Evaluation of pacemaker telemetry as a diagnostic feature for detecting atrial tachyarrhythmias in patients with sick sinus syndrome

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KEYWORDS pacemaker telemetry; atrial tachyarrhythmias; sick sinus syndrome; pacing

Abstract Aim The aim of the present study was to validate pacemaker telemetry as a diagnostic feature for detecting atrial tachyarrhythmias (AT) during pacemaker treatment in patients with sick sinus syndrome (SSS).

Methods and results Patients with SSS and bradycardia syndrome (n = 28, 20 women), mean age 71 ± 10.3 years, were included. The patients were treated with AAIR (n = 14) or DDDR pacing. At a routine follow-up visit pacemaker telemetry was reset and the patients underwent Holter recording for at least 24 h. Episodes of atrial fibrillation (AF) during Holter recording were compared with episodes of AT detected by the pacemaker. Only episodes of AF lasting for at least 1 min during Holter recording were registered.

AT detected by the pacemaker telemetry was defined as: an atrial high rate episode with a rate of ≥ 220 bpm for ≥ 5 min, atrial sensing with a rate of ≥ 170 bpm in ≥ 5% of total counted beats, mode-switching in ≥ 5% of total time recorded or a mode-switching episode of ≥ 5 min.

Twenty-eight Holter recordings (mean duration 31.5 h, range 20–72 h) were used for evaluation. Ten patients had one or more episodes of AF lasting at least 1 min on their Holter recordings. Nine of these patients had AT detected by their pacemaker telemetry according to our criteria. None of the patients had AT detected by the pacemaker telemetry and not by the Holter recording. The specificity and sensitivity for detection of AT recorded by the pacemaker telemetry in this study was 100% and 90%, respectively. The false-positive rate was 0%.

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Conclusion

Pacemaker telemetry was found to be a reliable tool for detecting AT in patients with SSS.
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Introduction

Atrial fibrillation (AF) is common in a pacemaker population, especially in those with sick sinus syndrome (SSS) and bradytachy syndrome (defined as bradycardia and at least one documented episode of atrial tachyarrhythmia) [1–5], and AF is associated with a worse prognosis [6,7].

Modern pacemakers have diagnostic features which may be used for detecting and quantifying atrial tachyarrhythmias (AT) after pacemaker implant [8–10]. Before considering therapeutic actions based on these findings, it is important to study the sensitivity and specificity for arrhythmia detection by the pacemaker telemetry.

We performed the present study to validate pacemaker telemetry as a diagnostic feature for detecting AT during follow-up of patients with SSS and bradytachy syndrome. The study was performed in a clinical setting where the patients received different types of pacemakers with different AT detecting abilities and algorithms, and, therefore, the information from atrial high rate episodes, mode-switching events and atrial rate histograms were combined.

Methods

Protocol

From January 2001 to April 2003 consecutive patients with SSS and bradytachy syndrome, who were seen for a planned outpatient pacemaker check at Skejby Hospital, Aarhus, Denmark, were asked to participate in the present trial.

All pacemakers were standard rate-adaptive single chamber and dual chamber pacemakers: Guidant (St Paul, MN, USA), St. Jude Medical (Sylmar, CA, USA), Medtronic (Minneapolis, MN, USA). All had the ability to report cumulative numbers of paced and sensed events for a 12-month period.

After resetting the pacemaker telemetry and counters the patients underwent Holter recording for at least 24 h. A standard Holter recorder was used, Tracker (Type TR2) by Reynolds Medical (UK). When the Holter recording finished, the data from the pacemaker telemetry and counters were also retrieved.

The true arrhythmia classification was based upon the real-time printout of the Holter recording. Each recording was converted to digitized format and subjected to routine processing of computerized analysis and manual editing on commercial equipment (Pathfinder 700 (Digital), Ambulatory ECG Analysis System, software version V8.257, Reynolds Medical). An experienced Holter technician on a digitizing board marked the onset and termination of each episode of AF. Episodes of AF lasting for at least 1 min were registered.

AT detected by the pacemaker telemetry was defined as: an atrial high rate episode (AHRE) with a rate of $\geq 220$ bpm for $\geq 5$ min, atrial sensing with a rate of $\geq 170$ bpm in $\geq 5\%$ of total counted beats, mode-switching in $\geq 5\%$ of total time recorded or a mode-switching episode of $\geq 5$ min. It was prespecified that episodes were required to be 5 min or more to be registered as an episode of AT, thereby eliminating both shorter bursts of AT and intermittent ventricular far-field oversensing.

Analysis of pacemaker telemetry was made without knowledge of the results of the Holter recordings, and the Holter technician evaluating the Holter tapes was also blinded to the results of the pacemaker telemetry.

Episodes of AF recorded by Holter monitoring were compared with episodes of AT detected and stored by the pacemaker telemetry.

The Institutional Scientific Ethical Committee approved the study and the patients gave written informed consent.

Pacemaker programming

No change was made to any pacing or sensing parameter for the purpose of this study. The programming of the pacemaker was left as it was programmed during the patients’ latest routine follow-up. Pacemaker models, number of patients with each device and programmable parameters pertinent to AT detection are listed in Table 1. Lower and upper rates and AV delays were individualised. In all patients the rate-adaptive function was active. In all DDD pacemakers the mode-switch was programmed on. Programming of the atrial sensitivity was individualised; most often the most sensitive setting at which no oversensing occurred at the time of programming was chosen.
Our safety margin was a programmed atrial sensitivity not exceeding half the measured P wave amplitude. All atrial leads were bipolar and actively fixed in the high right atrium, decreasing the probability of far-field R wave oversensing. The AHRE detection feature, only available in Medtronic pacemakers, was programmed on. The number of AHRE recorded differed according to the default in different Medtronic models, but the longest episode was always recorded, and this was used to categorise our patients.

**Results**

Twenty-eight patients with SSS and bradytachy syndrome were included (mean age 71±10.3 years, 20 women). The patients were treated with AAIR (n=14) or DDDR pacemakers. All patients had sinus rhythm at inclusion. Twenty-eight Holter recordings (mean duration 31.5 h, range 20–72 h) were suitable for analysis and used for the evaluation. The patients were Holter recorded at a mean of 1.4±1.1 years after their primary pacemaker implantation (range 3 months to 4 years).

Ten patients had one or more episodes of AF lasting at least 1 min during Holter recording. Nine of these patients had AT detected by their pacemaker telemetry according to our criteria as illustrated in **Table 2**. Eight of these nine patients fulfilled the criteria of atrial sensing with a rate of ≥170 bpm in ≥5% of total counted beats (sensitivity 89%). The AHRE feature was available in seven patients, only four of these patients fulfilled the criteria of an AHRE with a rate of ≥220 bpm for ≥5 min (sensitivity 57%). Only one patient had AF recorded during Holter monitoring, without having AT detected by the pacemaker telemetry. This patient had an AAIR pacemaker programmed with an atrial sensitivity of 1.0 mV and an atrial refractory period of 400 ms. The AF episode recorded had a duration of 14 h and a frequency of 64–157 bpm, the rhythm was AF but also including episodes of atrial flutter. None of the patients had AT detected by the pacemaker telemetry without having AF during Holter recordings (Table 3).

Ten of the 19 patients who did not fulfill the criteria for AT diagnosed by the pacemaker telemetry had no mode-switching episodes and no AHRE at all. In eight patients short AHRE or mode-switching episodes were recorded, but without fulfilling our criteria for detecting AT.

In the present study the specificity and sensitivity for detection of AT recorded by the pacemaker telemetry was 100% and 90%, respectively. The false-positive rate was 0%.

**Discussion**

The pacemaker telemetry as a diagnostic feature for detecting AT in a clinical setting was validated. Using the criteria of an AHRE with a rate of ≥220 bpm for ≥5 min, atrial sensing with a rate of ≥170 bpm in ≥5% of total counted beats, mode-switching in ≥5% of total time recorded or a mode-switching episode of ≥5 min we found it a reliable tool for detecting AT during routine follow-up of patients with SSS.

Many patients do not experience symptomatic AT. Holter recording and transtelephonic monitoring studies have demonstrated that asymptomatic episodes exceed symptomatic episodes by 12-fold.
or more, and the risk of complications such as thromboembolism are probably the same [11,12]. In these patients the availability of the pacemaker telemetry as a diagnostic tool may be highly valuable, enabling appropriate anticoagulation and antiarrhythmic medication.

The clinical relevance of detecting AT by the pacemaker telemetry has been proven in a sub-study of the MOST trial [4] including 312 patients. It was observed that AHRE detected by pacemakers in patients with SSS identified patients who were more than twice as likely to die or have a stroke, and six times as likely to develop AF as similar patients without AHRE [13].

In some patients, false-positive detections of AT may occur due to detections of far-field or near-field signals. Oversensing could be caused by near-field P wave, far-field R wave, or T wave detections [8,10]. This may depend on lead positioning as well as programmed parameters including atrial sensitivity. Myopotential oversensing has been found to be very rare with bipolar leads [14].

Evaluation of the Medtronic Thera® atrial high rate diagnostic feature in 17 patients showed a highly reliable detection of AT (sensitivity 98%, specificity 100%) when programmed as follows: detection rate 220 beats/min, detection beats 10, termination beats 20. The Thera® detected 12 episodes of AT as false-positives during four different 24-hour Holter recordings (sinus rhythm was detected as AT). The main reason was far-field R and T wave oversensing [8].

The ELA algorithm for identifying atrial arrhythmias, detected them with 93% sensitivity and 94.2% specificity verified by Holter monitoring [9,15].

In a sub-study of the MOST trial including 312 patients, 47 patients had their AHREs evaluated by Holter recording. In that study the sensitivity and specificity for detection of AF using AHREs recorded by pacemakers was 100% and 97.6%, respectively. The false-positive rate was 2.4% [13].

### Table 2

<table>
<thead>
<tr>
<th>Patients no.</th>
<th>Pacemaker model</th>
<th>P wave amplitude (mV)</th>
<th>Atrial sensitivity (mV)</th>
<th>Atrial refractory period (ms)</th>
<th>MS (one episode 5 min)</th>
<th>AHRE (rate ≥5% of total time)</th>
<th>MS (≥5% of total time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kappa® 700 DDDR</td>
<td>1.0</td>
<td>0.35</td>
<td>250</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>2</td>
<td>Kappa® 400 AAIR</td>
<td>2.8 (4.0)</td>
<td>0.7</td>
<td>330</td>
<td></td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>3</td>
<td>Affinity® SR AAIR</td>
<td>2.8 (2.5)</td>
<td>1.0</td>
<td>400</td>
<td></td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>4</td>
<td>Affinity® DDDR</td>
<td>5.0 (1.0)</td>
<td>0.5</td>
<td>330</td>
<td></td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>5</td>
<td>Kappa® 400 AAIR</td>
<td>4.0 (1.0)</td>
<td>0.5</td>
<td>330</td>
<td></td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>6</td>
<td>Kappa® 400 AAIR</td>
<td>1.0 (1.4)</td>
<td>0.7</td>
<td>330</td>
<td></td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>7</td>
<td>Kappa® 400 AAIR</td>
<td>1.4 (0.7)</td>
<td>0.35</td>
<td>330</td>
<td></td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>8</td>
<td>Kappa® 400 AAIR</td>
<td>5.0 (5.5)</td>
<td>1.0</td>
<td>330</td>
<td></td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>9</td>
<td>Kappa® 400 AAIR</td>
<td>5.5 (5.5)</td>
<td>1.0</td>
<td>330</td>
<td></td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>10</td>
<td>Discovery® AAIR</td>
<td>5.5 (5.5)</td>
<td>1.0</td>
<td>330</td>
<td></td>
<td>×</td>
<td>×</td>
</tr>
</tbody>
</table>

AHRE: atrial high rate episode; MS: mode-switching.

### Table 3

<table>
<thead>
<tr>
<th>Holter recording</th>
<th>+AF</th>
<th>−AF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacemaker telemetry</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>−AT</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>18</td>
</tr>
</tbody>
</table>
detection rate was 220 bpm. Only AHREs lasting at least 5 min were analysed.

Our validation has provided similar sensitivity and specificity results as compared with these prior studies.

In the present study only AHREs with a rate of \( \geq 220 \) bpm for \( \geq 5 \) min were recorded. A detection rate of 220 bpm has been observed to prevent false detection of AT due to far-field R and T wave sensing, 20 termination beats were optimal in preventing brief episodes of undersensing from terminating the episode prematurely and detection beats of 10 offered good sensitivity to detect episodes of all durations [8]. The duration of 5 min was chosen according to Pollak et al., who found that stored AHREs of more than 250 bpm and more than 5 min in duration had a high correlation (88%) with AF and atrial flutter when confirmed by simultaneous stored intracardiac atrial electrograms [16]. The 5-min cutoff excludes most episodes of oversensing.

In our patients the atrial sensitivity was programmed individually. During prior follow-up visits it was set according to the measured atrial amplitude and as sensitive as possible without any oversensing occurring during the programming. If the atrial amplitude was as high as 3–4 mV the atrial sensitivity was set to 1.0 mV. It cannot be ruled out that a sensitivity programmed to 1.0 mV in some patients could cause undersensing of AF, as P wave amplitudes commonly are smaller and have a higher variability during AF than those observed during sinus rhythm. Furthermore, a long atrial refractory period could cause undersensing of AF or atrial flutter.

Atrial oversensing and reaction to short atrial runs may reduce the specificity of the mode-switching feature. In patients implanted with a Medtronic Thera® DR pacemaker the mode-switching episodes were reliable markers of recurrences of PAF. The total duration of PAF during Holter recordings had a strong correlation with the total duration of mode-switching [17]. According to this result and to the optimal programming of the AHRE feature, mode-switching with a duration of 5 min or more was chosen as a criterion in the present study. Mode-switching in more than 5% of total time recorded was arbitrarily chosen.

Furthermore, we used the atrial rate histogram to detect AT. In this elderly population with SSS an atrial rate of more than 170 bpm invariably indicates AT. The criterion of more than 5% of total beats was arbitrarily chosen only to detect a significant proportion of AT. In fact we found that the atrial rate histogram was a very sensitive tool for detecting AT with a sensitivity of 89% compared with the AHRE feature having a sensitivity of 57%.

Of course, the criterion of mode-switching in more than 5% of total time and atrial sensing with a rate of \( \geq 170 \) bpm in \( \geq 5 \)% of total counted beats could be caused by far-field R wave oversensing, but is not very likely as all our patients had bipolar electrodes in the atrium.

The fact that eight patients had short AHREs or mode-switching episodes without having AT documented during Holter recording stresses the need for defining some strict criteria for ensuring correct detection of AT by the pacemaker telemetry before using such results clinically or in research.

The present study documented high reliability of pacemaker telemetry in detecting AT in a clinical setting using different pacemakers with different programming and different AT detecting algorithms.

Limitations

Our population sample was small and the patients were implanted with different pacemakers with different features and programming, in every case chosen by the physician implanting the pacemaker. Therefore, the pacemakers had different abilities and algorithms of detecting AT. Pacemaker parameters such as lower and upper rates and AV delays were individualised. Data on far-field R wave sensing were not prospectively recorded. The AHRE feature was not optimised, often the detection rate, detection duration limit and detection termination limit were left at default settings. The atrial refractory period was also at default setting.

For validation of the AT detection features we did not use storage of the intracardiac atrial electrograms in the pacemaker, which could have been useful to differentiate between real AT and oversensing. However, even with atrial electrograms it is still not possible to differentiate exactly between AF, atrial flutter or atrial tachycardia, as the atrial lead only shows local atrial activity.

Conclusion

Using the criteria of an AHRE with a rate of \( \geq 220 \) bpm for \( \geq 5 \) min, atrial sensing with a rate of \( \geq 170 \) bpm in \( \geq 5 \)% of total counted beats, mode-switching in \( \geq 5 \)% of total time recorded or a mode-switching episode of \( \geq 5 \) min we found them reliable in the detection of AT during routine follow-up of patients with SSS.
Acknowledgements

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References