7% reduction, P<0·001) (Fig. 2).

Number of mode switches (Table 1)

Three patients had no documented mode switches
throughout the study period. One patient had more than
250 episodes per month for all 4 months. Overall, there
was no statistically significant difference in the number
of mode switches between DDDR mode and
DDDR+consistent atrial pacing (Fig. 3).

Quality of life and symptoms checklist
(Table 2)

There was no significant difference between the two
modes in the overall quality of life scores. However,
significant improvements were observed with specific
questions. Compared with the baseline, both DDDR
modes reduced the time lost from work due to de-
pression or worries about the medical condition
(P<0·05) and a reduction in bodily pain during daily
activities (P<0·05).

The frequency of symptoms (range 16–80) was
29·5 ± 10·2, 26·3 ± 11·9 and 25·1 ± 9·7 at baseline, during
DDDR and DDDR+consistent atrial pacing mode,

Figure 1 Examples of pacing rate acceleration after a sensed atrial beat. In electrogram 1, a sensed
premature atrial complex at 660 ms is followed by a pacing cycle length of 640 ms if the programmed
decrement is 20 ms. In electrogram 2, a sensed premature atrial complex occurs at 500 ms. The subsequent
pacing cycle length is limited to 500 ms as the programmed maximum overdrive rate limit is 120 bpm to
avoid excessive high rate pacing. In electrogram 3, a premature atrial complex is sensed during the atrial
refractory period and does not change the atrial pacing rate.
respectively. A trend towards lower symptom frequency was observed in the DDDR+consistent atrial pacing mode over the baseline ($P = 0.07$). There was no difference in the severity of symptoms (range 16–48) between baseline and the two pacing modes ($8.6 \pm 7.2, 8.2 \pm 7.0$ and $7.9 \pm 7.0$).

**Holter recording and echocardiography**

The average atrial rates were similar in the two pacing modes, both during daytime and night-time (Table 1). There was no significant change in the ejection fraction ($66 \pm 10\%$ vs $65 \pm 11\%$), left atrial size ($37.7 \pm 9.1$ vs $35.9 \pm 7.0$ mm) and cardiac output ($4.0 \pm 1.2 \text{L.min}^{-1}$ vs $3.7 \pm 0.8 \text{L.min}^{-1}$) as measured by transthoracic echocardiography, between DDDR and DDDR+consistent atrial pacing modes.

**Discussion**

The major finding of this study is that atrial overdrive pacing using an injected pacemaker algorithm (consistent atrial pacing) effectively decreased the number of premature atrial complexes, although this did not result in significant atrial fibrillation episode suppression as measured by the number of mode switch episodes. Overdrive atrial pacing was found to be well tolerated, and did not produce excessively high pacing rates nor symptoms.

Atrial escape beats, when occurring in sinus node or intra-atrial reentry conditions, may initiate paroxysmal atrial tachyarrhythmias. Atrial pacing has been used to suppress atrial tachycardias early in 1980. Besides suppression of atrial escape beats, paced atrial wave front prevented delay in reentrant circuits and made atrial refractoriness more homogeneous\(^{[12]}\). More recently,
overdrive atrial pacing had been proven to be useful in abolishing or reducing arrhythmia recurrence in patients with postoperative atrial reentrant tachycardia in complex congenital heart disease\textsuperscript{13}.

Overdrive atrial pacing has been used to suppress arrhythmia. Murgatroyd et al\textsuperscript{14} studied the short-term effects of premature atrial complexes. In this new algorithm, the pacing rate varied in response to the frequency of premature atrial complexes. According to the Holter recording in that study, there was no significant change in the frequency of premature atrial complexes and atrial fibrillation episodes. This algorithm was well tolerated with no patient being aware of the activation of algorithm. More recently, overdrive atrial pacing is considered to play an important role in patients with early reinitiation of atrial fibrillation after defibrillation\textsuperscript{15}.

In our study, we showed significant reduction in the premature atrial complexes counts with consistent atrial pacing. There was no significant increase in the mean heart rate. Indeed, the recorded average atrial rate by Holter tended to be lower during DDDR+consistent atrial pacing than the rate with DDDR pacing. This was likely related to the suppression of premature atrial complexes which increased the average atrial rate. This also offered the explanation why DDDR+consistent atrial pacing is well tolerated, without symptoms related to overdrive pacing.

In a recent trial of pacing for suppression of atrial fibrillation by high right atrial pacing, Gillis et al\textsuperscript{8} failed to show the benefit of single site DDIR pacing (back-up rate 70 bpm) compared with no pacing. The proposed reasons for the lack of efficacy of pacing for paroxysmal atrial fibrillation included single site pacing, the lack of atrial overdrive and the use of DDIR instead of AAIR mode. We did not find significant reduction in atrial fibrillation episodes with DDDR+consistent atrial pacing using single site pacing, despite the achievement of a high percentage of atrial pacing. This raises the question whether the addition of dual site pacing is necessary for the maximal benefit\textsuperscript{9,10}. This is now the subject of three multicentre trials in patients with\textsuperscript{16} and without\textsuperscript{17,18} bradycardia.

**Limitations**

The number of mode switches was assumed to equal the number of episodes of paroxysmal atrial fibrillation in our study. This basic assumption holds true only if atrial fibrillation is adequately sensed. In addition, the device used did not allow confirmation of episodes of atrial fibrillation by stored electrograms, as this capability was lost after injection of the consistent atrial pacing algorithm. We have previously shown that the efficacy of mode switching is dependent on the programmed atrial sensitivity and the size of atrial signals\textsuperscript{19}. By using a setting of three times atrial sensitivity, we believe that optimal automatic mode switches with atrial fibrillation can be achieved. Another limitation of this study is that the total duration of atrial fibrillation is not known. The total duration in atrial fibrillation, instead of the number of episodes may be another reflection of severity of disease. However, this is not available in the current version of consistent atrial pacing. Lastly, the number of patients studied is small and the duration of observation

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**Table 2** SF-36 quality of life in different pacing modes. Maximum score is 100 for each dimension of quality of life

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>DDDR</th>
<th>DDDR + Consistent atrial pacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical functioning</td>
<td>71.4 ± 18.0</td>
<td>68.9 ± 19.2</td>
<td>70.0 ± 25.6</td>
</tr>
<tr>
<td>Physical role</td>
<td>57.1 ± 46.4</td>
<td>58.9 ± 49.6</td>
<td>83.9 ± 36.2</td>
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<tr>
<td>Bodily pain</td>
<td>68.4 ± 31.7</td>
<td>69.3 ± 26.4</td>
<td>82.4 ± 20.7</td>
</tr>
<tr>
<td>General health</td>
<td>59.9 ± 23.8</td>
<td>60.9 ± 19.1</td>
<td>56.4 ± 24.4</td>
</tr>
<tr>
<td>Vitality</td>
<td>60.3 ± 34.9</td>
<td>49.3 ± 32.5</td>
<td>53.6 ± 30.9</td>
</tr>
<tr>
<td>Social functioning</td>
<td>84.2 ± 19.2</td>
<td>80.4 ± 18.8</td>
<td>80.4 ± 17.5</td>
</tr>
<tr>
<td>Emotional role</td>
<td>52.4 ± 50.2</td>
<td>64.3 ± 46.2</td>
<td>83.3 ± 36.4</td>
</tr>
<tr>
<td>Mental health</td>
<td>73.1 ± 24.8</td>
<td>74.6 ± 22.7</td>
<td>69.7 ± 25.7</td>
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was only for 2 months, thus, we cannot exclude a small benefit of DDDR+consistent atrial pacing over DDDR pacing. However, as most of our patients had high frequency of atrial fibrillation, our results suggest that single site overdrive pacing may not contribute to significant atrial fibrillation suppression in the short term in the type of patients studied.

**Clinical implications**

We have documented the efficacy of atrial overdrive pacing in the suppression of premature atrial complexes. The number of atrial fibrillation episodes was not reduced in this small study. However, consistent atrial pacing can be achieved without an undue increase overall heart rate and was well tolerated. As single site overdrive atrial pacing does not demand extra techniques or expertise, nor does it require any additional hardware during implantation, it can potentially be combined with other atrial fibrillation prevention manoeuvres and therapeutic strategies, such as dual site pacing and in atrial fibrillation suppression after atrial defibrillation.

**Conclusion**

Single site atrial overdrive pacing with consistent atrial pacing effectively decreased the number of atrial ectopies. Although it did not reduce the recurrence of paroxysmal atrial fibrillation in the short term, it was well tolerated and did not cause an undue increase in pacing rate. These results have positive implications on the use of pacing in prevention of atrial fibrillation in patients with conventional pacing.

**References**


