# Simulation of Monitoring Strategies for Atrial Fibrillation Detection

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## Abstract

*Paroxysmal atrial fibrillation (PAF) is a difficult disorder to investigate because of its intermittent and sometimes asymptomatic nature. The aim of this study was to simulate several daily ECG monitoring strategies applied on data extracted from Burden II Study (patients implanted with pacemaker for Brady-Tachy Syndrome). Daily monitoring strategies were obtained by varying the following key parameters: the hour of the day when the monitoring begins, the duration of the recording during each day, and the number of consecutive days the monitoring lasts. The day when the monitoring starts was randomly chosen over the observational period. We found that a short-term daily ECG monitoring could be optimized if performed starting from 8 AM (almost 50% of diagnosed patients). Temporally-optimized monitoring allows to detect a higher percentage of patients than 1-day Holter monitoring and to be at least as effective as a 7-days 24h monitoring.*

## 1. Introduction

Paroxysmal atrial fibrillation (PAF) is a difficult disorder to investigate because of its intermittent and sometimes asymptomatic nature. The monitoring strategies usually adopted for a PAF patient include sporadic ambulatory ECG control, transtelephonic monitoring, event monitor, sporadic 24h Holter, 7-days Holter. Given the intermittent nature of both arrhythmic events and current monitoring methods, the ability of monitoring strategy to diagnose PAF is highly dependent on whether or not the moment selected for monitoring coincides with the occurrence of PAF episodes.

On the basis of the scientific data available and of socio-economic considerations, an efficient monitoring of AT/AF should consider a daily ECG monitoring at home [1-4].

Of course, care has to be paid for the correct timing of such monitoring, to increase the probability to detect AT/AF episodes. AT/AF onset daily pattern could be of extreme importance for the monitoring of (not-implanted) patients suspected to be prone to atrial arrhythmias, since it could help in determining the day moments when the probability to experience the arrhythmia is higher.

Patients with cardiac implantable devices represent a good experimental model to perform the analysis of the temporal distribution of AT/AF episodes' occurrences, given the ability of such devices to store information about AF and AT episode, such as date and duration [5-8].

The aim of this study was to simulate several daily ECG monitoring strategies for the detection of AF events. Simulations were based on data extracted from Burden II Study (patients implanted with pacemaker for Brady-Tachy Syndrome), reporting date, time and duration of each mode switch episodes.

## 2. Methods and materials

### Study population

In this study, we analyzed data from 250 patients enrolled in Burden II investigation. Burden II study involved patients with brady-tachy syndrome, symptomatic sinus bradycardia, and at least one documented AT or AF episode within 3 months prior to pacemaker implant. Exclusion criteria include: chronic heart failure, angina pectoris, dilated left atrium (>50 mm), prior or intended atriumventricular (AV) node ablation, indication for dialysis/ hemofiltration.

The Burden II study was designed as a multicenter single-blinded randomized trial with crossover between three preventive pacing therapies [9]. Each pacing therapy was active for periods of 3 months. Scheduled follow-ups occurred 1 month postimplant and afterwards every 3 months, up to the tenth month. Antiarrhythmic therapy was unchanged throughout the study follow-up.

Patients were included in the analysis if they had less than 30% of episode misclassification for each follow-up, if they had at least 10 documented episodes of atrial arrhythmias during the observational period, and if they concluded the protocol (all 4 follow-ups).

### Simulation of monitoring strategies

We simulated several daily monitoring strategies by varying the following key parameters: the hour of the day

when the monitoring begins (hour, H), the duration of the monitoring (in minutes, M), and the number of consecutive days the monitoring lasts (days, D). The day when the monitoring starts (day of beginning, DB) was randomly chosen over the 10-months follow-up period (Figure 1). Particularly, 5 simulations with different days of monitoring beginning were performed for any combinations of the key parameters.

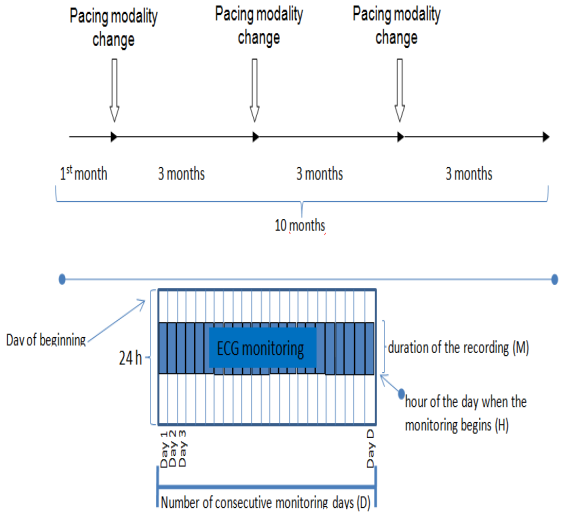


Figure 1. Schematic representation of simulated monitoring strategies.

Key parameters were varied as follows:
H: from 0 AM to 23 PM, 1 hour step;
M: 30, 60 and 120 minutes;
D: 30 and 60 days.

To perform a comparison with the standard 24-h Holter monitoring strategies, we also simulated the classical 1-day ECG monitoring and the more recent 7-days and 30-days ECG monitoring.

Results are presented as the percentage number of AF-detected patients, computed as the ratio between the number of patients experiencing AF during the monitoring period, and thus virtually detected, and the total number of analyzed patients.

## 3. Results

Analysis was performed on 119 patients fulfilling the inclusion criteria, for a total number of more than 11000 AT/AF episodes. Figures 2 and 3 show the results obtained for any combination of the key parameters H, M and D. Particularly, the percentage number of detected patients is reported as a function of H (hour of the day the monitoring starts), for different durations of recording in terms of both number of minutes/day (M) and of number of consecutive monitoring days (D=30 days in figure 2; D=60 days in figure 3).

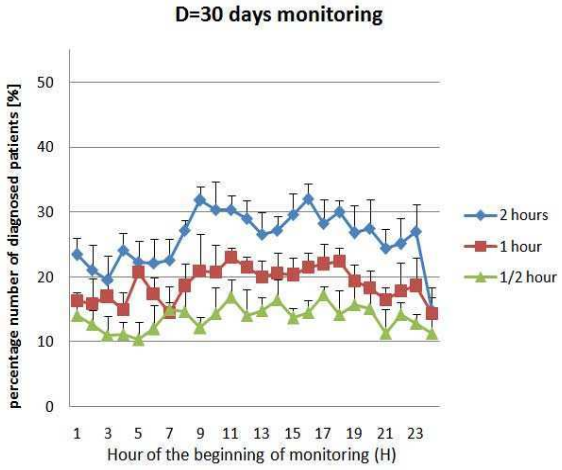


Figure 2. Percentage number of detected patients as a function of H (hour of the day the monitoring starts), for different durations of recording in terms minutes/day (M) and for 30 days of consecutive monitoring.

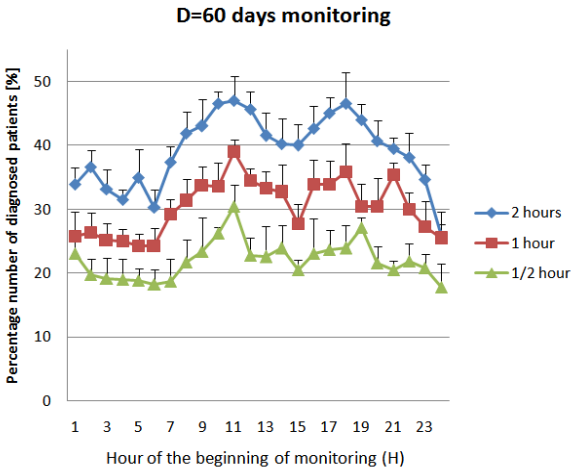


Figure 3. Percentage number of detected patients as a function of H (hour of the day the monitoring starts), for different durations of recording in terms minutes/day (M) and for 60 days of consecutive monitoring.

The number of detected patients varies depending on the hour of the day when the monitoring starts (H), with peaks in the morning (9-10 A.M.). The lowest number of detected patients is obtained at late evening (10-11 P.M.).

A 2-hour ECG daily monitoring temporally optimized to be active between 9-10 AM for 60 consecutive days can detect about 50% of patients experiencing PAF episodes in the observational period; when performed on 30 consecutive days the percentage of detected patients is about 35%. A shorter monitoring (half-an-hour) allows to detect up to 25% (for 60 consecutive days).

These results indicate that a temporally-optimized monitoring should begin at morning, starting at about 9-10 AM.

Figure 4 shows the results obtained from the comparison with the standard Holter ECG monitoring, performed randomly over the observational period. In this figure, the temporally-optimized monitoring is set to begin at 10 AM. Similar results have been obtained when the beginning of recording is set to 8 AM and 10AM.

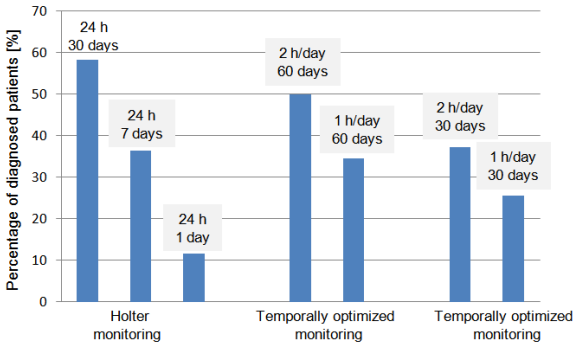


Figure 4. Percentage of virtually diagnosed patients for standard 24h Holter monitoring (lasting 30 days, 7 days and 1 day), and for the temporally optimized one.

One-day and 7-days Holter monitoring turned out to detect about 10% and 35% of patients with AF episodes, respectively. Temporally-optimized monitoring allows to detect a higher percentage of patients than 1-day Holter monitoring. In addition, a 2h/day ECG temporally optimized monitoring turns out to be at least (with D=30) as effective as a 7-days 24h monitoring.

## 4. Discussion

This study analyzed several ECG daily monitoring strategies for AF episode detection. The currently adopted methodologies to monitor the recurrence or the first occurrence of AF are based on the use of one single ECG monitoring performed few minutes in an ambulatory or 24h by an Holter recording system. The day and the moment of the day when this single ECG monitoring is performed is chosen by chance. Given the intermittent nature of the arrhythmia, the current strategies revealed to be less sensitive and specific.

The knowledge of the daily temporal distribution of AF episodes, would be very helpful to detect the presence of specific moments when AF episode are more likely to occur. This information could in turn be used to optimize the ECG monitoring in PAF patients, currently undergone to sporadic ambulatory or 24h Holter ECG recording, with scarce results in terms of AF episodes detection. Recently Arya et al, [3] analysed the accuracy of several follow-up strategies after AF ablation, indicating that the method with a degree of accuracy closer to the theoretic gold standard – or to the implantable device – is the daily ECG. Following this indication, it could be of extreme importance to understand if AF episode occur randomly throughout the day or if there are some moments when the AF is more prone to appear.

Previous attempts to investigate the temporal distribution of AF episodes were based on the retrospective analysis of 24h Holter ECG monitoring or of symptomatic AF episodes [10-17].

The experimental model we used allows us to analyzed AF episodes distribution over a 10-months period, regardless symptoms, overcoming many limitations of the two previously described approaches. After the construction of the database, obtained from implantable devices log files, we could perform an objective analysis of the temporal distribution of AT/AF episodes, in terms of their onset and maintenance.

Our results show that the number of virtually detected patients is highest when the ECG monitoring is performed in the morning starting from 8 AM. Thus it appears that the monitoring of PAF patients would be optimized if it were done soon after the waking up. When compared with standard, and less comfortable, 24h Holter approach, a temporally-optimized ECG monitoring strategies turned out to outperform. Particularly, 1-day Holter monitoring resulted to be a weak strategy to detect patients with PAF, since it can detect only 10% of patients. The 30-days long Holter recording resulted rather suitable to monitor PAF patients. The new simulated strategies based on a temporally-optimized daily ECG monitoring for a short period (1 or 2 hour) turned out to perform better than 7-days Holter technique, being undoubtedly more comfortable.

It is worth noting, however, that the number of detected patients from our database could be an under-estimation of the potential detectable patients from a real population, given the finite number of storable AF episodes on pacemaker memory (64 episodes). So if a patient in the period between 2 follow-ups (3 months) experienced less than 64 episodes, the 3-month period has been correctly monitored by the pacemaker; if the number of AF episodes logged in this 3-month period were 64, it is possible that some occurred episodes are lost, and they cannot be considered for the analysis. Figure 5 gives a representation of this limitation, explaining the two possible scenarios given the finite number of storable AF episodes on pacemaker memory. On the left, some

episodes cannot be included in the database, since more than 64 episodes occurred during the period between 2 follow-ups. On the right, the 3-month period has been correctly monitored by the pacemaker in terms of AF episode occurrences.

However, besides these limitations, the results obtained by this experimental model represent an important indication for the optimization of ECG daily monitoring for PAF or post-ablated patients.

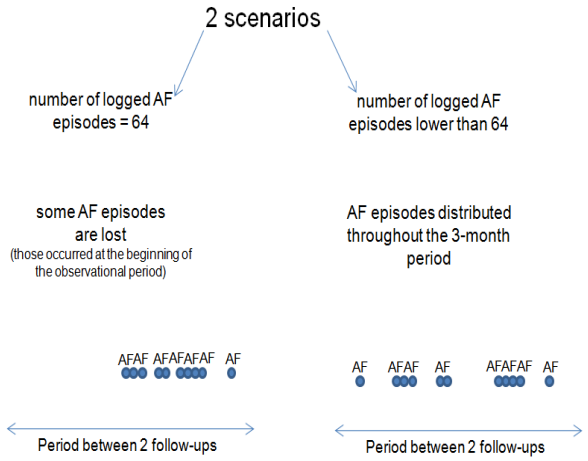


Figure 5. The two possible scenarios given the finite number of storable AF episodes on pacemaker memory.

In conclusion we found that a short-term daily ECG monitoring could be optimized if performed starting from 8 AM (almost 50% of diagnosed patients). Temporally-optimized monitoring allows to detect a higher percentage of patients than 1-day Holter monitoring and to be at least as effective as a 7-days 24h monitoring.

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