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# Bachmann's Bundle Pacing not Only Improves Interatrial Conduction but Also Reduces the Need for Ventricular Pacing

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**A** – research concept and design; **B** – collection and/or assembly of data; **C** – data analysis and interpretation; **D** – writing the article; **E** – critical revision of the article; **F** – final approval of article

## Abstract

**Background.** Patients treated for sick sinus syndrome may have interatrial conduction disorder leading to atrial fibrillation.

**Objectives.** This study was aimed to assess the influence of the atrial pacing site on interatrial and atrioventricular conduction as well as the percentage of ventricular pacing in patients with sick sinus syndrome implanted with atrioventricular pacemaker.

**Material and Methods.** The study population: 96 patients (58 females, 38 males) aged 74.1 ± 11.8 years were divided in two groups: Group 1 (n = 44) with right atrial appendage pacing and group 2 (n = 52) with Bachmann's area pacing. We assessed the differences in atrioventricular conduction in sinus rhythm and atrial 60 and 90 bpm pacing, P-wave duration and percentage of ventricular pacing.

**Results.** No differences in baseline P-wave duration in sinus rhythm between the groups (102.4 ± 17 ms vs. 104.1 ± 26 ms, p = ns.) were noted. Atrial pacing 60 bpm resulted in longer P-wave in group 1 vs. group 2 (138.3 ± 21 vs. 106.1 ± 15 ms, $p < 0.01$). The differences between atrioventricular conduction time during sinus rhythm and atrial pacing at 60 and 90 bpm were significantly longer in patients with right atrial appendage vs. Bachmann's pacing (44.1 ± 17 vs. 9.2 ± 7 ms $p < 0.01$ and 69.2 ± 31 vs. 21.4 ± 12 ms $p < 0.05$, respectively). The percentage of ventricular pacing was higher in group 1 (21 vs. 4%, $p < 0.01$).

**Conclusions.** Bachmann's bundle pacing decreases interatrial and atrioventricular conduction delay. Moreover, the frequency-dependent atrioventricular conduction lengthening is much less pronounced during Bachmann's bundle pacing. Right atrial appendage pacing in sick sinus syndrome patients promotes a higher percentage of ventricular pacing (**Adv Clin Exp Med 2016, 25, 5, 845–850**).

**Key words:** atrial pacing, sick sinus syndrome, right atrial appendage, Bachmann's bundle, atrioventricular conduction.

The implantation of a permanent pacemaker alters the electrophysiological and hemodynamic relations in a heart. The electrical physiological activation of the atria comes from the sinoatrial node. The left atrium activation is achieved throughout the conductive tissue layer called the Bachmann's bundle, which ensures fast activation within the left atrium producing a single P-wave in a surface electrocardiogram. A slower interatrial conduction takes place in the coronary sinus. The physiological left atrial contraction delay amounts to 22 ± 11 ms in relation to the right atrium [1–3].

The interatrial conduction disorders are relatively common in sick sinus syndrome patients, which contribute to atrial arrhythmias, in particular atrial fibrillation. Moreover, atrioventricular conduction delay is present in up to 20% of them. This last disorder can worsen overtime and ventricular pacing could be needed; however, its course has not been well established in observational or randomized studies. Implantation of the right atrium appendage (RAA) is the reason for the longer atrioventricular and interatrial conduction time, especially in patients with previously existing disorders. Many studies dealing with the altered electrophysiology have shown that the potentially harmful or beneficial effects of pacing are related to its hemodynamic and arrhythmogenic influences. Roithinger et al. studied the total atrial activation time in 28 individuals without structural heart diseases [4]. They studied patients after supraventricular arrhythmias catheter ablation. It was shown that the total activation time is the shortest during the Bachmann's bundle stimulation in comparison to other pacing sites: The ostium of the coronary sinus, its distal part or a high and low lateral wall of the right atrium. The different right atrial pacing sites and their influence on signal-averaged intracardiac electrocardiogram were investigated by Kutarski et al. [5]. The study group consisted of 24 patients during a biatrial pacemaker implantation. The authors observed that the right atrial appendage stimulation prolongs the atrial potential duration recorded by external and internal leads.

The existing data indicates the beneficial influence of Bachmann's bundle pacing in comparison to the standard or even some alternative, i.e. coronary sinus ostium, locations of atrial electrode. Nevertheless, there are none data dealing with interatrial and atrioventricular conduction in paced patients with sick sinus syndrome.

# Objectives

The aim of this study was to prospectively assess the influence of atrial pacing site on interatrial and atrioventricular conduction and the percentage of ventricular pacing in population with SSS implanted with DDD pacemaker.

# Material and Methods

The study group consisted of 96 patients (58 women and 38 men aged 74.1 ± 11.8 years) in whom dual chamber pacemakers were implanted for primary diagnosed sick sinus syndrome. The patients selected for this analysis presented spontaneous sinus bradycardia during the implantation procedure and more than 80% of atrial pacing during first follow-up visit, which usually took place 4 weeks after the procedure. The exclusion criteria involved the presence of atrial fibrillation during the follow-up and the lack of atrial pacing at rest during the visit in pacemaker outpatient clinic.

Patients were divided into two groups: Group 1 (n = 44) with RAA pacing, group 2 (n = 52) with Bachmann's area pacing. The Bachmann's bundle implantation technique included a more rigid stylet curved into a smaller J shape in comparison with the classic one dedicated to RAA location and also included a combined counter clockwise movement of the electrode during its retraction, pointed to the left side of the patient's thorax. The electrode in the PA fluoroscopy position shows no or only a very small tip movement in comparison to the RAA location. The proper placement was also assessed in 30º LAO fluoroscopy.

The patients were implanted with Verity ADx dual chamber pacemakers (St. Jude Medical). Immediately after the implantation, all the pacemakers were identically programmed. The devices were set to 60 bpm with a fixed atrioventricular delay of 220 ms, without rest/night rate, rate response function or hysteresis.

During the first follow-up visit, differences in atrioventricular conduction in sinus rhythm and AAI 60 and 90 bpm pacing were assessed using a pacemaker programmer (St. Jude Medical). Also P-wave duration in sinus rhythm and during atrial pacing as well as percentage of ventricular stimulation were compared. The duration and morphology of P-waves was assessed in lead I, II and V1 of ECG tracings at a paper speed of 50 mm/s and 20 mm/mV magnitude, not including pacing artifact by one independent cardiologist in training, blinded to the study data.

All the investigated patients and control subjects were informed in detail about the objective and course of the study and gave their consent.

The study protocol was approved by the Bioethical Committee, Wroclaw Medical University.

## Statistical Analysis

The investigated parameters were presented as mean values and their standard deviations. The significance of differences in the parameters during spontaneous sinus rhythm, 60 bpm and 90 bpm AAI pacing was evaluated by means of a non-parametric Wilcoxon rank-sum test. Differences in the studied parameters between groups were evaluated by means of a non-parametric Mann-Whitney U test. The significance of correlations between investigated variables was determined by means of Spearman's correlation coefficient. The $\chi^2$ test was used to examine the differences with categorical variables. The values of $p < 0.05$ were considered statistically significant.

The STATISTICA 10 statistical software (StatSoft Inc., Tulsa, USA) was used to perform all statistical analyses.

## Results

The investigated populations did not differ with respect to age, sex, spontaneous heart rate or comorbidities. Eighty-five percent of all the patients studied had arterial hypertension treated according to the clinical needs with a single drug or the combinations of ACE inhibitors, diuretics, dihydropyridine calcium channel blockers and beta-blockers. No therapeutic scheme included a non-dihydropyridine calcium channel blocker.

Table 1 presents demographic and clinical data of the investigated population.

There were no differences in baseline P-wave duration in the sinus rhythm between the groups (102.4 ± 17 ms vs. 104.1 ± 26 ms, p = ns.). Atrial pacing 60 bpm revealed longer P-wave duration with atrial lead location in RAA in comparison to Bachmann's bundle region (138.3 ± 21 vs. 106.1 ± 15 ms, $p < 0.01$). In group 2 the P-wave morphology (lead I, II and V1) was more comparable with sinus P wave. The morphology was assessed as monophasic or only slightly notched (less than 10 ms interval between the peaks) positive P-wave in lead II. This criterion was fulfilled in 18 patients in group 1 and in 42 patients in group 2 ($p < 0.001$).

The differences between atrioventricular conduction time during sinus rhythm and atrial pacing at 60 and 90 bpm were significantly longer in patients with RAA vs. Bachmann's pacing,

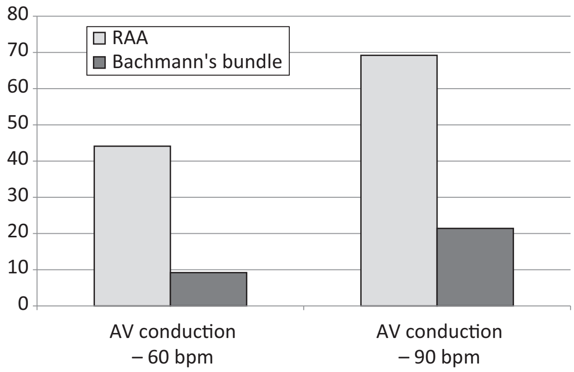


**Fig. 1.** The differences between atrioventricular conduction time during sinus rhythm and atrial pacing at 60 and 90 bpm in patients with RAA vs. Bachmann's bundle pacing

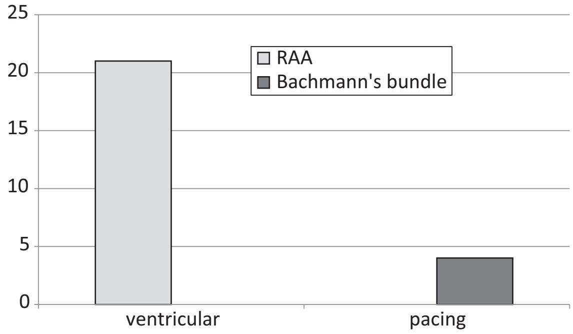


**Fig. 2.** The percentage of patients with ventricular paced pre-excitation at established pacing setting

(44.1 ± 17 vs. 9.2 ± 7 ms $p < 0.01$ and 69.2 ± 31 vs. 21.4 ± 12 ms $p < 0.05$, respectively), which was depicted in Fig. 1.

The percentage of patients with ventricular paced pre-excitation (fusion beats) at abovementioned pacing setting was higher in group 1 (21 vs. 4%, $p < 0.01$), which was shown in Fig. 2.

**Table 1.** Demographic and clinical data of the investigated patient groups

| | Group I (RAA) | Group II (Bachmann) | p-value |
|---|---|---|---|
| Age (years) | 73.4 ± 11.9 | 74.8 ± 11.5 | ns. |
| Sex (female %) | 22.7 | 25.0 | ns. |
| Spontaneous HR (bpm) | 52.4 ± 3.8 | 54.8 ± 4.3 | ns |
| Paroxysmal atrial fibrillation (%) | 43.2 | 46.2 | ns. |
| Hypertension (%) | 86.6 | 84.6 | ns. |
| Beta-blocker use (%) | 59.1 | 61.5 | ns. |
| BMI (kg/m$^2$) | 29.6 ± 2.8 | 29.2 ± 2.6 | ns. |
| LA (mm)<br>Median (IQ range) | 43.3 ± 6.2<br>43 (7) | 44.0 ± 5.6<br>44 (8) | ns. |
| EF (%)<br>Median (IQ range) | 62.9 ± 8.9<br>65 (10) | 63.0 ± 7.8<br>65 (6) | ns. |

## Discussion

The method of choice of assessing electrical activity in the atria includes a measurement of the P-wave duration in a surface electrocardiogram. Certain evidence indicates that the prolongation of the P-wave width as intra- and interatrial conduction disorders sign is related to atrial arrhythmia episodes. As the atrial arrhythmia is a substantial compound of sinus node disease, the first and most important finding of our study is that the implantation of an atrial electrode and pacing of the Bachmann's bundle area results in upholding or nearly restoring a physiological atrial activation pattern in comparison to the right atrial appendage placement. Prolongation of the P-wave duration was related to a higher risk of atrial fibrillation episodes and a risk of atrial fibrillation in a postoperative period [6–8]. The duration of the P-wave (lasting more than 120 ms) concomitantly with typical morphology in the inferior ECG leads (biphasic (+/–) or notched (+/+)), was an indicator of interatrial conduction disturbances and a greater risk of atrial arrhythmia in a few studies [6, 9, 10]. Taking this into consideration, our results indicate also that the Bachmann's bundle electrode placement is a better pacing site than RAA. Kristensen et al. [11] assessed these parameters during a sinus rhythm and during 70 and 100 bpm atrial pacing with the electrode located within the interatrial septum and the high right atrium. The duration of the P-wave during high atrium pacing was much longer comparing to septal placement.

The aforementioned atrial conduction abnormalities in patients undergoing the pacemaker implantation coexist with a chronotropic dysfunction as a primary cause of device placement. A non-physiological atrial electrode placement in individuals with such pre-existing disturbances brings about its worsening. The alternative atrial pacing locations and the P-wave duration were assessed in a number of small studies. They showed that the right atrial appendage pacing resulted in the longest duration of activation within both atria as compared to the Bachmann's bundle and the interatrial septum [4, 12–15]. The stimulation of the interatrial septum is deemed by many researchers to be the best pacing placement with regards to the activation time of both atria, which seems to be in line with the theoretical model [16, 17]. In some studies this kind of atrial pacing was also combined with paroxysmal atrial fibrillation prevention [18, 19]. The most important factor influencing the study results and the clinical effect in a particular population was the interatrial conduction disorder leading to the electrical and/or hemodynamic deterioration and subsequent atrial fibrillation. The results of some investigations suggest that the disorders of interatrial conduction affect approximately 30% of sick sinus syndrome patients and up to 12% of individuals with atrioventricular conduction problems [20].

Interatrial and intraatrial conduction disorders result in the loss of synchrony of atrial contractions, being particularly important to the left atrium. The mechanical effects of changed left atrium contraction sequence has a profound impact on its systolic function. The improper time relations of left atrium vs. left ventricle and left ventricular diastolic and systolic function lead to pressure overload of left atrium as well as its remodeling and enlargement [21].

The beneficial hemodynamic changes resulting from interatrial septum stimulation were observed in the investigation of Miyazaki et al. [22]. The authors showed that the atrial depolarization shortening by such pacing pattern also shortens the difference in contraction of both atria assessed as the difference between the A-wave peak of tricuspid and a mitral diastolic flow. During a 2-year long follow-up the mitral diastolic flow increased and the left atrium dimensions decreased. The study patients already had a history of atrial fibrillation events and a delay of interatrial conduction.

The parameters of atrial activation were investigated by Bennet using an electrophysiological invasive study with a single and 2 pacing sites in the right atrium [13]. The positions studied involved the following: A right atrium appendage, ostium of coronary sinus, the interatrial septum and then simultaneously: coronary sinus ostium and a right atrium appendage. The assessed parameters included the duration of the activation of both atria, atrioventricular conduction time and a synchronous activation of both atria. The total activation of the atria lasted much longer during the pacing of the appendage of right atrium in comparison to septal, coronary sinus ostium and biatrial pacing. The right atrium appendage stimulation resulted also in a longer atrioventricular conduction. Taking into account the conclusions from this study indicating similar effects of septum, coronary sinus and biatrial pacing there is a strong suggestion of the benefits from interatrial septal pacing, keeping in mind that the implantation procedure is relatively simple in comparison to the coronary sinus cannulation. The results and conclusions are against the biatrial pacing using two electrodes and not carrying any additional benefits from this stimulation approach.

Bailin et al. assessed the group of 57 patients implanted with the atrial electrode positioned in the appendage of right atrium which was compared to the 63 patients with the pacing of Bachmann's bundle [12]. The paced P-wave was significantly shorter in the Bachmann's bundle pacing group comparing to the sinus rhythm P-waves, whilst the right atrium appendage stimulation gave a longer P-wave. In a follow-up period the patients with Bachmann's bundle stimulation were free from atrial fibrillation for a longer time as compared to other electrode location. The implantation procedure duration did not differ significantly between the two groups indicating the safety and feasibility of the Bachmann's bundle implantation. No differences were also observed with regards to the pacing thresholds, P-wave sensing parameters and pacing impedance among the studied patients during the implantation and after 6, 24 and 52 weeks.

The second important result of our study was the shorter atrioventricular conduction resulting from Bachmann's bundle pacing compared to RAA pacing. The difference increased much further by higher atrial pacing rate, which was already described by Kristensen et al. [11]. To the best of our knowledge there are only a few reports dealing with this problem, including our own data [15]. The broad implementation of Bachmann's bundle pacing would contribute to the reduction of the unnecessary ventricular pacing and its known deleterious consequences. This is surprisingly not in line with many efforts to avoid ventricular pacing not only by device programming but also by sophisticated pacemaker algorithms. Recently, Watabe et al. in the study of 102 dual-chamber pacemaker recipients with SSS concluded that low septal pacing results in shorter atrioventricular conduction [23]. This is concordant with results of that Miyazaki et al. observed in a group of 202 patients [24]. From the anatomical point of view this kind of electrode placement enables achieving even shorter atrioventricular conduction, but this result could detrimentally influence the atrial mechanical function. Therefore, the implantation pattern used in our study seems to be optimal in these patients to avoid ventricular pacing. The slight shift of the electrode tip toward the front of the interatrial septum can shorten intrinsic atrioventricular conduction, which in fact was observed by us in individual patients. The short follow-up period of our study was not set to assess the antiarrhythmic influences of the Bachmann's bundle pacing but longer observation could provide us with this kind of data. Further clinical investigations regarding long-term hemodynamic consequences of different atrial pacing sites are necessary to introduce the optimal atrial electrode placement into the pacing guidelines.

The Bachmann's bundle pacing decreases interatrial and atrioventricular conduction delay. Moreover, the frequency-dependent atrioventricular conduction lengthening is much less pronounced during Bachmann's bundle pacing. In SSS patients the right atrium appendage pacing promotes atrioventricular conduction disorders, which results in a greater percentage of ventricular pacing in DDD mode.

## References


[1] **Wang K, Xiao HB, Fujimoto S, Gibson DG:** Atrial electromechanical sequence in normal subjects and patients with DDD pacemakers. Br Heart J 1995, 74, 403–407.

[2] **Rein AJ, O'Donnel CP, Colan SD, Marx GR:** Tissue velocity Doppler assessment of atrial and ventricular electromechanical coupling and atrioventricular time intervals in normal subjects. Am J Cardiol 2003, 92, 1347–1350.

[3] **Zhang Q, Kum LC, Lee PW:** Effect of age and heart rate on atrial mechanical function assessed by Doppler tissue imaging in healthy individuals. J Am Soc Echocardiogr 2006, 19, 422–428.

[4] **Roithinger FX, Abou-Harb M, Pachinger O, Hintringer F:** The effect of the atrial pacing site on the total atrial activation time. Pacing Clin Electrophysiol 2001, 24, 316.

[5] **Kutarski A, Głowniak A, Szczęśniak D, Ruciński P:** Effects of different atrial pacing modes evaluated by intracardiac Signac-averaged ECG. Cardiol J 2008, 15, 129–142.

[6] **Bayes de Luna A, Cladellas M, Oter R:** Interatrial conduction block and retrograde activation of the left atrium and paroxysmal supraventricular tachyarrhythmia. Eur Heart J 1988, 9, 1112–1118.

[7] **Buxton A, Josephson M:** The role of P-wave duration as a predictor of post-operative atrial arrhythmias. Chest 1981, 80, 68–73.

[8] **Frost L, Lund H, Pilegaard H:** Re-evaluation of the role of P-wave duration and morphology as predictors of atrial fibrillation and flutter after coronary artery bypass surgery. Eur Heart J 1996, 17, 1065–1071.

[9] **Watson RM, Josephson ME:** Atrial flutter. 1. Electrophysiologic substrate and mode of initiation and termination. Am J Cardiol 1980, 45, 732–736.

[10] **Cohen J, Scherf B:** Complete interatrial block (atrial dissociation). Am Heart J 1965, 70, 24–34.

[11] **Kristensen L, Nielsen JC, Mortensen PT:** Sinus and paced P-wave duration and dispersion as predictors of atrial fibrillation after pacemaker implantation in patients with isolated sick sinus syndrome. Pace 2004, 27, 606–614.

[12] **Bailin SJ, Adler S, Giudici M:** Prevention of chronic atrial fibrillation by pacing in the region of Bachmann's bundle: Results of a multicenter randomized trial. J Cardiovasc Electrophysiol 2001, 12, 912–917.

[13] **Bennett DH:** Comparison of the acute effects of pacing the atrial septum, right atrial appendage, coronary sinus os, and the latter two sites simultaneously on the duration of atrial activation. Heart 2000, 84, 193–196.

[14] **De Voogt WG, van Mechelen R, Scheffer M:** Electrocardiographic characteristics in low atrial septum pacing. J Electrocardiol 2005, 38, 166–170.

[15] **Skoczyński P, Sławuta A, Gajek J:** Influence of different atrial lead positions on interatrial and atrioventricular conduction and percentage of ventricular stimulation in population with SSS treated by atrioventricular pacing. Eur Heart J 2010, 31, Abstract Supplement, 263.

[16] **Spencer W, Zhu D, Markowitz T:** Atrial septal pacing: A method for pacing both atria simultaneously. Pacing Clin Electrophysiol 1997, 20, 2739–2745.

[17] **Katsivas A, Manolis AG, Lazaris E:** Atrial septal pacing as a method to synchronize atrial depolarization in patients with delayed interatrial conduction. Pacing Clin Electrophysiol 1998, 21, 2220–2225.

[18] **Padeletti L, Porciani MC, Michelucci A:** Interatrial septum pacing: A new approach to prevent recurrent atrial fibrillation. J Interv Card Electrophysiol 1999, 3, 35–43.

[19] **Manolis AG, Katsivas AG, Vassilopoulos C:** Prevention of atrial fibrillation by inter-atrial septum pacing guided by electrophysiological testing, in patients with delayed interatrial conduction. Europace 2002, 4, 165–174.

[20] **Ausubel K, Klementowicz P, Furman S:** Interatrial conduction during cardiac pacing. Pacing Clin Electrophysiol 1986, 9, 1026–1031.

[21] **Satoh T, Zipes DP:** Unequal atrial stretch id dogs increases dispersion of refractoriness conductive to developing atrial fibrillation. J Cardiovasc Electrophysiol 1996, 9, 833–842.

[22] **Miyazaki H, Noma K, Date T:** Atrial septal pacing to resynchronize atrial contraction and improve atrial transport function. J Cardiol 2005, 45, 239–246.

[23] **Watabe T, Abe H, Kohno R:** Atrial pacing site and atrioventricular conduction in patients paced for sinus node disease. J Cardiovasc Electrophysiol 2014, 25, 1224–1231.

[24] **Miyazaki H, Miyanaga S, Shibayama K:** Beneficial effect of alternative site pacing from right atrial mid-septum in patients with bradycardia-tachycardia syndrome. Eur Heart J 2013, 34, Abstract Supplement, 490.


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