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THE EFFECT OF ATRIAL PACING ON THE RISK OF ATRIAL TACHYARRHYTHMIAS IN PATIENTS WITH DUAL-CHAMBER CARDIAC PACEMAKERS: A PILOT STUDY

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Aim. To evaluate the effect of atrial pacing (AP) on the development of atrial extrasystoles and episodes of supraventricular tachycardia in patients with dual-chamber cardiac pacemakers.

Methods. The study included 97 patients who underwent implantation of dual-chamber cardiac pacemakers. The analysis of 169 control examinations in the period from 1 to 20 months after surgery was carried out. The parameters of atrial stimulation, group atrial extrasystoles, and episodes of supraventricular tachycardia were evaluated. The initial data was processed in Microsoft Excel and Access, statistical analysis was performed in Jupyter Notebook (Python 3.x).

Results. A moderate positive correlation was established between atrial extrasystoles and episodes of supraventricular tachycardia ($p=0.623$, $p<0.001$). In the AP group $\geq 91\%$, there was a decrease in the frequency of AT/AF >24 hours ($p=0.060$). Logistic regression showed a significant reduction in the risk of AT/AF >24 hours with AP 51 - 90% (odds ratio 0.31, $p=0.002$).

Conclusion. High level of atrial stimulation may reduce the risk of prolonged episodes of supraventricular tachycardia, however, the effect of atrial stimulation of cardiac pacemaker on episodes of atrial extrasystoles has not reached statistical significance.

Key words: electrocardiostimulation; atrial stimulation; atrial fibrillation; atrial extrasystole; dual-chamber pacemaker; cardiac pacemaker.

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Atrial fibrillation (AF) is one of the most common arrhythmias observed in patients with implanted pacemakers (PMs). AF increases the risk of serious complications such as stroke, heart failure, and all-cause mortality. Importantly, long episodes of AF (lasting more than 24 hours) are most strongly associated with stroke risk [1].

According to the European Society of Cardiology (ESC), the risk of AF in patients with atrioventricular (AV) block and sinus node dysfunction (SND) increases with insufficient atrial pacing [1]. The introduction of adaptive atrial pacing (AP) algorithms is one of the approaches to rhythm disorder prevention and to reducing the incidence of prolonged AF episodes [2-4].

Despite a considerable body of research, the impact of AP on AF risk remains a subject of debate. On the one hand, AP can improve haemodynamics, enhance atrioven-

tricular synchrony, and prevent pathological myocardial remodelling [5]. On the other hand, excessive AP may promote atrial premature contractions (APCs), which in turn increase the likelihood of AF development [6, 7].

We previously published our data on the performance of supraventricular tachycardia prevention algorithms in patients with implanted PMs [8]. The objective of the pres-

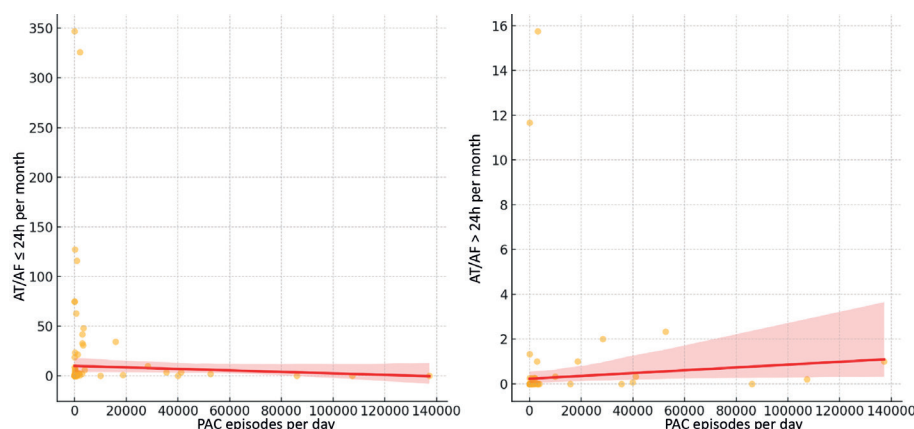


Fig. 1. Analysis of the relationship between PACs and AT/AF lasting no more than 24 hours (a) and more than 24 hours (b). Here and below, PACs = grouped premature atrial contractions; * - it should be noted that the programmer also counts PACs during AF; AT/AF = atrial tachyarrhythmias/atrial fibrillation.

ent study is to evaluate the effect of AP on the risk of AF and APCs in patients who underwent implantation of dual-chamber pacemakers.

METHODS

Study design

This study is a retrospective cohort analysis conducted at the Tver State Medical University Clinic. It included patients who underwent implantation of dual-chamber PMs between January 2022 and August 2024, with a programmed basic pacing rate of 60 bpm.

Inclusion criteria:

- implantation of a dual-chamber PM;
- available data on AP;
- follow-up period of at least 1 month.

Exclusion criteria:

- patients with cardiac resynchronization therapy (CRT) or implantable cardioverter-defibrillators (ICDs);
- insufficient data on atrial tachyarrhythmias (ATs) and/or AF, or AP;
- patients with permanent AF;
- patients with severe structural heart disease requiring surgical correction;
- patients who underwent catheter ablation of ATs prior to inclusion or during follow-up.

Information on antiarrhythmic and other pharmacological therapy was not included in the analysis. Significant baseline clinical differences between groups that could affect the results were not anticipated. Assessment of AP and atrial tachyarrhythmia episodes was based on data obtained from the Medtronic programmer. In Medtronic programmers, atrial tachyarrhythmias are designated as AT/AF; therefore, in this study the same designation (AT/AF) is used. The following parameters were analysed: percentage of AP, number of atrial premature contraction (APC) clusters, and incidence of AT/AF episodes lasting ≤ 24 hours and > 24 hours (AT/AF ≤ 24 and AT/AF > 24 , respectively).

The number of grouped atrial premature contractions (APCs) was assessed per day according to the formula:

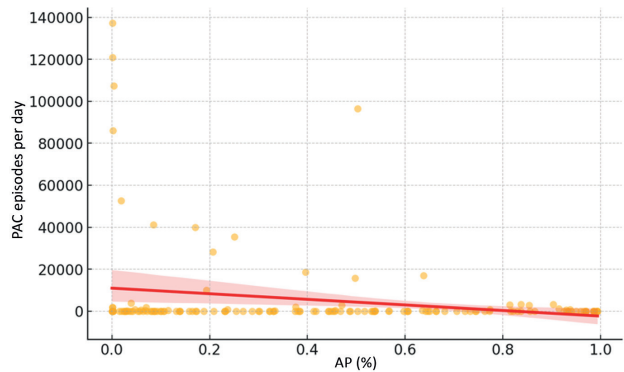


Fig. 2. Analysis of the relationship between atrial pacing and episodes of atrial extrasystole. Here and below, AP = atrial pacing.

Date/Time	Duration hh:mm:ss		Rate (bpm)	
			Max A	Max V
10.03.2025 15:32	17:20:12	Suspended...	> 400	183
High-rate ventricular episodes : 0				
Pacing (% of total):			Event counters	
A pacing	< 0,1%		Single PVCs	23
V pacing	60,1%		PVC runs	1
Reduced VP+	On		PAC runs	79659

Fig. 3. Report data from the programmer of patient E. (see explanation in the text).

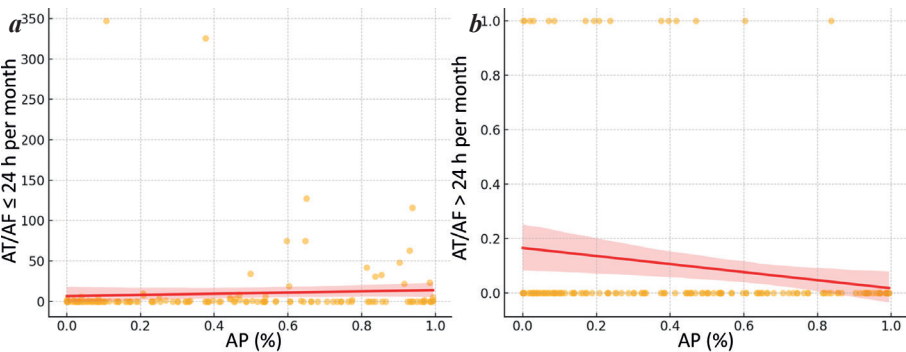


Fig. 4. Analysis of the relationship between atrial pacing and AT/AF episodes lasting no more than 24 hours (a) and more than 24 hours (b).

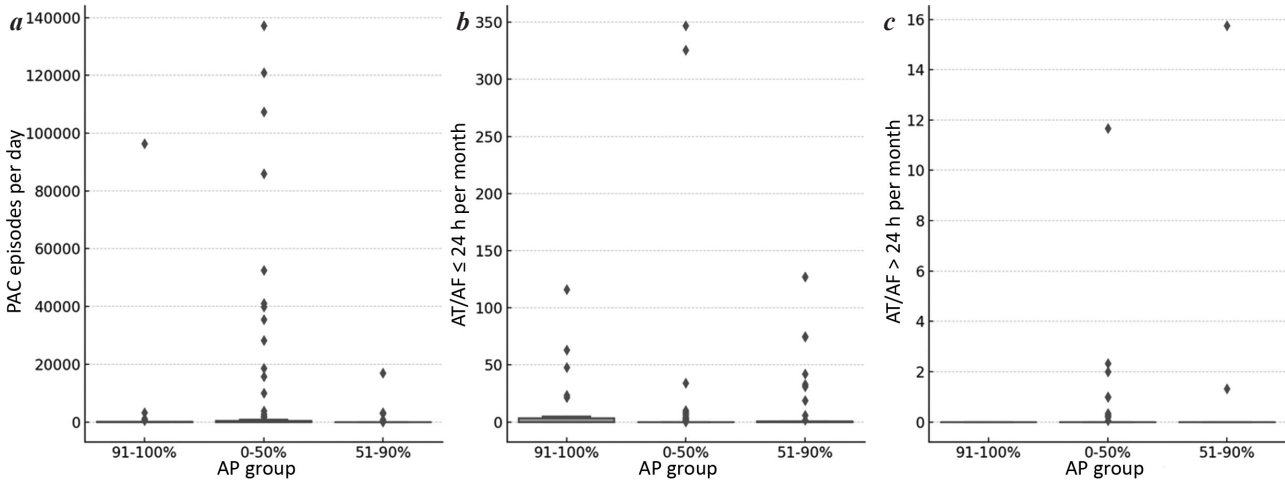


Fig. 5. Comparative analysis of the frequency of grouped PACs (a), AT/AF episodes lasting no more than 24 hours (b), and more than 24 hours (c), depending on the level of AP (AP 0-50%, AP 51-90%, AP 91-100%).

Number of APC episodes per day = Number of APC episodes during the observation period / Observation period, days.

The number of AT/AF episodes lasting no more than 24 hours and more than 24 hours was recalculated as the number of episodes per month. The recalculation was performed using the following formula:

Number of AT/AF episodes per month = Number of AT/AF episodes during the observation period $\times$ 30 / Observation period, days.

Single PACs were not evaluated, as the programmer of this model did not include the corresponding function.

In the first stage, the effect of PACs on the development of AT/AF episodes lasting no more than 24 hours and more than 24 hours was assessed. In the second stage, the effect of atrial pacing (AP) on the number of recorded grouped PACs and on the development of AT/AF ≤ 24 and AT/AF > 24 was evaluated.

Subsequently, patients were divided into three groups according to the percentage of AP: 0-50% (AP 0-50%), 51-90% (AP 51-90%), 91-100% (AP 91-100%) and the impact of AP on the number of PACs per day, AT/AF ≤ 24 and AT/AF > 24 per month was assessed in each group.

Statistical analysis

Patient data were processed using Microsoft Access and Excel. Data analysis was performed with Jupyter Notebook software (Python 3.x). Categorical variables were compared using the chi-square test (χ^2), and continuous variables using Student's t-test or the Mann-Whitney U test. Correlation analysis was conducted using Spearman's correlation coefficient (ρ). Logistic regression was applied to assess predictors of AT/AF. Statistical significance was set at $p < 0.05$.

RESULTS

General characteristics of the study population

The study included 97 patients, of whom 44.3% were men. The mean age at the time of surgery was 68.8 ± 14.3 years. In 32% of cases, a Medtronic DR pacemaker was implanted, and in 68% a Vitatron device. The mean follow-up period was 6.68 ± 4.42 months (ranging from 1 to 20 months). The indications for pacemaker implantation were distributed as follows: AV block - 33.0% of patients ($n=32$), sinus node dysfunction (SND) - 21.6% ($n=21$), and a combination of AV block and SND - 44.3%

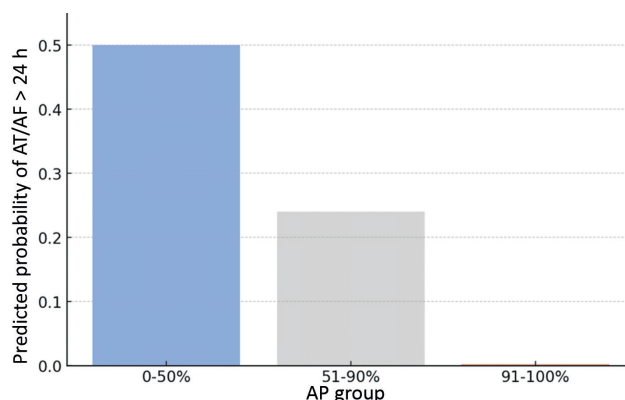


Fig. 6. Probability of AT/AF episodes > 24 h depending on the level of AP (results of Firth logistic regression, 95% CI).

($n=44$). A history of paroxysmal AF was diagnosed in 33.0% of patients.

Association Between PAC Episodes and AT/AF

Figure 1 shows the correlation analysis, which demonstrated a moderate positive association between the frequency of grouped PACs and AT/AF episodes recorded during pacemaker data analysis. Spearman's correlation coefficient $\rho = 0.623$ ($p < 0.001$) indicates a moderate positive relationship between daily PACs and short episodes of AT/AF ≤ 24 hours, while $\rho = 0.443$ ($p < 0.001$) points to a moderate positive relationship between daily PACs and prolonged episodes of AT/AF > 24 hours. Both results are highly statistically significant, confirming the association between an increased frequency of grouped PACs and a higher likelihood of AT/AF. However, the less pronounced correlation with prolonged episodes (> 24 hours) may suggest the influence of additional factors contributing to the chronification of arrhythmia. These findings support the hypothesis regarding the importance of atrial activity control and timely correction of PACs in patients with dual-chamber PMs, which may help reduce the risk of clinically significant AT/AF episodes.

Analysis of the Impact of AP on PAC Episodes

Figure 2 presents a scatter plot illustrating the relationship between AP level and the frequency of daily PAC episodes. Spearman's coefficient $\rho = -0.067$ ($p = 0.752$) indicates no significant association. Linear regression (red line) shows a trend toward a slight decrease in the number of PAC episodes with increasing atrial pacing; however, this does not reach statistical significance. The wide dispersion of values, especially at low levels of AP, indicates considerable variability among patients. The absence of a clear linear trend, confirmed by a low coefficient of determination ($R^2 = 4.6\%$), highlights the limited explanatory power of the model. This suggests the need for a larger sample size and inclusion of additional parameters for a more accurate assessment of the effect of AP on PACs.

It is noteworthy that in some patients, the programmer recorded a very high number of "grouped PACs"—more than 100,000 episodes per day. A detailed examination revealed that this was related to PAC detection algorithms, since such a high number of PACs was observed during episodes of AF. Figure 3 demonstrates programmer data from patient E. during an AF paroxysm. Over 17 hours and 20 minutes of monitoring, 79,659 PAC episodes were recorded, which extrapolates to more than 110,000 per day. Throughout the entire monitoring period, AF was continuously present. Holter monitoring performed during the same time interval also confirmed AF. This situation clearly highlights certain limitations regarding PAC detection in programmer data.

Analysis of the impact of AP on the development of AT/AF

Figure 4 presents graphs of the relationship between AP and the monthly frequency of atrial tachyarrhythmia episodes.

In Figure 4a (AT/AF ≤ 24 h), no clear linear association between AP and short-term AT/AF episodes is observed. The regression line shows only a weak trend toward a reduction in AT/AF ≤ 24 h with increasing atrial pacing, but this effect is minimal. Spearman's coefficient:

$\rho = -0.087$, $p = 0.324$ (not statistically significant). The wide scatter of values suggests variability in the data and possible influence of additional factors. The absence of a clear association between short AT/AF episodes and the percentage of AP may indicate either the predominance of other mechanisms in their occurrence or an insufficient sample size.

In Figure 4b (AT/AF >24 h), a negative correlation was found between AP and the frequency of long-lasting AT/AF episodes. The regression line demonstrates a moderately expressed decrease in the frequency of AT/AF >24 h with increasing AP. Spearman's coefficient: $\rho = -0.312$, $p = 0.002$ (statistically significant). A high level of atrial pacing (AP $\geq 91\%$) shows a trend toward reduced risk of long-lasting AT/AF episodes, which is confirmed by the statistically significant correlation ($\rho = -0.312$, $p = 0.002$).

Analysis of differences between groups depending on AP level

Figure 5 presents the results of a comparative analysis of patient groups stratified by AP level with respect to grouped PACs, AT/AF ≤ 24 h, and AT/AF >24 h. The Kruskal-Wallis test was used to assess differences.

The number of PAC episodes per day did not show a significant association with AP level ($H = 0.57$, $p = 0.752$), and the differences between groups were not statistically significant. This confirms the absence of a clear effect of AP on PACs in the studied cohort.

AT/AF ≤ 24 h showed a tendency to increase with higher AP levels, but the differences between groups did not reach statistical significance ($H = 4.27$, $p = 0.118$). This may indicate that short-term AT/AF episodes are less sensitive to changes in AP level.

AT/AF >24 h demonstrated a tendency toward reduction in the AP 91-100% group; however, $p > 0.05$ ($H = 5.62$, $p = 0.060$). This may suggest a possible protective effect of high AP in preventing long-lasting AT/AF episodes. At the same time, statistical significance was not achieved, which warrants further investigation in a larger sample.

Analysis of the impact of AP on the risk of prolonged AT/AF based on Firth logistic regression

To assess the effect of AP on the risk of prolonged AT/AF episodes, Firth logistic regression was performed. The predicted probability plot demonstrated a reduction in the risk of AT/AF >24 h with increasing AP, with the lowest probability observed in the AP 91-100% group (Fig. 6).

For the AP 51-90% group (compared with the reference group AP 0-50%): $\beta = -1.154$, $p = 0.002$ (statistically significant). The odds ratio of 0.31 indicates a marked reduction in the likelihood of AT/AF >24 h, confirming the protective effect of moderate AP.

For the AP 91-100% group (compared with the reference group AP 0-50%): $\beta = -6.052$, $p = 0.151$ (not statistically significant). Although there was a pronounced reduction in the risk of AT/AF >24 h, the result did not reach statistical significance due to the small sample size.

DISCUSSION

The results obtained demonstrate that a high AP burden may reduce the risk of long (>24h) supraventricular

tachycardia episodes, although its effect on PACs was not significant. These findings are consistent with those of B.L. Wilkoff et al. (2003), who showed that maintaining sinus rhythm with a high percentage of AP can reduce the risk of prolonged AF episodes [9].

Previous studies have pointed to potential mechanisms underlying the protective effect of AP. For example, J.B. Thambo et al. (2016) reported that atrial pacing improves haemodynamics and reduces atrial remodelling [7]. Conversely, C.A. Morillo et al. (2021) noted that excessive atrial pacing may promote arrhythmia in predisposed patients [10]. Our results support this dual role of atrial pacing: in the AP 51-90% group, a significant reduction in the risk of AT/AF >24h was observed (hazard ratio 0.31, $p = 0.002$), whereas in the AP 91-100% group, statistical significance was not reached ($p = 0.060$), which may be explained by the limited sample size.

Correlation analysis confirmed a moderate association between PACs and AT/AF episodes ($\rho = 0.623$, $p < 0.001$), consistent with A.M. Gillis et al. (2017), who demonstrated that atrial extrasystoles may act as triggers for AF onset [2]. However, despite this association, atrial pacing did not have a significant impact on grouped PAC frequency ($p = 0.752$), supporting the hypothesis of the multifactorial nature of AT/AF mechanisms.

Study limitations

Despite the significant findings obtained, this study has several limitations. Its retrospective design does not allow for control over confounding factors during follow-up; the limited sample size constrains the strength of final conclusions; and no analysis was performed of concomitant factors such as structural heart disease, comorbidities, antiarrhythmic and other pharmacological therapy, left atrial volume, or alternative pacemaker algorithms. In addition, the relatively short observation period precludes assessment of long-term outcomes.

To confirm the present findings and enable their translation into clinical practice, further research is required. This should include prospective studies with longer follow-up periods, multivariable analyses incorporating additional parameters (e.g., echocardiography, 24-hour Holter monitoring, comorbidities), and investigations of different pacing algorithms (comparing device models and their specific programming strategies for AF prevention). Such studies would allow for a more precise definition of optimal pacing parameters and support the development of individualised pacemaker programming approaches aimed at AF prevention in patients with diverse cardiac conditions.

CONCLUSION

It may be assumed that atrial pacing exerts a potential protective effect against prolonged episodes of supraventricular tachyarrhythmias and atrial fibrillation. However, definitive confirmation requires further research with larger sample sizes and the application of multivariable analyses that incorporate additional parameters such as left atrial volume, concomitant cardiovascular comorbidities, and alternative pacemaker algorithms.

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