A New Concept for Right Atrial Sensing Using Permanent Biatrial Pacing

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Summary

Biatrial pacing is an accepted non-pharmacological treatment for re-entrant atrial arrhythmias in patients with atrial conduction disturbances. The problem of assuring the synchrony of atrial excitation not only during pacing but also during sinus rhythm and premature atrial beats has not yet been solved. Standard J-shaped leads with a short distance between the tip and ring located in the right atrial appendage (RAA) provide optimal sensing conditions. Due to anatomical conditions, sinus and ectopic atrial excitation reach the RAA with a minimum 20-30 ms delay; they also make early left atrial pacing and proper resynchronization possible. The aim of this study was to investigate a new sensing configuration in the right atrium (RA) that would offer earlier sensing of spontaneous excitation. The study shows that when using a standard J-shaped lead with its tip positioned in the RAA, the beginning of sinus atrial activation is detected with a minimum 30 ms delay after the onset of the P-wave. The potential, which may serve for pacemaker function control, is detected after another 10 ms. Increasing the distance between the tip and ring of the atrial lead by moving the anodal electrode to the opposite site of the arc of a standard J-shaped lead (positioned in the central-superior region of the RA) causes significantly earlier (16-20 ms) detection of the RA activation wave; it does not result in significant deterioration of the sensing conditions in the atrial channel. It seems that localizing the tip of a lead and its ring in the horizontal plane towards the main ventricular activation vector will be one of the solutions used to decrease ventricular potential sensing by the atrial channel. Introduction of an additional anodal ring into the central-inferior part of the lead arc provides the opportunity for earlier detection of premature beats originating in the lower RA region without a negative influence on sensing and pacing conditions. The proposed configuration of electrodes does not create the risk of phrenic nerve pacing even after the maximal energy output has been programmed.

Key Words

Biatrial pacing, atrial sensing, atrial pacing lead, electrode spacing, atrial timing

Introduction

In patients with conduction disturbances within the atria, numerous researchers have proposed a variety of resynchronized atrial pacing modes (bifocal right atrial pacing, biatrial pacing) that have become widely accepted. These non-pharmacological methods have prevented the recurrence of atrial arrhythmias [1-8]. Simultaneous pacing of two distant atrial regions aids in rebuilding the synchrony of their activation and diminishes the possibility for completion of re-entry [1-8]. One of the most relevant current problems in bifocal and biatrial pacing is assuring the synchrony of atrial activation not only during pacing but also during sinus rhythm and premature ectopic beats initiated within the right or left atrium [1-8]. In order to achieve resynchronization of atrial beats during spontaneous rhythm acceleration above the programmed pacing rate of the pacemaker, Saksena prefers rate-responsive pacemakers with "hyperchronotropic" rate programming; furthermore, he uses beta-blockers to decrease the spontaneous rhythm rate [2,3,8,9]. Daubert pro-
proposed incorporating an additional, new resynchronization algorithm into the RAM of the Chorus 7034 pacemaker (Ela Medical, France). The algorithm enables AAT pacing from the atrial channel with standard coordination of the atrial and ventricular channels [1-8]. Each spontaneous atrial beat (both sinus and ectopic ones originating within the right or left atrium) causes immediate triggering for pacing in both atria, and makes activation less asynchronous [1-8]. It is well-known that premature beats are the most frequent factor initiating episodes of arrhythmia. More efficient suppression is achieved by overdrive pacing, and in recent years several new (similar as far as the final result is concerned) algorithms for consistent atrial pacing have been implemented [10-12].

The right atrial appendage (RAA) is a conventional site for atrial pacing because it provides optimal conditions both for lead placement, pacing, and sensing [13-19]. However, due to its anatomical condition, waves of sinus beats as well as ectopic beats (often originating within Koch's triangle and the ostium of the pulmonary veins) reach the RAA after a 20 or even 30 ms delay [20-23] (Figure 1). Therefore, Daubert proposed fixating the tip of the RAA lead as high as possible when implanting biatrial pacing systems [4-7,8,24].

For over 30 years (ever since the time of Smyth, Kastor, Zucker, Porstmann and Schaldach [13-16]) creators of atrial leads have concentrated on improving the sensing conditions, hoping for maximal elimination of the ventricular potential. This effect has been achieved in bipolar leads by decreasing the distance between the tip and the ring of the lead [17-19,25-29]. It resulted in establishing the "local" right atrial potential, which was ideal for operating the pacemaker (and for ventricular routing in standard DDD systems). However, those advantages appear to be shortcomings in biatrial pacing systems [4-7,24]. The possibility of connecting two bipolar, atrial leads (for pacing both atria) with two (DDD) pacemaker ports (e.g., the Biotronik Logos DS as well as other devices) [20] created a challenge. Therefore, a completely new lead for RAA pacing was created to facilitate the sensing of spontaneous atrial activation (sinus or ectopic).
Figure 2. X-ray of a female patient with trifocal atrial pacing. A previously implanted biatrial pacing system with a screw-in lead (Y 53/S-BP, Biotronik, Germany) was implanted according to Padeletti’s method [30] in the posterior-inferior part of the interatrial septum (white arrow). Please note the position of the lead ring in the high atrium (black and grey arrows). a) postero-anterior plane view; b) lateral plane view.

Figure 3. IEGM recordings performed in the same female patient with the trifocal atrial pacing system. Panel a) Atrial channel – right atrial appendage (UP sensing), ventricular channel – interatrial septum (UP sensing). The onset of the P-wave is detected with a 75 ms delay by the tip of the septal lead. Panel b) Atrial channel – right atrial appendage (UP sensing), ventricular channel – interatrial septum (BP sensing). Earlier detection of the A-wave in the ventricular channel (10 ms earlier than P-wave onset). Panel c) Atrial channel – biatrial recording (BP sensing), ventricular channel – interatrial septum (BP sensing). The remarkable early atrial activation detection results from the localization of the septal lead ring in the high right atrium. UP = unipolar, BP = bipolar.
Previous, a conventional system for biatrial pacing had been implanted in a 56-year-old female patient with severe bradytachycardia syndrome. She also experienced recurrent episodes of non-typical atrial flutter several times per day/week. The weak antiarrhythmic effect of biatrial pacing, unfavorable hemodynamic effects of tachyarrhythmia, and predominant conduction disturbances within the right atrium required us to implant an additional lead in the posterior-inferior region of the interatrial septum using the technique proposed by Padeletti [30] and Katsivas [31] (Figure 2). For interatrial septum pacing, we used a screw-in lead (Y 53/s-BP, Biotronik).

Recording of the intracardiac potentials (Figure 3) was conducted during the implantation procedure using the technique described in previous reports [32,33]. The recordings appeared to be extremely interesting and informative. They clearly showed the earlier appearance of an A-wave in the bipolar recordings originating from the bipolar "septal" lead rather than the classical J-shaped RAA lead. We believed that positioning the ring of the lead (which served as an anode during pacing) within the high right atrium would provide earlier detection of the right atrial beat (Figure 4).
of the leads were successively connected to a pacemaker (cathode and anode configurations are shown in Figure 6). Measurements of the sensing and pacing parameters (A-wave potential, pacing threshold) were performed both in the atrial (standard configuration) and ventricular (non-standard configuration) channels. As the measurements were completed, we recorded simultaneously the intracardiac electrogram (IEGM) and a (standard II lead) surface electrocardiogram at a speed of 50 mm/s. We also measured the temporary parameters by moving the cursors on the frozen screen of the programmer at a speed of 100 mm/s. Pacing threshold measurements were summarized by using the maximal energy output (9.2 V/0.5 ms) to estimate the pacing threshold of the phrenic nerve.

Justification of the Selection Method
To maximally shorten the measurement and recording times, we employed a universal tool that allowed us to reduce the number of connective changes, as well as other procedures. The use of the standard pacemaker enabled us to eliminate the influence of filtering and to amplify the recordings using different hardware from electrophysiologic studies. The documented IEGM recordings facilitated A-wave and V-wave amplitude measurements despite the known inaccuracy of this method; quite often the maximum deflection of the A-wave is cut off. However, it was the only way we could gain at least approximated values of the most important parameter for atrial sensing of the A-wave to V-wave ratio.

Results
Table 1 shows that moving the ring (anode) of the atrial lead from the typical position to the opposite side of the arc of the lead within the atria causes a slight decrease in the amplitude of the atrial potential (from 3.95 mV to 3.55 mV). Doubling the amplitude of the ventricular potential (from approximately 0.25 mV – 0.7 mV) did not influence the value of fluctuations in the recorded atrial potential, but it was highly relevant in increasing of the duration (from 70 ms to 130 ms).

Analysis of the modified connections did not change the pacing threshold; most importantly, the beginning of the atrial activation wave was detected 19 ms (and the potential over 0.5 mV/15 ms) earlier in the non-standard (N1) configuration rather than in the classical one (St). In the non-standard (N2) configuration, which consisted of two connected anodal electrodes (rings) positioned in the central-superior and -inferior lumen of the right atrium, the results were similar to those in
Figures 7 – 11 illustrate our collective findings in the ECG and IEGM recordings. The recordings from the atrial channel showed typical IEGM images detected by a standard J-shaped lead with its tip in the RAA.

Table 1. Sensing/pacing timing parameters and conditions during right atrial pacing/sensing using different configurations (anode location). Onset of A-wave is measured for signals > 0.2 mV; first deflection is measured for signals > 0.5 mV.

N1, except they had slightly lower values (average 0.15 V) for the pacing threshold. Despite pacing with a maximum energy output, we did not observe phrenic pacing in any patients.
Non-standard configurations (N₁ and N₂) were recorded in the ventricular channel. When the recorded IEGMs in both channels were compared, we observed differences between the non-standard and classical connections, respectively:

- earlier beginning of the A-wave,
- clearly wider A-waves, and
- slightly higher V-waves.

These impressions were confirmed using precise measurements (Tables 1 and 2). Due to incorrect programming of the pacemaker’s sensing device, extreme deflection of the A-wave may be automatically cut off. That is why the relationship of the A-wave to V-wave amplitude is fraught with mistakes; (however, in practice the relationship may be much more advantageous).

### Discussion

For many years designers of atrial leads have concentrated on achieving the optimal right atrial pacing conditions, i.e., looking for the maximum local atrial potential at the site, while maintaining the furthest distance from the ventricular muscle [13-19,25-29]. In the era of non-programmable and early programmable pacemakers, elimination (or at least maximal limitation) of the ventricular potential detected by the atrial port was an improvement; this assured correct functioning of the pacemaker and prevented endless loop tachycardia [17-19,34]. The existing options for programming most pacemaker parameters and new algorithms [35] significantly increase the safety of pacing therapy and diminish the role of recording the maximal local atrial potential. New methods of pacing and new algorithms for bifocal and biatrial pacing in pacemakers establish new requirements for designers. The "ideal lead" for right atrial pacing should detect the
activation of the right atrium as quickly as possible (sinus beats and premature beats originating in the low-posterior region of the right atrium) to permit the earliest pacing of the left atrium. So far, new continuous atrial pacing algorithms do not assure re-synchronized pacing during premature beats of high prematurity [10-12], which determine the most frequent triggers for atrial fibrillation [36-38].

The study shows that moving the anodal electrode to the opposite site of its atrial arc (positioned in the central-superior region of the right atrium) causes detection of a relevant earlier right atrial activation wave without significant deterioration of the sensing functionality in the atrial port of currently available pacemakers. It seems that localizing the tip of a lead and its ring in the horizontal plane towards the main ventricular activation vector will be one of the solutions for decreasing ventricular potential sensing by the atrial channel of a pacemaker [17-19].

Introduction of an additional anodal ring into the central-inferior part of the lead arc provides earlier detection of premature beats originating in the pulmonary vein ostium and the triangle of Koch region without negative-
ly influencing sensing and pacing conditions. The study also showed that this kind of configuration (i.e., ring location) did not increase the risk of phrenic nerve pacing even after programming the maximal energy output.
Conclusion

Our work has led to the following conclusions:

- The lead with its tip in the right atrial appendage (cathode) and its ring located in the central-superior part of the right atrium (anode) detects the beginning of the atrial activation about 19 ms earlier than the standard lead.
- Increasing the distance between the tip and ring of the atrial lead does not significantly worsen sensing conditions, nor influences the pacing parameters.
- Adding a second ring positioned in the central-inferior region of the right atrium for earlier detection of premature beats originating in that part of the atrium does not change sensing and pacing conditions compared to the single-ring configuration.

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References


