How Useful are Telemetrically Obtained Intracardiac Electrocardiograms for Evaluating Atrial Conduction Disturbances in Patients with an Implanted Biatrial Pacing System?

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Summary

Biatrial pacing modes have created new therapeutic chances for patients with interatrial conduction disturbances and recurrent atrial arrhythmias. Biatrial pacing systems offer the possibility to record the right and left atrial activation simultaneously. However, due to different and not exactly definable coronary sinus lead positions, their usefulness for evaluating interatrial conduction has remained doubtful. We examined and compared the values of interatrial conduction time (P-wave onset to onset of the left atrial A-wave) and atrial activation time (P-wave onset to the end of the left atrial A-wave) during sinus rhythm and right atrial pacing in 21 patients, either with biatrial pacing systems already implanted or during their implantation. The left atrial A-wave was recorded from the coronary sinus (using the biatrial pacing system's telemetry feature) or from the bipolar esophageal lead (the same recording method was used). The results showed that the differences of the examined parameters did generally not exceed 10 ms, and that there was significant accordance and correlation between the results obtained from the two measuring locations. The analysis of lateral X-ray images indicates that "mid coronary sinus position" in practice means a coronary sinus electrode position distal enough to allow sensing of the posterior part of the atrium. The performed examinations confirmed the high practical value and utility of intracardiac electrograms obtained from biatrial pacing systems for the evaluation of interatrial conduction.

Key words

Atrial conduction disturbances, biatrial sensing, esophageal ECG, intracardiac electrogram

Introduction

Resynchronizing atrial pacing modes (biatrial (BiA) pacing, bifocal right atrial pacing, Bachman´s bundle region pacing, posterior interatrial septum pacing) has provided a new therapeutic option for patients with persistent recurrences of drug-resistant atrial arrhythmias [1-3]. The BiA pacing mode proposed by Daubert in 1990 has gained the greatest popularity [4]. Application of this pacing method frees about 50 % to 60 % of the patients completely from recurrences of atrial arrhythmias and from the need for an antiarrhythmic drug therapy. Another 20 % to 30 % of the patients have sporadic episodes of arrhythmia in spite of both pacing and pharmacotherapy, and in 10 %, one cannot observe any therapeutic effect of this kind of pacing [1,3,5-20].

To date of the investigations, there was no pacemaker specially designed for BiA pacing. In the clinical practice, two variations of the pacing system are used: In the first, both atria are paced from the atrial channel of a dual-chamber pacemaker [5,9,10,13,15,18,19,21-24], while in the second system, the left atrium is paced from the ventricular port [6-9,12,17,20], as presented in Figure 1.

Current pacemakers allow the telemetric recording and measurement of the amplitude of intracardiac potentials. Both of these functions are used to evaluate sensing and pacing parameters. They are also applied for a precise diagnosis of arrhythmias and pacing disturbances in patients with an implanted pacemaker. Biatrial pacing systems offer the possibility to record

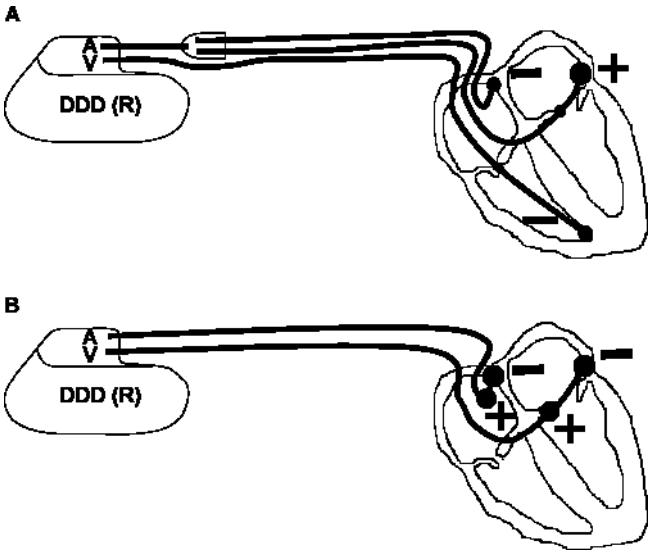

Figure 1. Illustration of different biatrial (BiA) pacing systems, A: Split bipolar (SBP) (Daubert's configuration); B: DDD pacemaker, right atrial lead connected to atrial channel, left atrial lead connected to ventricular channel, interatrial delay 0 ... 15 ms.

potentials from both the right and left atrium at the very same moment in time [25-28] and, thus, a new tool for diagnosis and research studies that enables the evaluation of electrophysiologic parameters in a completely non-invasive way. Previously, such parameters have usually only been accessible during classical (invasive) electrophysiologic studies (measurements of atrial conduction time, etc.).

Due to the option of programmed atrial pacing, future pacemaker generations can be expected to enable measurements of the refractory time and other parameters, such as the maximal time and the zones of interatrial conduction delay. This will allow to precisely evaluate the electrophysiologic state of the atria [29-31]. With help of the simultaneous recording of ECG and IEGM thanks to telemetry, noninvasive electrophysiologic atrial studies, which continuously observe the changes of the atrial condition, e.g., in order to evaluate the effects of antiarrhythmic drugs, can be performed. This could be helpful for the evaluation of effects of different atrial pacing modes and configurations obtained by reprogramming the pacemaker. We will try to contribute to the exact selection of the patient population (with or without interatrial conduction disturbances), as classical invasive electrophysiologic investigations are usually not performed in these patients.

The usefulness of esophageal recordings of atrial potentials for a non-invasive estimation of interatrial conduction has been widely accepted. Esophageal measurements can also be one of the elements of a complete electrophysiologic study when substituting for recordings of potentials from the distal coronary sinus (CS) [29-31]. It has been proven that the atrial potential that is recorded by a bipolar esophageal lead at the point of contact with the left atrium is the left-atrial potential. Therefore, it is adequate to the potential from the distal CS, as far as timing is concerned [32-34].

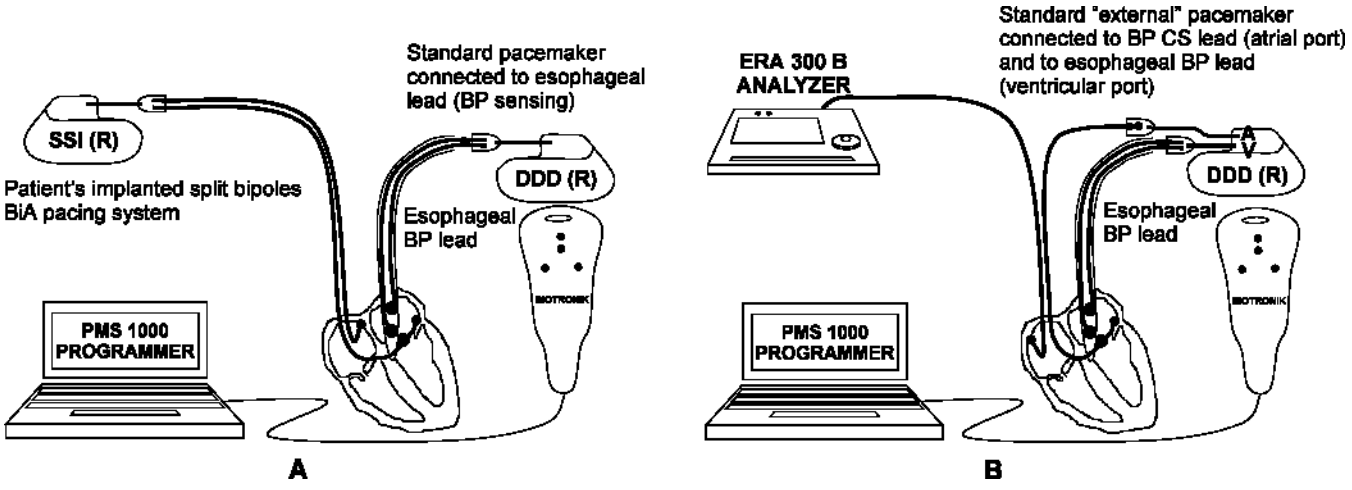

Figure 2. A: Setup for postoperative measuring intracardiac electrogram (IEGM) during sinus rhythm using BiA/SBP and (atrial port) and to esophageal BP lead (ventricular port) during implantation.

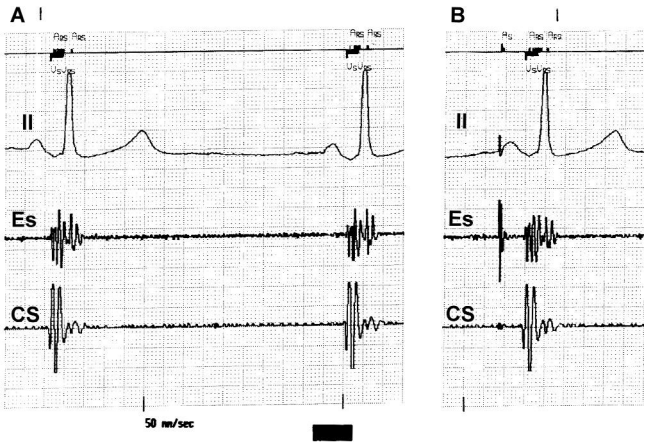

Figure 3. Intracardiac electrogram (IEGM) taken with CS and esophageal lead and surface electrocardiogram (ECG).

Long-term experiments have shown that the middle part of the CS is the most appropriate location for left-atrial pacing [35-37]. Although conditions for sensing and pacing are slightly better in the proximal part of the CS, the middle part definitively provides securer lead stabilization. In the distal part, which has no muscular coating [38,39], both pacing and sensing parameters are less favorable [35-37]. It may be questionable whether the left-atrial potential recorded from the middle part of the CS is useful for an electrophysiologic evaluation of the conduction within the atria.

This study aimed at verifying the worth and usefulness of CS atrial potentials gained by telemetry from a BiA pacing system for the evaluation of electrophysiologic timing parameters in the atrium when compared with esophageal left-atrial potential recordings.

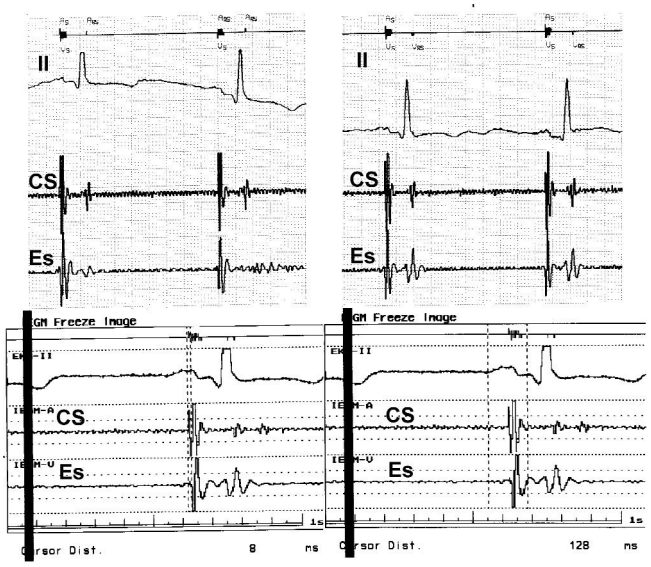

Figure 4. IEGM and ECG recorded via the atrial port of a non-sterile pacemaker via a sterile lead.

Material and Methods

The study was performed in two groups of patients applying two methods that deliberately used the same (telemetric) way of recording the IEGM, i.e., with a standard pacemaker (Actros D) and programmer (PMS 1000, both Biotronik, Germany).

Measurements in Patients with a Previously Implanted BiA Pacing System

In 14 patients who previously had BiA pacing systems implanted (leads connected in series with a "Y" connector by Biotronik [7,18,21-24, 28]), an atrial arrhythmia was reverted by DC esophageal cardioversion [40-42]. We then carried out a routine evaluation of the system's efficacy by telemetrically recording and estimating potentials detected at the atrial port of the pacemaker during sinus rhythm, right atrial pacing, and BiA pacing (Figure 2). Next, we connected 2 adjacent poles of a multipolar esophageal lead (Bream Zabrze, Poland) to another, external, standard pacemaker and executed an analogous recording of the atrial potentials (Figure 3) during sinus rhythm, right-atrial pacing, and BiA pacing by the implanted system.

After retraction of the esophageal lead, we chose an optimal pacing program.

Measurements during the Implantation of the Pacing System

In patients with brady-tachycardia syndrome, a significant decrease in the heart rate can occur during the implantation of a BiA pacing system. Here, temporary esophageal pacing is a valuable therapeutic option that avoids the possible proarrhythmic influence of catecholamines and makes an additional semi-stiff right-atrial lead, which complicates the search for the CS ostium, unnecessary. In 7 such patients, the left-atrial lead was connected to the atrial port of a non-sterile pacemaker used only for the measurements via a sterile lead after successful implantation of the intracardiac leads. Two poles of the esophageal lead - previously used for pacing - were connected to the ventric-

	Post-Eso DC cardioversion measurements						Intraoperative measurements	
	values		significance		correlation		values	
	no.	mean (± SD)	t	p	r	p	no.	mean (± SD)
Compared parameters (mV)				**sinus rhythm**				
P-wave onset to first deflection of A-wave from CS	14	118.2 (33.9)	2.154	0.05	0.521	0.0035	7	109.3 (27.1)
P-wave onset to first deflection of A-wave from Eso (BP)		104.6 (22.6)						110.0 (22.0)
P-wave onset to end of A-wave from CS (BP)	14	168.9 (34.9)	1.4822	0.1621	0.5496	0.0024	7	182.1 (33.9)
P-wave onset to end of A-wave from Eso (BP)		159.6 (25.8)						177.8 (21.6)
Compared parameters (mV)				**right-atrial pacing**				
P-wave onset to first deflection of A-wave from CS	11	155.9 (37.2)	0.174	0.865	0.785	0.00028	6	149.1 (19.8)
P-wave onset to first deflection of A-wave from Eso (BP)		156.8 (33.8)						139.1 (16.5)
P-wave onset to end of A-wave from CS (BP)	11	197.3 (37.1)	0.943	0.3674	0.628	0.0036	6	219.1 (27.8)
P-wave onset to end of A-wave from Eso (BP)		190.9 (28.7)						215.0 (14.8)

Table 1. A comparison of different atrial conduction timing parameters obtained from the atrial CS and esophageal signals. Both groups of patients presented separately.

	Intraoperative and post-Eso DC cardioversion measurements					
	values		significance		correlation	
	no.	mean (± SD)	t	p	r	p
Compared parameters (mV)		**sinus rhythm**				
P-wave onset to first deflection of A-wave from CS	21	115.2 (31.4)	1.766	0.0925	0.4719	0.0006
P-wave onset to first deflection of A-wave from Eso (BP)		106.4 (22.0)				
P-wave onset to end of A-wave from CS (BP)	21	173.3 (34.3)	1.257	0.2232	0.3646	0.0037
P-wave onset to end of A-wave from Eso (BP)		165.7 (25.5)				
Compared parameters (mV)		**right-atrial pacing**				
P-wave onset to first deflection of A-wave from CS	17	153.2 (31.6)	0.663	0.5168	0.6787	0.00005
P-wave onset to first deflection of A-wave from Eso (BP)		150.6 (29.6)				
P-wave onset to end of A-wave from CS (BP)	17	205.1 (34.9)	0.8598	0.4026	0.4155	0.0052
P-wave onset to end of A-wave from Eso (BP)		199.4 (26.9)				

Table 2. A comparison of different atrial conduction timing parameters obtained with atrial CS and esophageal signals. Both groups of patients joined together.

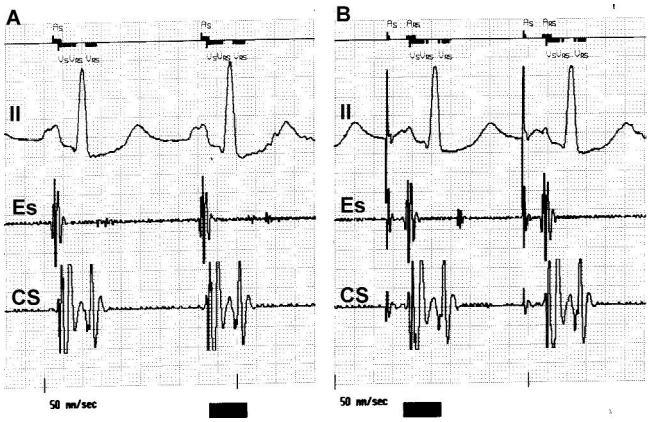

Figure 5. Programmer printout of IEGM.

ular port of the same "external" pacemaker (see Figure 2 for setup and Figure 4 for a recorded example).
Subsequently, we used the programmer's telemetry option to record potentials of the left atrium from the CS (atrial port of the pacemaker) and from the esophagus (ventricular port) simultaneously during sinus rhythm and right-atrial pacing. For pacing, we used a system consisting of the external threshold analyzer ERA 300 B (Biotronik) and a standard "J"- shaped lead

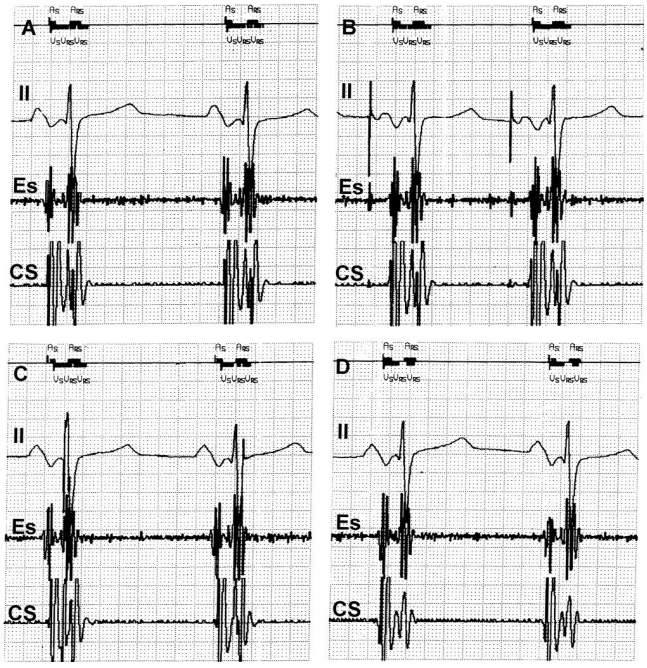

Figure 6. Programmer printout of IEGM.

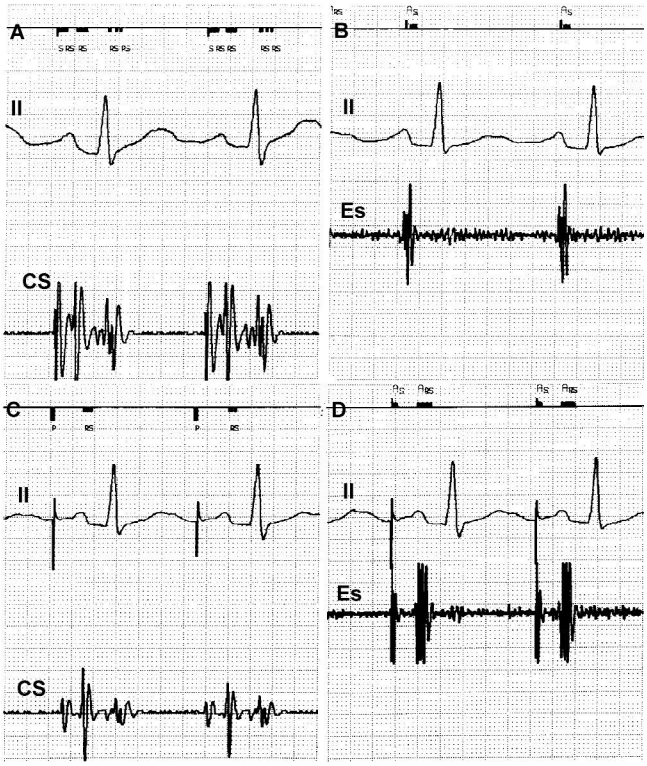

Figure 7. Programmer printout of IEGM.

implanted into the right-atrial appendage.
After finishing the recording, we connected the leads through a "Y" connector to the other, standard pacemaker which was implanted in the usual way.
In both groups of patients, all recordings were made on paper at a speed of 50 mm/s. Measurements of timing parameters were performed automatically on the frozen screen of the programmer (at a speed of 100 mm/s), using cursors. While carrying out the intraatrial recordings, we simultaneously recorded lead II of the classical ECG at a gain of 1 mV = 20 mm in both patient groups.
The following timing parameters were analyzed:

- onset of the $P_{II\text{-}wave}$ to first deflection of the A_{LA}-wave in the recording from the CS
- onset of the $P_{II\text{-}wave}$ to first deflection of the A_{LA}-wave in the esophageal) recording
- onset of the $P_{II\text{-}wave}$ to end of the A_{LA}-wave in the recording from the CS
- onset of the $P_{II\text{-}wave}$ to end of the A_{LA}-wave in the esophageal recording

For the statistical analysis, we first compared the above-mentioned parameters: the first with the second

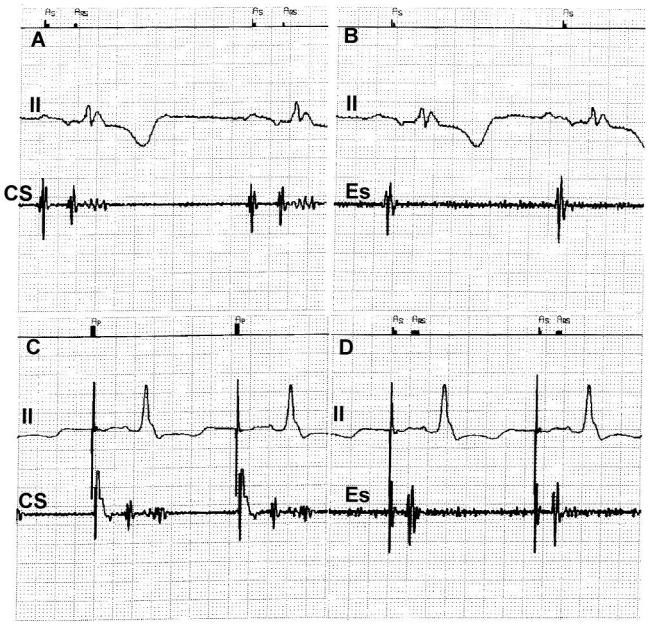

Figure 8. Programmer printout of IEGM.

one, and the third with the fourth one, applying the t-test for dependent variables. Subsequently, we used Pearson's correlation test to measure the potential correlation between the values of the compared parameters.

Results

The results are presented in Tables 1 and 2. Figures 4 - 9 show examples for illustration.

Table 1 presents the results obtained from the 14 patients with an implanted BiA pacing systems after a DC esophageal cardioversion (group 1) and from 7 other patients during the implantation of the BiA pacing system (group 2). Due to the relatively low number of intraoperative measurements, we did not perform a separate statistical analysis in that group of patients. As both the intraoperative measurements and those performed after esophageal DC cardioversion were made in similar groups of patients (with atrial conduction disturbances and recurrences of atrial arrhythmias), the obtained results were then combined into one larger and more representative group (group 3), shown in Table 2.

The results show a high degree of agreement between the left-atrial activation timing parameters obtained from the "middle" part of the CS via telemetry and those recorded from the esophagus (from the site where pacing was possible and the amplitude of the spontaneous potential was the highest).

In the studied patient groups 1 to 3, the mean interatrial conduction time (from the onset of the $P_{II\text{-}wave}$ to the first deflection of the A-wave) during sinus rhythm was 118 ms, 109 ms, and 115 ms, respectively, in the recordings from the CS. Thus, it was even longer than during the recording of the left-atrial potentials from the esophagus, which resulted in 104 ms, 110 ms, and 106 ms, respectively. During right-atrial pacing, the interatrial conduction time was 156 ms, 149 ms, and 153 ms, respectively, while recording from the CS; and 157 ms, 140 ms, and 150 ms, respectively, in recordings from the esophagus. Differences of several seconds between the corresponding parameters were not statistically significant. We also confirmed a significant correlation between the two measurement methods both during sinus rhythm and right-atrial pacing in the two groups of patients (group 1 and 2).

The average total atrial activation time (from the onset of the $P_{II\text{-}wave}$ to the end of the deflection of the A-wave) during sinus rhythm was 168 ms, 182 ms, and 173 ms, respectively, in the analyzed three patient groups in recordings from the CS, whereas it amounted to 160 ms, 178 ms, and 165 ms, respectively, when recording the left-atrial potentials from the esophagus. The differences between the corresponding parameters

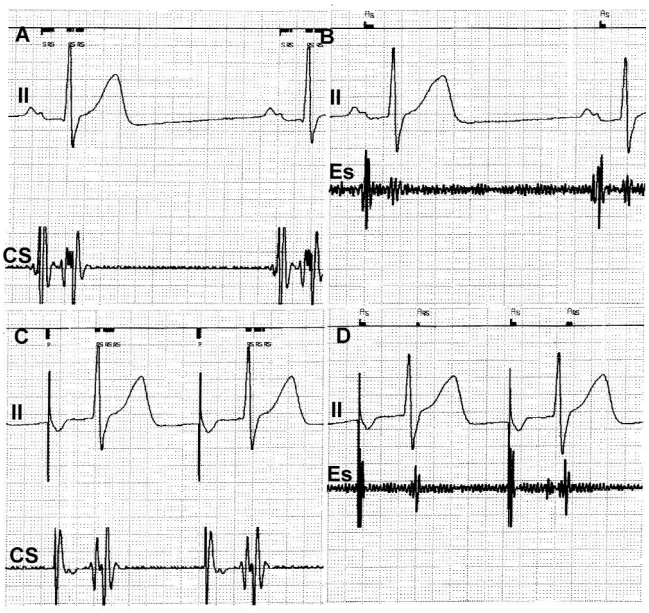

Figure 9. Programmer printout of IEGM.

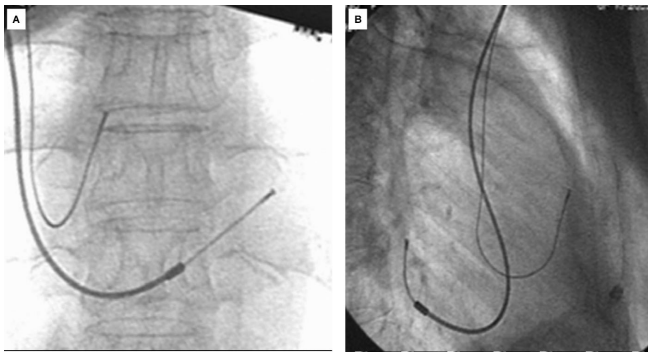

Figure 10. Posterior-anterior fluoroscopy scan: final position of the lead tip.

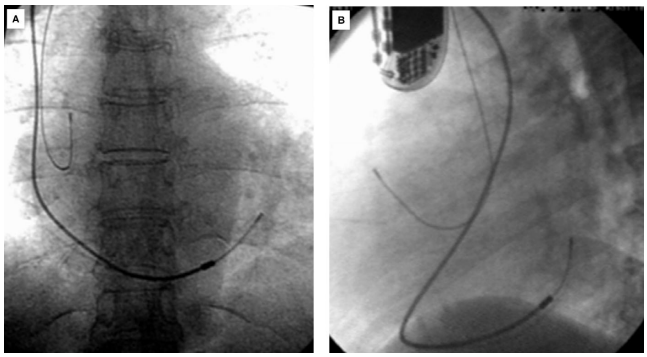

Figure 11. Evaluation of the position of the left atrial lead in the CS.

did not exceed 10 ms and were not statistically significant. During right-atrial pacing, the mean interatrial conduction time was 197 ms, 219 ms, and 205 ms, respectively, from the CS, and 191 ms, 215 ms, and 199 ms, respectively, from the esophagus. The corresponding mean values obtained with the two compared methods did not differ by more than 6 ms which was not statistically significant.

We also confirmed a significant correlation (r = 0.4 to 0.6) between the timing parameters of atrial activation determined with the two methods of left-atrial potential recording, either from the esophagus or the CS, despite the small number of measurements.

Discussion

Biatrial pacing is a therapy method mostly applied in patients with interatrial conduction disturbances and persistent recurrences of atrial arrhythmias [1-3,5-20]. Conduction disturbances within the atria are usually diagnosed based on the morphology of the P-waves (P-wave duration > 120 ms with biphasic morphology in leads II, III, and aVF of the standard ECG) [1,6-8,14,16,17,20,24,27,28]. To date, a simultaneous recording of potentials from both atria has been performed in only a few patients, in order to evaluate and estimate the intensification of an interatrial conduction disturbance more precisely, and this was done mostly for research rather than for diagnostic purposes [14].

If there is only a limited indication for a classical electrophysiologic study, the most commonly used method to investigate interatrial conduction disturbances has been recording the ECG from the esophagus, using bipolar esophageal leads. The interatrial conduction time was then calculated as the difference between the onset of the P-wave and the beginning of the A-wave recorded at the level of the left atrium [20,43-48].

Some researchers regard the onset of the right-atrial A-wave, obtained via telemetry from a classical pacing system [49-51], as the beginning of atrial activation. The widely accepted location for recording left-atrial potentials is, in a standard electrophysiologic study, the distal part of the CS (with the final position of the lead tip being judged by posterior-anterior fluoroscopy scan, see Figures 10-13) [29-31].

Current BiA pacing systems allow for simultaneous recording of potentials from both the right and left atrium [25,26], although that possibility was used only sporadically in practice to evaluate interatrial conduction parameters and to follow the dynamics of their changes [6-8,17,27,28] because the position of the left-atrial lead in the CS could not be evaluated precisely as shown in Figure 11.

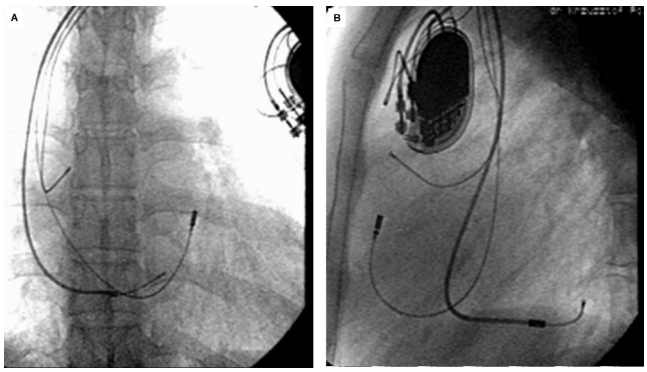

Figure 12. Anterior and lateral view of the pacing system.

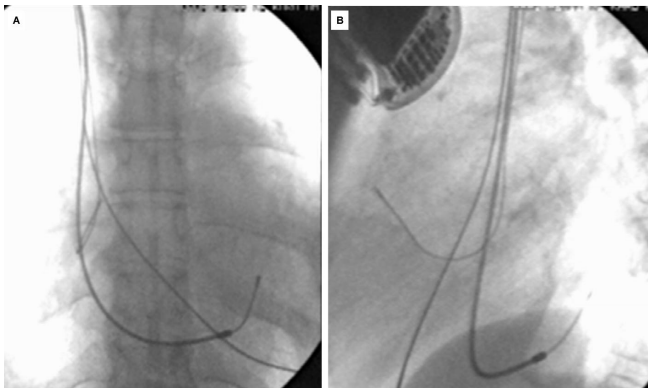

Figure 13. Anterior and lateral view of the pacing system.

It has been known since the 1970s and confirmed by recent studies that the proximal part of the CS is the optimal location for measuring both sensing and pacing parameters [35-37]. However, the large diameter of the CS in that region makes it practically impossible to secure a stable lead fixation. The distal part of the CS offers considerably worse sensing parameters (lower A-wave amplitudes with higher V-wave amplitudes), a higher left-atrial pacing threshold, and a higher risk of left-ventricular pacing [35-37]. That is why the most optimal place for CS pacing is its "middle" part. Utilizing the results of a posterior-anterior fluoroscopic scan, it is the point just in the middle between the most distal and the most proximal localization. Because of both technical reasons and the unquestionable need for a sterile implantation procedure, it is practically impossible to perform a lateral X-ray scan intra-operatively, which could show the real location of the pacing tip of a lead in relation to the posterior wall of the left atrium. The recorded X-ray examples present very typical situations, in which a - according to the posterior-anterior fluoroscopy scan - middle lead location in the CS with the lead tip just next to the vertebral column, i.e., in the region of the left-atrial posterior wall, proved to be adequate. On the one hand, the noticed observation may explain certain misunderstandings, while on the other hand, it seems to confirm the usefulness of intraatrial potential recordings from a BiA pacing system for the evaluation of atrial activation timing parameters. We have been performing all these measurements for several years [6-8,17,27,28], but certain methodical doubts led us to compare them to the values of the same parameters recorded by an esophageal lead.

Conclusions

The left-atrial potential is recorded almost simultaneously from both the bipolar esophageal lead and the most optimal pacing point in the CS.
In most patients, the "middle" part of the CS is in practice defined as the portion that is close to the low posterior part of the left atrium.
Simultaneous recording of left and right atrial potentials from a BiA pacing system via telemetry is a valuable diagnostic and research tool.

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