Biatrial and Coronary Sinus Pacing-
Long-term Experience with 264 Patients

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Summary

For the last few decades, the scope of electrotherapy of the heart has expanded from purely live-saving measures to restoring the patient's quality of life. Moreover, the gap between the once distinct disciplines of antitachycardic and antibradycardic treatment is being closed. One "connecting" topic that has sparked much interest of late is the prevention of supraventricular tachycardias through cardiac pacing. Presumably due to a reduced dispersion of refractoriness and higher conduction velocities, cardiac pacing in the atria suppresses the development of supraventricular tachyarrhythmias to a large extent. This article investigates the prevention of atrial flutter (AFl) and atrial fibrillation (AF) by either pacing both atria simultaneously (biatrial pacing) or pacing the coronary sinus with high energy. Both approaches show excellent results, with up to 90 % of the patients with AFl and AF showing no recurrence at the 3-month follow-up. In these studies, standard bipolar leads were used for stimulating the CS. Additional, preliminary results with new leads, specifically designed for use in the CS, are presented, which show a dislocation rate of only 1/22.

Key Words

Prevention of atrial tachycardias, biatrial pacing, coronary sinus, CS-leads

Introduction

Atrial fibrillation (AF) is one of the most frequently observed supraventricular tachyarrhythmias. The overall prevalence is 0.5 % and increases with age, reaching values from 4 to 14 % in patients of 64 years of age and older [1]. Apart from symptoms like nausea, palpitation, fatigue, sweating, dyspnea, vertigo, and anxiety, paroxysmal AF bears the danger of converting into chronic AF, a conversion that is accelerated by "remodeling"-effects in the myocardium [2]. Chronic AF results in loss of atrial function with two major consequences. One is a decrease in cardiac output due to incomplete atrial contraction and missing AV synchrony. Patients with advanced cardiac diseases in particular would benefit from the hemodynamic improvement following recovery of atrial functionality. Another risk of AF is that the slowed atrial blood flow promotes formation of intracardiac thrombi. As much as 5 % of the patients suffering from AF develop thromboembolism without anticoagulation treatment [3]. Due to these consequences, the treatment of AF, whether with drug therapy, invasive methods, or cardioversion, is an important issue in tachyarrhythmia management.

Even more appealing is the idea to prevent atrial tachycardias before they are established, thus avoiding both the consequences of AF and the side effects of its termination. Originally introduced to treat bradyarrhythmias, cardiac pacing was shown to prevent AF in patients with vagally mediated paroxysmal fibrillation [4] and bradycardia-tachycardia syndrome [5] in the 80s. Since then, the antitachycardic effect of cardiac pacing has been demonstrated in several retrospective studies for patients with sick sinus syndrome [6-8]. While the preventative effect of cardiac pacing on AF is generally undisputed, the best stimulation site is still a topic of discussion. Besides single-site pacing at the interatrial septum [9] and from the coronary sinus (CS) [10], two major approaches exist that represent multi-site pacing. The first, proposed by Saksena et al., consists of pacing the high right atrium and the ostium of the

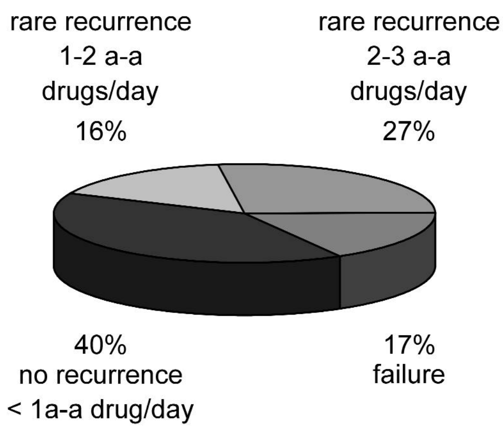

Figure 1. Preventative effect of BAP on AFl. 83 % of the patients (n = 64) had less recurrences after stimulation of both atria (a-a = antiarrhythmic drugs).

coronary sinus simultaneously [11]; the second approach of Daubert and coworkers is based on pacing both atria, reaching the left one via the CS [12].

In this article, we report our experience with the prevention of atrial tachyarrhythmias using either biatrial pacing (BAP) or exclusive pacing from the CS with high energies. Furthermore, our clinical results are presented for both the standard bipolar (BP) leads used for CS pacing and the leads especially designed for the CS.

Materials and Methods

Of 1950 consecutive patients, 264 (mean age 66 ± 10 years) were paced from the CS due to the following reasons: problems with lead fixation in the right atrial appendage (RAA), severe RAA lead exit block, repeated dislocation of the RAA lead, hypertrophic and dilated cardiomyopathy (to avoid pacemaker syndrome and ventricular capture), and several weekly recurring atrial arrhythmias. They were implanted with standard BP electrodes in the CS. In addition, 64 patients received a second, typically j-shaped electrode in the right atrium, thus having biatrial pacing capabilities. Of the patients exclusively paced from the CS, 103 patients were paced in the AAI mode, whereas the 97 who depended on ventricular stimulation were set to DDD mode after the implantation of standard ventricular leads.

In the group with permanent biatrial stimulation (n = 64), the right atrial lead was connected to the atrial channel of a DDD pulse generator (Dromos or Physios, both BIOTRONIK) in 44 patients. Stimulation of the CS could be achieved by using the ventricular channel. In this configuration, it was possible to stimulate the right, left, or both atria by applying AAI, VVI, or DDD mode, respectively. In this case, the AV delay represents the time between right and left atrial stimulation in DDD mode. It was set to the minimum value of 15 ms. In 20 patients, a combined electrode was used in a bipolar configuration. Of those 20, in 7 patients, it delivered the cathodic pulse to the right atrium (comparable to [12]); and in the remaining 13 patients, the polarity of the atrial electrodes was switched, delivering the cathodic pulse to the CS.

Follow-ups took place monthly (presently, the total follow-up period has reached 6 months), including one examination one week after implantation. The documented measurement values included P-wave amplitudes, atrial thresholds, intracardiac electrograms (IEGM), and surface ECGs. The IEGMs were used to deduce the total atrial activation time (TAAT), which extends from either the onset of the P(II)-wave in sinus rhythm or the pacemaker spike to the end of the P-wave measured in the opposite atrium. The P-wave duration was taken from the ECG in the second deviation (p(II)-wave duration).

Results

1. Prevention of atrial tachycardias with permanent biatrial pacing (n = 64)

Figure 1 shows the preventative effect of permanent resynchronization of both atria in 64 patients. All patients in this group had several episodes of atrial flutter (AFl) per week before the BAP system had been implanted. Twenty-five patients had no recurrent arrhythmia and took less than one type of antiarrhythmic medication per day. Twenty-seven percent of the patients showed rare recurrence of AFl, receiving 2 to 3 types of antiarrhythmic medication per day. A third group of patients (16 %) were treated with 1 to 2 antiarrhythmic drugs per day. The attempt to prevent AFl with BAP failed in only 17 % of the study group. In this subgroup, labeled "failure," either no preventative effect was detectable, dislocation of the CS-lead or exit block appeared, or AF developed. By using specially designed CS-leads (see below), this quota is expected to decrease, for instance, because of a lower incidence of dislocation.

An explanation for the good preventative effects of BAP can be derived from observing the electrophysio-

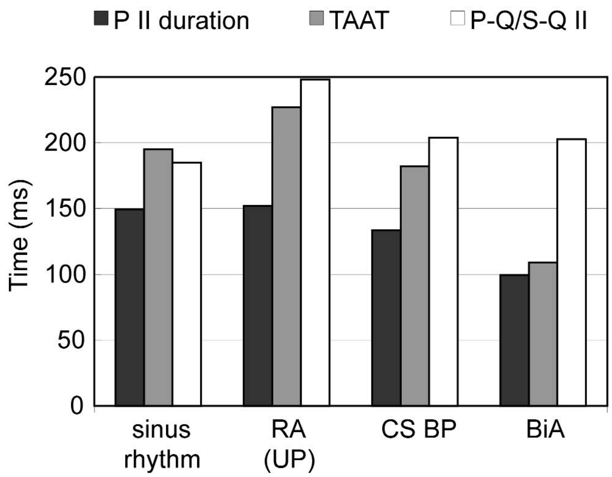

Figure 2. Different electrophysiologic quantities as a function of pacing mode. Biatrial pacing ensures the fastest activation of the atria, thus offering an explanation for its preventative antitachycardic effect (TAAT = total atrial activation time).

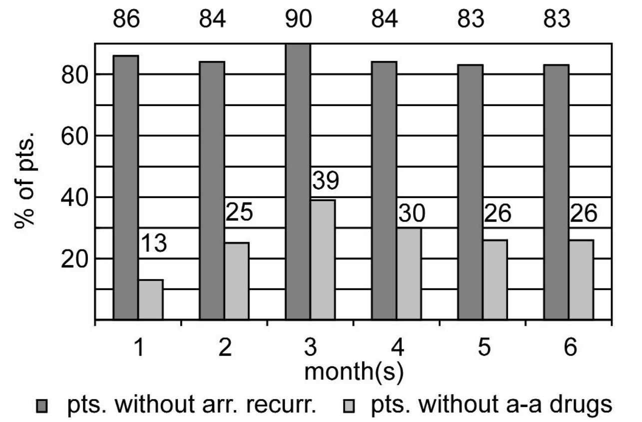

Figure 4. Pacing the atria from the CS with high energies (4.8 to 6.0 V) leaves more than 80 % of patients suffering from AF and AFl without recurrence of the atrial arrhythmias and, furthermore, makes antiarrhythmic drugs unnecessary for some patients.

logic quantities in the selected group, as depicted in figure 2. The P-wave duration of 150 ms in sinus rhythm indicates that the patients had serious interatrial conduction block (IACB). Both single CS pacing and biatrial stimulation led to faster atrial activation, resulting in a physiologic P-wave duration of 100 ms in the latter case. Another parameter representing the speed of atrial activation is the TAAT, which is indicated with

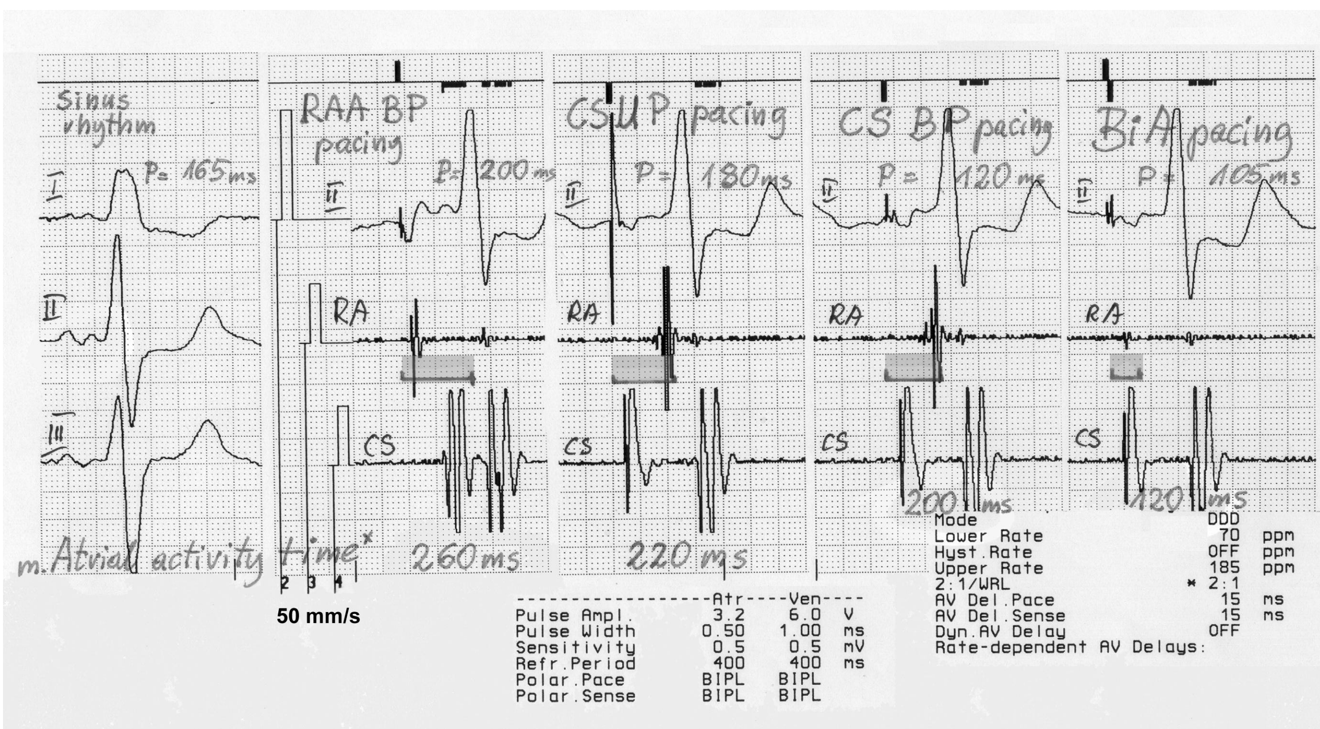

Figure 3. Typical P-wave duration and TAAT as a function of pacing mode in a patient with severe interatrial conduction block.

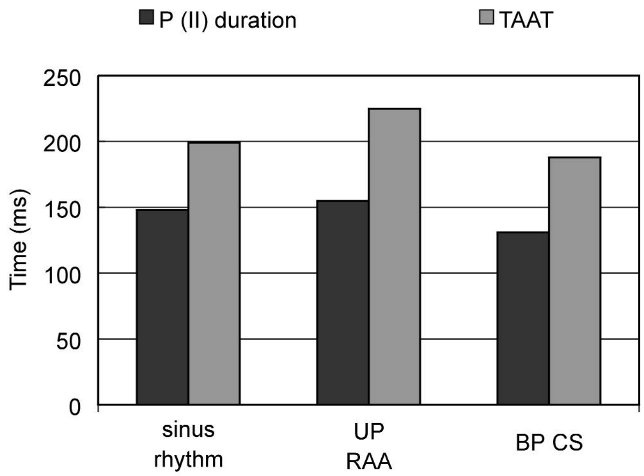

Figure 5. P-wave duration and TAAT comparing sinus rhythm, unipolar, right-atrial pacing, and high-energy, left-atrial pacing.

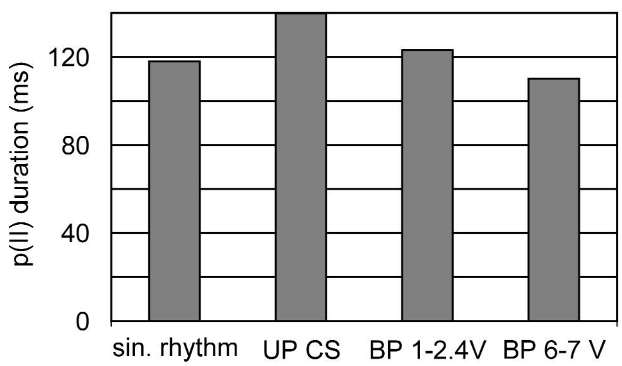

Figure 6. The P-wave duration in the bipolar CS configuration can be further decreased by selecting a higher pacing energy.

gray bars in figure 3 for one typical patient. It can be seen that the TAAT decreases to some degree when comparing CS pacing to stimulation in the right atrium, but it declines dramatically with BAP. While the activation of the atrium is significantly accelerated using BAP, the sequence of atrial and ventricular contraction is not altered to a comparable extent as can be derived from the almost unchanged P-Q or S-Q intervals.

2. Prevention of atrial tachycardias with high-energy, bipolar CS pacing

Exclusive CS pacing has been shown to prevent the

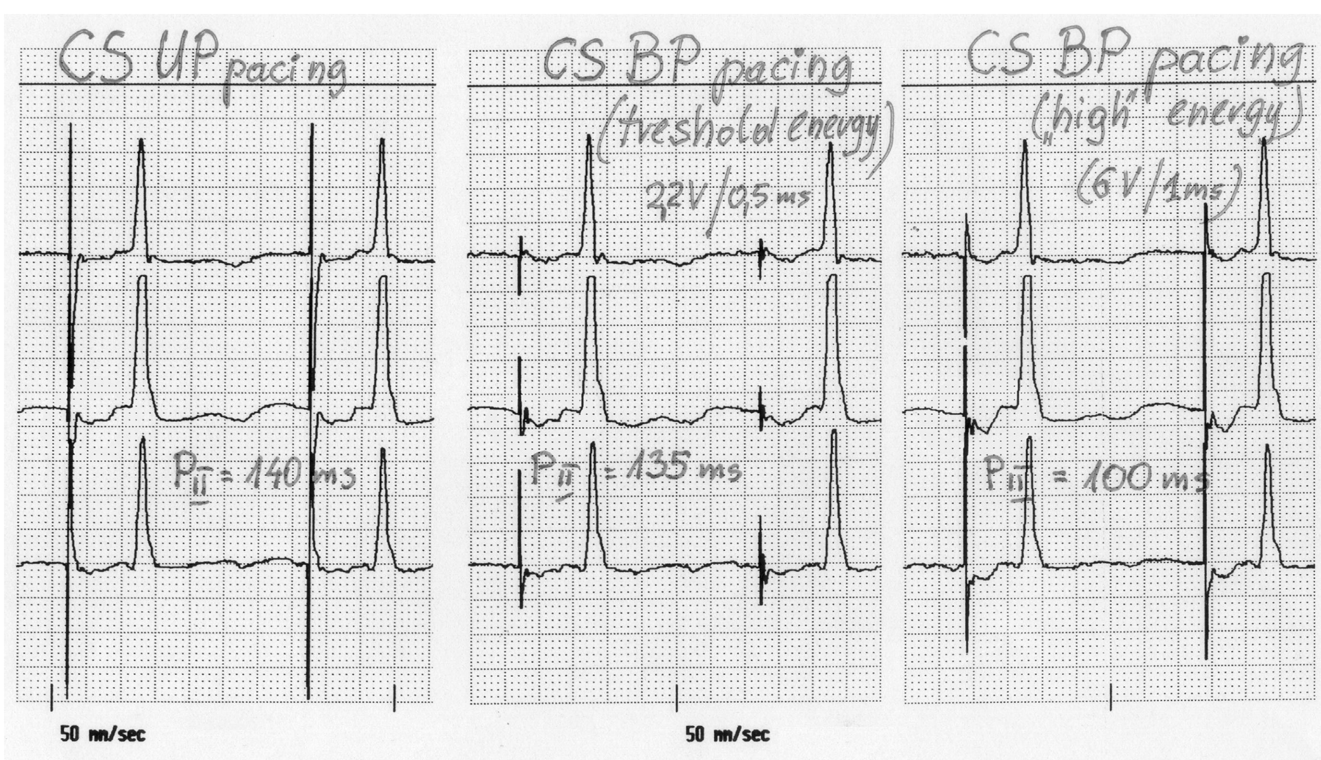

Figure 7. ECG demonstrating the reduced P-wave at bipolar pacing from the coronary sinus with high pacing.

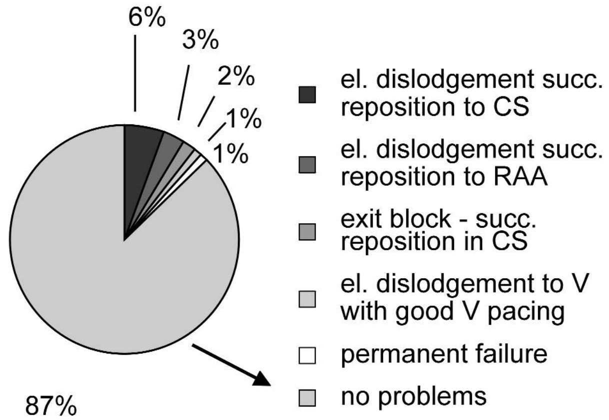

Figure 8. Pacing the CS with standard electrodes is possible in 87 % of the patients (n = 264). The reasons for failure are listed in detail. Only in 1 % of the patients, permanent failure occurred.

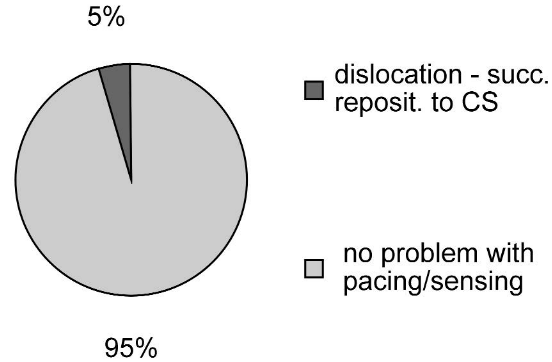

Figure 9. With specifically designed CS leads, the success rate for CS pacing further improves.

induction of AF through extrastimuli from the high right atrium [10]. We investigated whether pacing the atria exclusively from the CS has a preventative effect on the recurrence of atrial tachycardias. For this purpose, we stimulated 81 patients, 56 with paroxysmal AF and 26 with AFl, exclusively from the CS with high energies, i.e., 4.8 to 6.0 V at pulse widths of 1.0 ms. The results obtained over 6 months are shown in figure 4. The percentage of patients who remained without arrhythmia permanently exceeds 80 %, reaching 90 % at the 3-month follow-up. At the same time, up to 40 % of the patients did not need antiarrhythmic drugs. For this patient population, typical times for the activation of the atria are depicted in figures 5 and 6. As already mentioned in the last section, bipolar pacing from the CS results in faster atrial activation compared to unipolar, right-atrial pacing. The values shown in figure 5 compare well with those in figure 3. Figure 6 shows the corresponding mean values for 120 patients. It can be seen that higher energies in bipolar configuration further reduce the P(II)-wave duration from 123 ms to 110 ms. Yet, the even lower value for BAP (100 ms) is not reached. ECGs demonstrating the P-wave reduction for a typical patient are shown in figure 7.

3. Lead stability

To access the antitachycardic benefits multi-site pacing offers, it is necessary to have easily implantable leads with good pacing/sensing qualities and long-term stability. Conventional electrodes already enable reliable CS pacing in 87 % of all cases. This number is based on acute measurements of the 264 patients and follow-up data from 1 (n = 182) to 6 months (n = 84). Among the remaining 13 %, most problems were solved with additional surgery as presented in figure 8. Only in 3 of 264 patients, permanent failure occurred. Although satisfactory in most cases, the necessity to re-operate 1/7 of the patients leaves room for further lead improvement. The preliminary results from the 22 patients who were equipped with leads especially designed for use in the CS are promising. Short tines allowed fixation in the distal CS. Pacing and sensing were performed via two ring electrodes, the distal ring being apart from the fixation tip. With these leads, only one patient needed re-operation, during which the electrode was repositioned. Although no long-term results are yet available, these results appear very promising (figure 9). The corresponding A-wave amplitudes and threshold voltages for both standard and special CS-leads are depicted in figures 10 and 11, showing stable pacing and sensing values.

Discussion

From Allessie's wavelength concept (wavelength = refractory period x conduction velocity) [13], it can be deduced that the probability of tachycardias increases in tissue with long refractory periods and slow conduction velocity. Although dispersion of refractoriness exists in healthy humans, too, still a high dispersion is considered one of the main underlying reasons for the inducibility and persistence of AF [14]. It has been reported that cardiac pacing, in general, can lower the

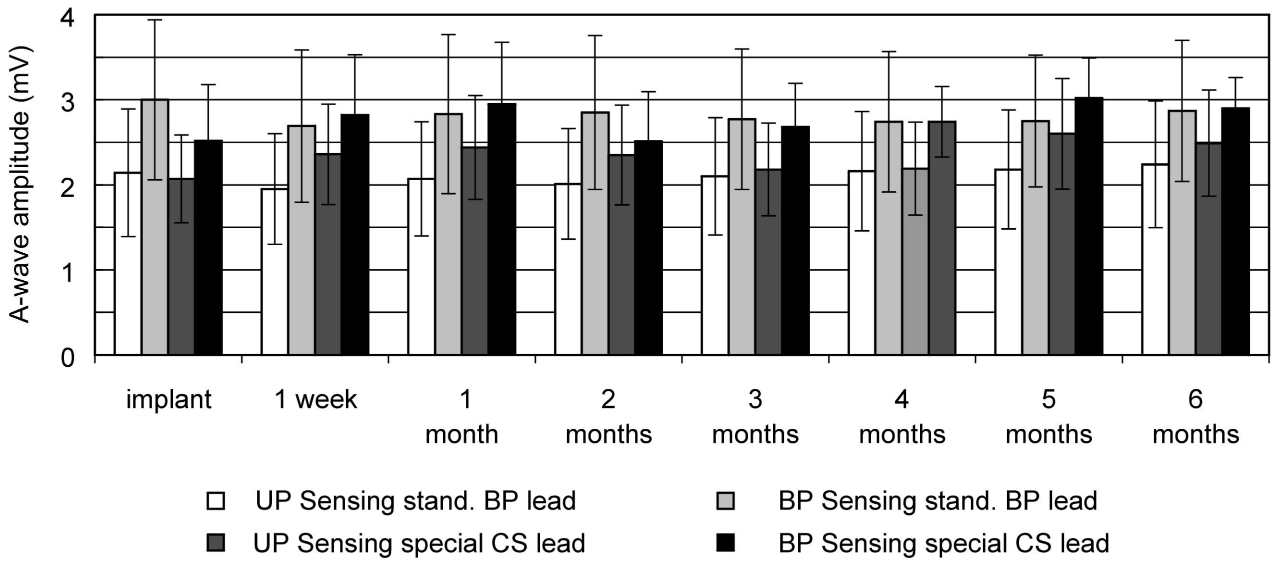

Figure 10. Sensing values for both standard and special CS-leads.

dispersion of refractoriness [15-17]. The effect of resynchronizing both atria on dispersion of refractoriness is obvious in patients with IACB. By starting atrial activation at two points "opposite" each other, the slowed interatrial conduction does not lead to drastically different refractory states in different areas of atrial tissue. In other words, BAP reduces the dispersion of refractoriness in patients with IACB.

A second explanation for the preventative effect of cardiac pacing can be offered by looking at the acceleration of cardiac conduction. According to the presented results, stimulating the high right atrium leads to slower atrial activation compared with CS pacing. Papageorgiou et al. explain similar data with the slow conduction zones around the triangle of Koch [18]. A further decrease in TAAT and P(II)-wave duration can be achieved by stimulating both sites, the right atrium and the CS (figure 6). Although no direct relation be-

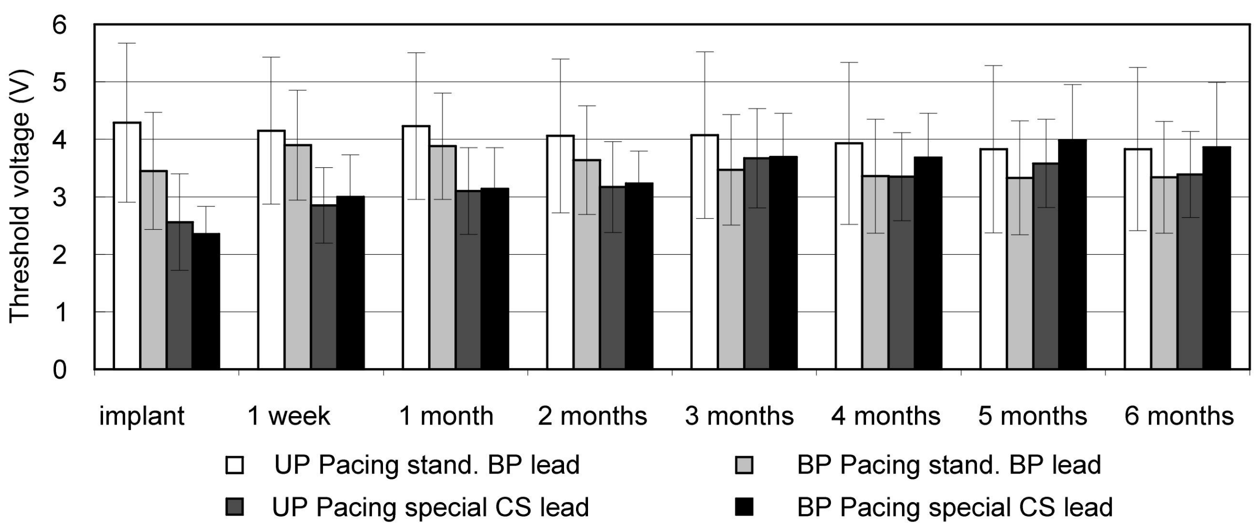

Figure 11. Threshold values for both standard and special CS leads.

tween P-wave duration and the suppression of AF was found in a study with dual right-atrial pacing [19], according to Allessie's theory, the faster activation of the atria in BAP might explain the little recurrence of AF in our data.

A last point can be derived by looking at the results of pacing the CS exclusively. On the one hand, this offers an opportunity of stimulating patients where pacing from the right atrium is not feasible due to reasons mentioned above. On the other hand, by increasing the stimulation energy, CS pacing has a preventative effect on the recurrence of supraventricular tachycardias. Because of the high energy consumption and the superiority of BAP regarding conduction velocities, this option might not be the first choice, yet some patients suffering from atrial tachyarrhythmias could benefit from this method of stimulation.

Conclusion

1. Biatrial pacing has a preventative effect on supraventricular tachyarrhythmias. Furthermore, the number of antiarrhythmic drugs used can often be reduced.
2. In patients who cannot receive a right atrial lead, pacing from the CS offers an attractive alternative. By increasing the pacing energy, a preventative antitachycardic effect is shown.
3. The individual disease of the patient determines which pacing mode is the best for preventing AF. This question will be further pursued by ongoing prospective studies. The pacemaker of the future will include algorithms and functions which allow the physician to choose an individualized preventative pacing mode and site.

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