The New Concept of Permanent Atrial Resynchronisation Using a Single Atrial Lead – A Case Report

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Summary

Resynchronized atrial pacing is becoming more and more widely used for prevention of atrial arrhythmias, but all proposed systems pose distinct disadvantages. During right-atrial-appendage-potential-triggered septal pacing modes (Saksena's dual site right atrial pacing system) or coronary sinus (CS) pacing modes (Daubert's biatrial pacing system), detection of the front of excitation is delayed by about 30 – 40 ms compared to the onset of the P-wave. This means that resynchronization during sinus rhythm is not optimal. On the other hand, simple single site CS ostium region pacing in the ostium (Padeletti's system) offers symmetrical atrial activation only during pacing, but even new algorithms (consistent atrial pacing) cannot assure continuous pacing. Our long-term experience with different resynchronized atrial pacing modes indicate that increasing of the distance between the tip and ring of the atrial lead widens the sensing spectrum and makes it possible for earlier detection of the onset of native atrial excitation. We used a modified (with tip-ring distance up to 8 cm) screw-in lead with the tip attached at the lower posterior atrial septal region and the ring floating in the mid anterior part of the right atrium. We obtained excellent pacing in the CS ostium triggered with the onset of atrial excitation in a female patient with incessant atrial fibrillation, using a simple SSI unit and SST program. The system worked perfectly and had a satisfactory clinical effect. Widening of the dipole was not accompanied by deterioration of sensing and pacing conditions (A-wave amplitude, A/V ratio, pacing threshold, and impedance), which remained at acceptable limits. Our primary experience indicates a new direction towards a simple but effective resynchronized atrial pacing system for refractory atrial arrhythmias in patients who experience atrial conduction disturbances without chronotropic incompetence.

Key Words

Atrial resynchronisation, septal pacing, atrial sensing, screw-in lead

Introduction

Resynchronized atrial pacing is the generally accepted method for preventing reentrant atrial arrhythmias, especially in patients with inter/intraatrial conduction disturbances [1-9]. During the last few years, five different atrial pacing systems (Figure 1) have been introduced to improve the synchronism of atrial excitation:

- Daubert's biatrial pacing by split right atrial appendage (RAA) and coronary sinus (CS) leads [4-8];
- Markewitz-Osterholzer's biatrial pacing by pacing both atria using both channels of the DDD pacemaker [10-14];
- Saksena's dual site right atrial pacing by split RAA and septal bipolar lead configuration [9,15-18];
- Padeletti's low posterior septal (single lead) pacing [19-24];
- Spencer's Bachmann's bundle region (single lead) pacing [25-26].

One of the most important unsolved problems of resynchronized pacing modes is assuring the synchrony of atrial activation not only during pacing, but also during sinus rhythm and premature ectopic beats originating from the right or left atrium [1-9,15-26].

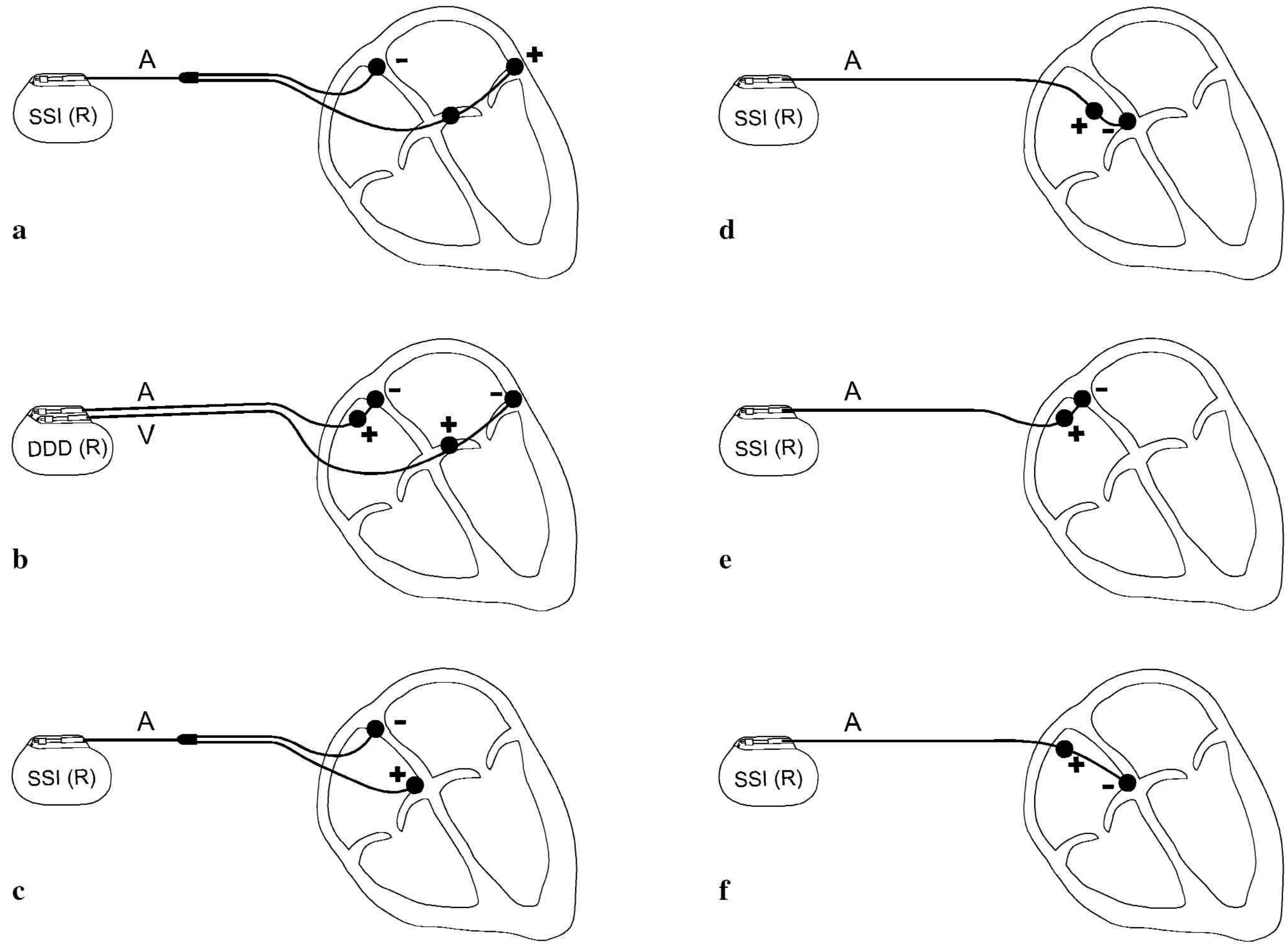

Figure 1. Different atrial resynchronizing systems. a) Daubert's biatrial pacing system; split (with "Y" connector) atrial leads; pacing of the left atrium with anodal current. Simultaneous pacing of both atria, or left atrial pacing triggered with RAA local potential. b) Biatrial pacing using a standard DDD pacemaker; ventricular channel serves for left atrial pacing. CS can be paced in the BP configuration. Simultaneous pacing of both atria, or left atrial pacing triggered with RAA local potential. c) Saksena's dual site pacing of the RA. Both atrial leads are split with the "Y" connector and the CS ostium region is paced with an anodal current. Simultaneous dual site RA pacing or pacing the CS ostium region triggered with RAA local potential. d) Padeletti's low posterior atrial septal pacing system. Consistent atrial pacing (CAP) algorithm enables significant predominance of paced rhythm. e) Spencer's Bachman's bundle region (antero-superior septal) pacing system. The hyperchronotropic sensor response or CAP algorithm enables significant predominance of paced rhythm. f) Authors proposal. Special screw-in lead enables very early detection of native atrial activation (sinus or ectopic) and instantaneous preexcitation of the CS ostium region.

Daubert proposed an additional resynchronized algorithm for the Chorus 7034 pacemaker (ELA Medical, France), which enables triggered atrial pacing (AAT) pacing from the atrial channel with standard cooperation of atrial and ventricular channels [4-8]. In order to resynchronize atrial beats during spontaneous rhythm acceleration, Saksena and Spencer used rate responsive pacemakers with "hyperchronotropic" rate programming, as well as beta-blockers to decrease the sinus rate [9,15-18]. For the same reasons, Padeletti ensured the same type of pacing regardless of the sinus rate by using the recently introduced algorithm for "consistent atrial pacing" [19-24]. Due to anatomical and electrophysiological conditions, the tip electrode, which is located in front of the RAA, senses atrial excitation 30 – 40 ms after onset of the P-wave [14,27-33].

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b
c

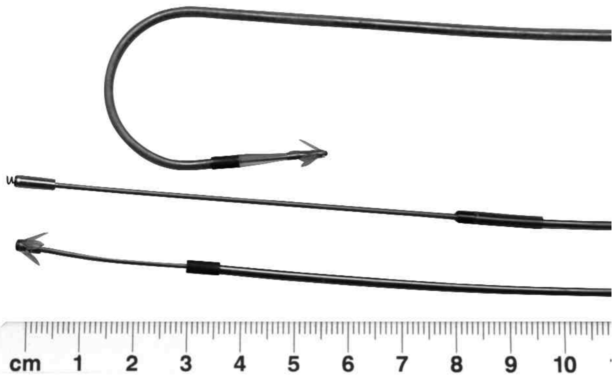


Figure 2. The new screw-in lead (b) for low posterior atrial septal pacing triggered by early detected intrinsic atrial activation (sinus or ectopic). Standard screw-in lead was modified by enlarging the distance between the tip and ring of the lead to 8 cm. Standard straight TIR 60 BP (c) and "J" shaped SX 60 BP (a) leads are shown for comparison (all products from Biotronik, Germany).

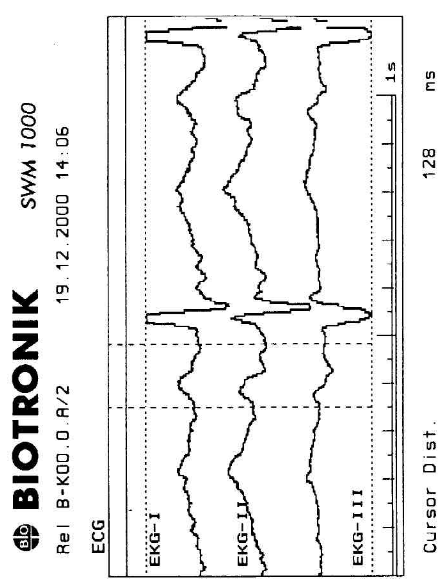
Review of the literature leads to the conclusion that detection of spontaneous atrial activation (sinus or ectopic) plays a key role in effective atrial resynchronization [1-9,12-14]. An "ideal" resynchronized atrial pacing system should have the following:

- simple and easy for implantation (single lead is preferred),
- have the same symmetrical activation in both atria,
- provide for continuous preexcitation (pacing) in one of the most arrythmogenic areas in the atria (triangle of Koch region), and
- allow for sensing of atrial excitation (sinus and ectopic) as early as possible.

Our long-term experience with different biatrial pacing systems [13] and recent experience with the dual site RA and low posterior septal pacing indicates that the latter system seems to be closest to the "ideal" (except for early sensing of atrial excitation). In our recent, study [42], we proved that additional ring electrode (cathode for sensing, anode for pacing) located far from the tip of the lead in the lumen of the upper part of the right atrium, do not change pacing conditions, and allow detection of right atrial excitation.

Our goal was to find a simple, easy to implant (and explant if necessary) pacing system fulfilling most of the features of an "ideal" resynchronized atrial pacing system. On the basis of performed examinations [42], a standard, straight, screw-in lead (Y 60 BP, Biotronik, Germany) was slightly modified, with the anodal ring shifted proximally 80 mm from the tip of the lead (Figure 2).

a



b

Figure 3. Standard ECG of the patient before surgery. Slight atrial conduction disturbances can be suspected. Captured picture on monitor screen enables exact measurement of P-wave duration (128 ms).

Figure 4. UP pacing of (mid part) of the coronary sinus with typical paced P-wave morphology. Temporary insertion of the lead tip into the coronary sinus (confirmed with pacing of left atrium) allows for easier location of the coronary sinus ostium and ensures proper lead placement.

Case Report

A 68-year-old female patient, with incessant [43] (over 12/24 hours of Holter ECG monitoring), drug resistant atrial fibrillation and only moderate atrial conduction disturbances (Figure 3), received a pacing system for low posterior (single site) atrial pacing. We first introduced the lead tip into the CS whereby its location was confirmed by the typical morphology of paced P-waves (Figure 4). Subsequently, the lead tip was carefully withdrawn, rotated back, and screwed into the typical position (Figure 5). Using a threshold analyzer (ERA 300 B, Biotronik), we recorded intracardiac electrograms (IEGM) in the unipolar (UP) and bipolar (BP) configurations (Figure 6), and measured standard sensing/pacing conditions. The A-wave amplitude was 2.4 and 2.5 mV, the slew rate 0.3 and 0.6 V/s, the pacing threshold values at 0.5 ms were 0.8 and 0.9 V, the impedance was 360 and 504 W, and the threshold current 2.1 and 1.5 mA, respectively (UP/BP).

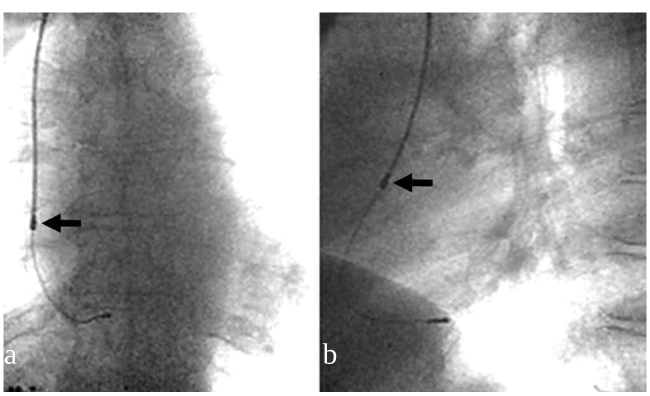


Figure 5. Proper lead placement (intraoperative X-ray) shown by postero-anterior view (a) and lateral view (b). Arrows indicate the lead ring located in the upper part of the right atrium. Note that a 8 cm distance between electrodes (tip-ring) of the lead is not excessive for a slightly enlarged heart.

For simultaneous recording of the IEGM (using both configurations) and the ECG, we used a external DDD pacemaker (Actros D, Biotronik), a programmer (PMS 1000, Biotronik), and a four-conductor sterile cable (Figure 7). We obtained very favorable results indicat-

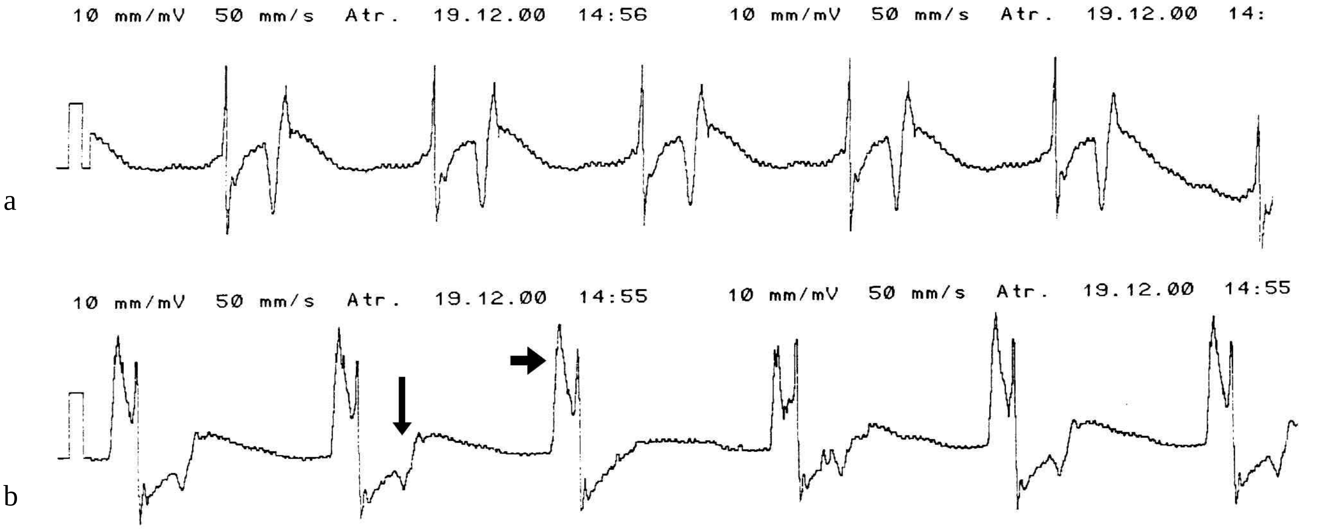
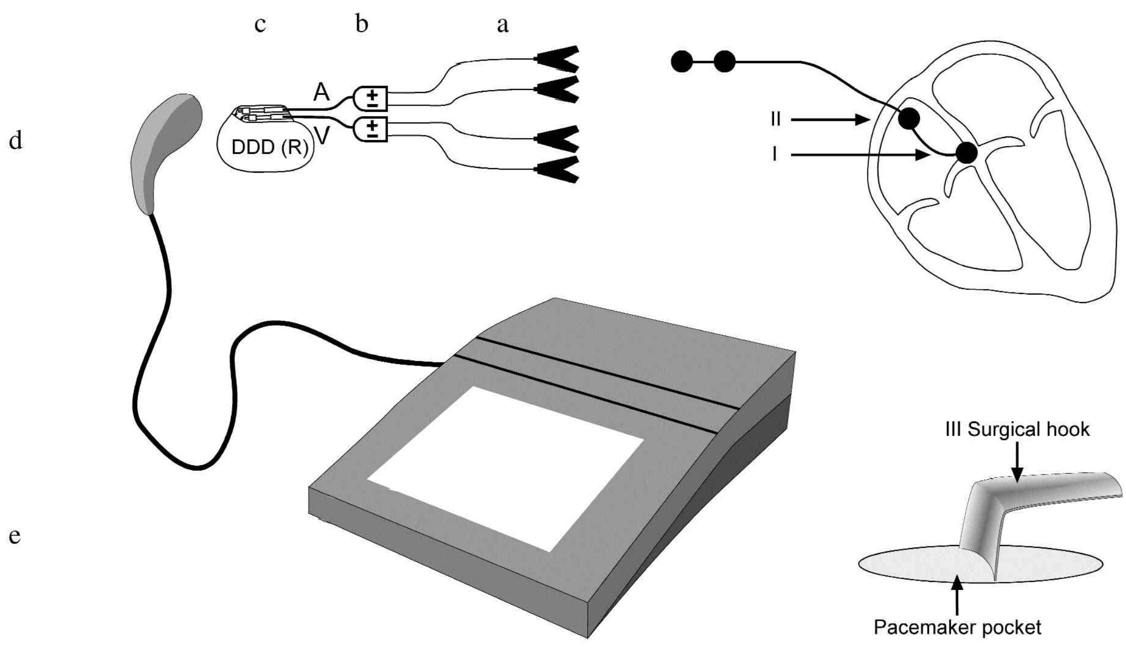
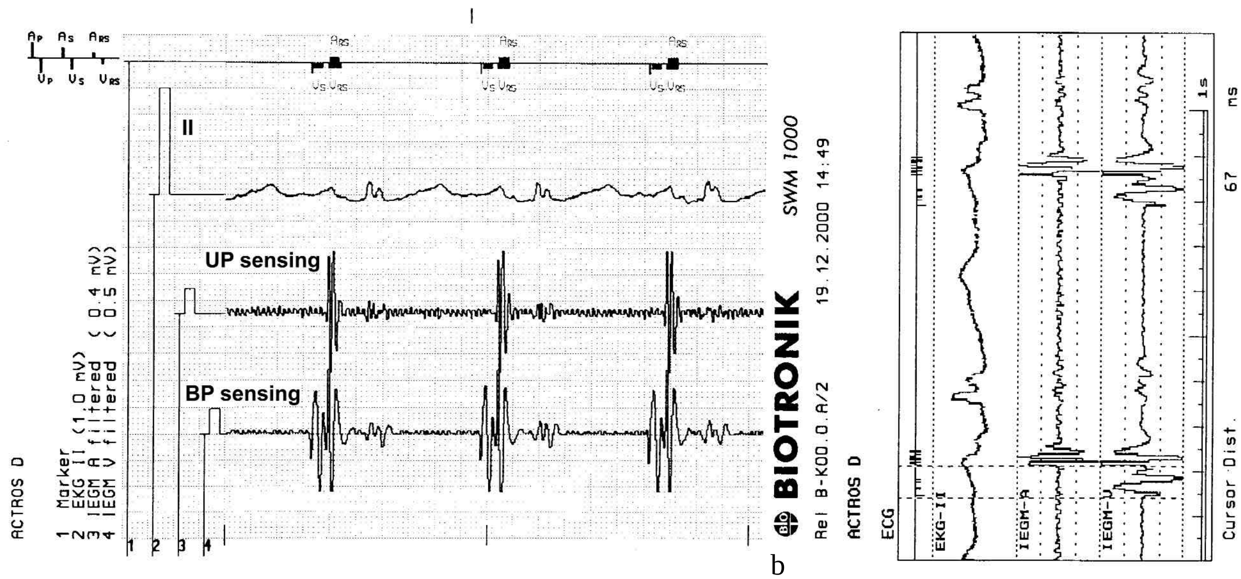


Figure 6. IEGM recorded with a threshold analyzer (ERA 300 B, Biotronik, Germany) after final lead location: UP sensing between the coronary sinus ostium and the pacemaker pocket (a) and BP sensing between tip and ring of the lead (b). Separate, additional high right atrium A-wave is seen in bipolar configuration (bold, horizontal arrow). Note that in spite of a big sensing dipole, the V wave is smaller than recorded in UP sensing configuration (narrow vertical arrow).



Sensing configuration	**Cathode (different)**	**Anode (indifferent)**
Channel A (UP sensing)	I	III
Channel V (BP sensing)	I	II
Reversed sensing configuration	**Cathode (different)**	**Anode (indifferent)**
Channel A (BP sensing)	I	II
Channel V (UP sensing)	I	III

Figure 7. Sensing configurations during intraoperative examination. For the reversed sensing connection, the pacemaker channels were replaced to exclude potential influence of slightly different pacemaker filters. Set for simultaneous (intraoperative) sensing atrial potentials in both (UP and BP) configurations: sterile cable, external pacemaker (Actros D, Biotronik) and programmer (PMS 1000, Biotronik). Obtained recordings are presented in Figures 8 and 9.



a b

Figure 8. UP recordings between the lead tip and the pacemaker pocket (atrial channel) and BP recordings between the lead tip and ring (ventricular channel) for sinus rhythm; standard recording at 50 mm/s (a) and frozen monitor screen with a resolution of 100 mm/s (b). In BP configuration, onset of atrial activation is seen up to 67 ms earlier. Note that the onset of the A-wave is recorded even slightly earlier than the P-wave.

ing much earlier detection of sinus atrial excitation in the BP configuration (Figure 8). In order to exclude the influence of different filters in the A and V channels of the pacemaker, we replaced the connections. "Captured" IEGMs on the monitor screen provided exact measurements with a resolution of 100 mm/s (Figure 9). Subsequently, the proximal end of the lead was routinely connected with a standard SSI pacemaker (Actros S, Biotronik), which was implanted into an already prepared subcutaneous pocket in the left subclavian region. Postoperative examination using transmission of IEGMs from the implanted pacemaker, confirmed our intraoperative observations that much earlier sensing of sinus atrial excitation is achieved in the BP configuration (Figure 10). It is very important that we recorded the onset of the A-wave simultaneously with the onset of the P-wave. The triggered BP pacing program (SST, 30 beats/min, pulse amplitude over the pacing threshold) effectively resulted in excellent atrial resynchronization (Figure 11). The triggered BP pacing program (SST, 30 beats/min, pulse amplitude under the pacing threshold) did not have a positive effect on atrial resynchronization (Figure 12). The UP triggered pacing program provided the same electrophysiological effects a significant delay in detection of atrial excitation and ineffective pacing (Figure 13). UP septal pacing provided satisfactory, but not optimal synchronous atrial excitation (Figure 14). During her 5-day hospital stay, the patient was free from arrhythmias. Holter monitoring showed excellent functioning of the pacing system.

Discussion

All recently-used, resynchronized, atrial pacing systems have specific disadvantages [38-39,41]. The common disadvantage of RAA potential-driven systems (Saksena's dual site RA pacing, Daubert's and Markewitz-Osterholzer's biatrial pacing) is delayed sensing at the beginning of atrial excitation (about 30 – 40 ms) and delayed pacing of the CS ostium or mid CS regions [14,27-33]. In addition, less significant disadvantages consist of the implantation of two atrial leads and the utilization of a potentially proarrhythmic anodal current for atrial pacing in Daubert's and Saksena's systems. Single lead (Padeletti's and Spencer's) septal pacing systems offer relatively symmetrical atrial activation, but their systems work only during pacing [44-48]. Different new overdrive pacing ("consistent atrial pacing") algorithms can never pro-

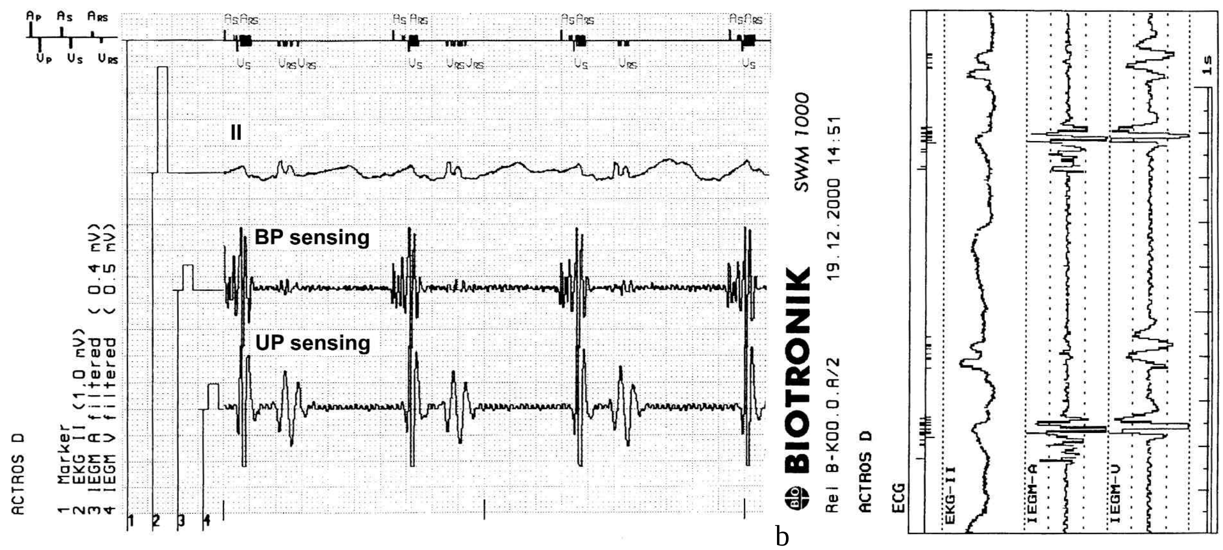


Figure 9. UP recordings between the lead tip and the pacemaker pocket (ventricular channel) and BP recordings between the lead tip and ring (atrial channel) for sinus rhythm; standard recording at 50 mm/s (a) and frozen monitor screen with a resolution of 100 mm/s (b). Findings and conclusions are the same as in Figure 8.

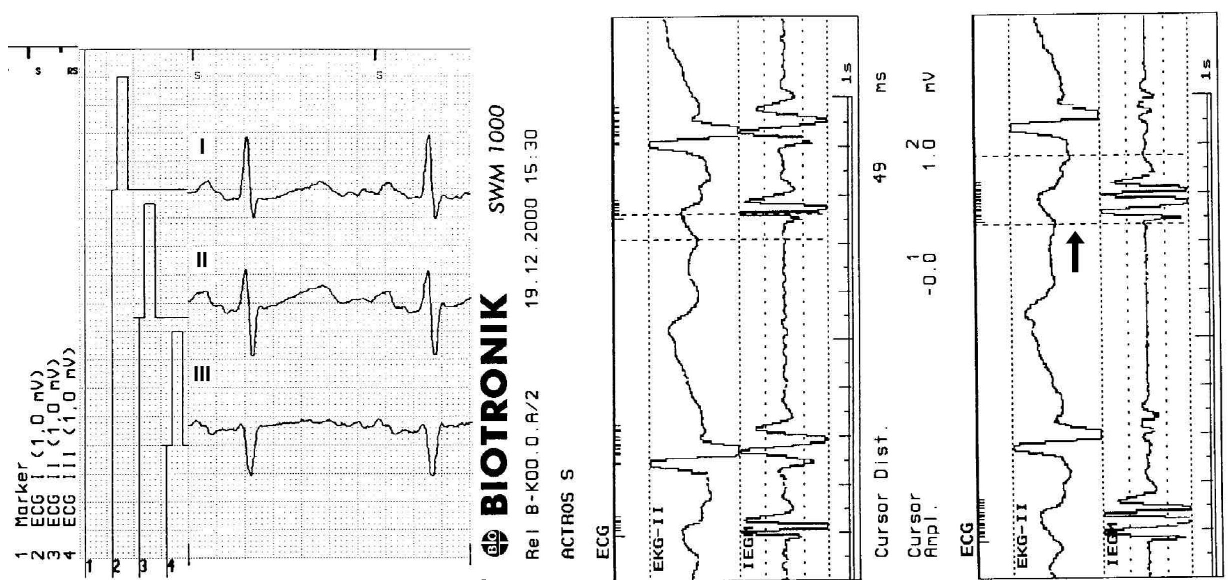


Figure 10. Postoperative ECG (a) and IEGM recorded in UP (b) and BP sensing configurations (c). Sinus rhythm; recently implanted (SSI) pacemaker was programmed at a basic rate of 30 beats/min. Significant differences between morphology of IEGM performed in UP and BP sensing configuration are visible. Onset of RA A-wave is recorded simultaneously with the onset of P-wave (c) and delay of recordings of septal potential is delayed by about 50 ms in comparison to the onset of the P-wave. The "a" Arrow indicates the onset of sensing of atrial activation simultaneous with or slightly earlier than the onset of the P-wave.

vide 100 % of the paced beats and very early premature ectopic atrial excitations usually are not resynchronized [19-24]. Missed atrial premature beats probably are responsible for unsatisfactory and ineffective clinical pacing in some patients. During the last 20 years, fabricators of atrial leads concentrated on sensing the local atrial potential in order to reduce the risk of accidental sensing of ventricular potentials

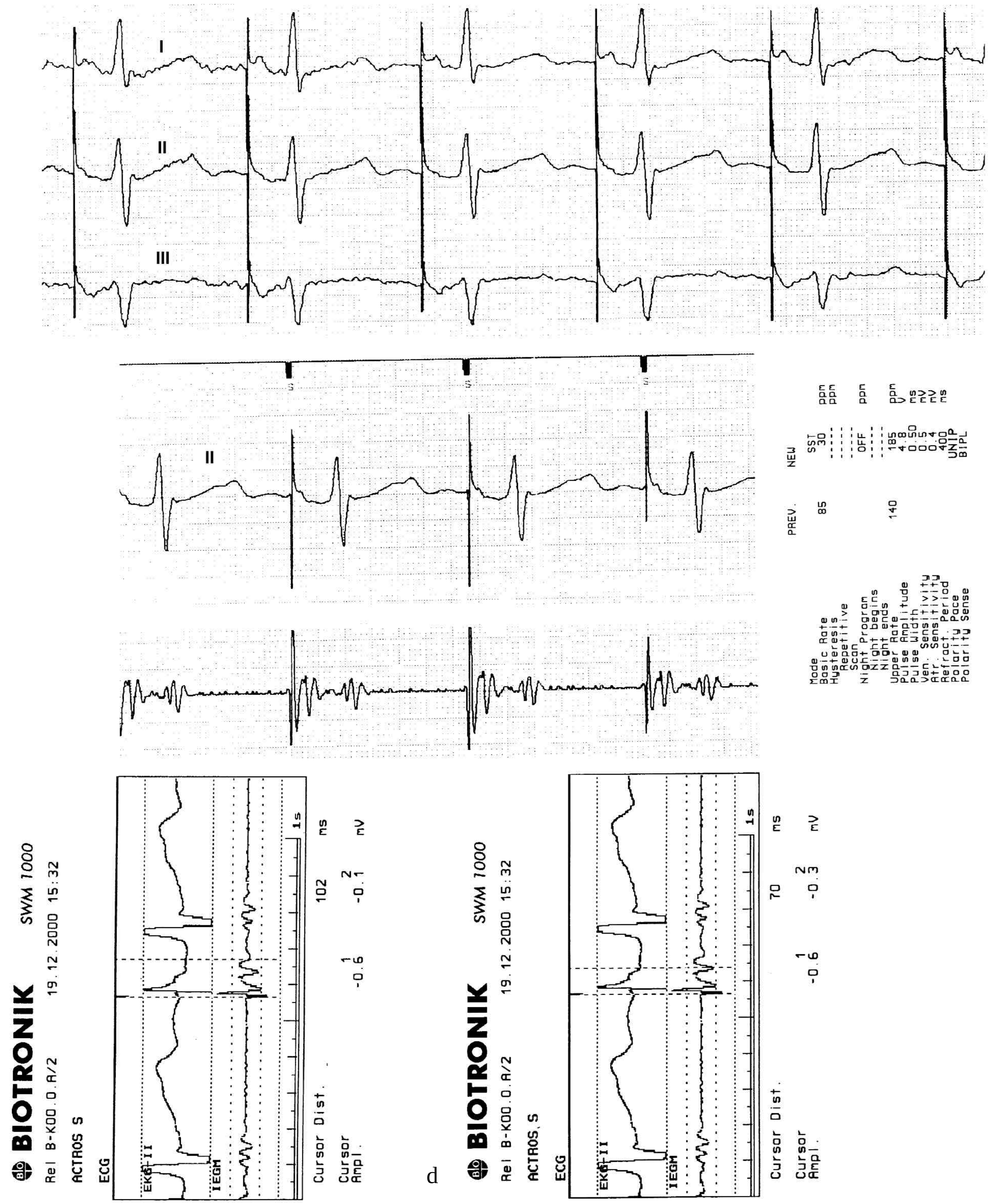


Figure 11. Septal pacing triggered with HRA potential recorded from the ring of the study lead. Standard ECG (a) and IEGM recorded during triggered pacing (b) for BP pacing and sensing configuration. Paced P-wave duration (d) was reduced from 130 ms up to 70 ms and atrial activation time from 140 up to 100 ms, in comparison to sinus rhythm without triggered pacing. Note that the pacing spike was delivered directly after onset of the sensed high right atrium potential (b). Recordings were obtained with pulse amplitude exceeding threshold values.

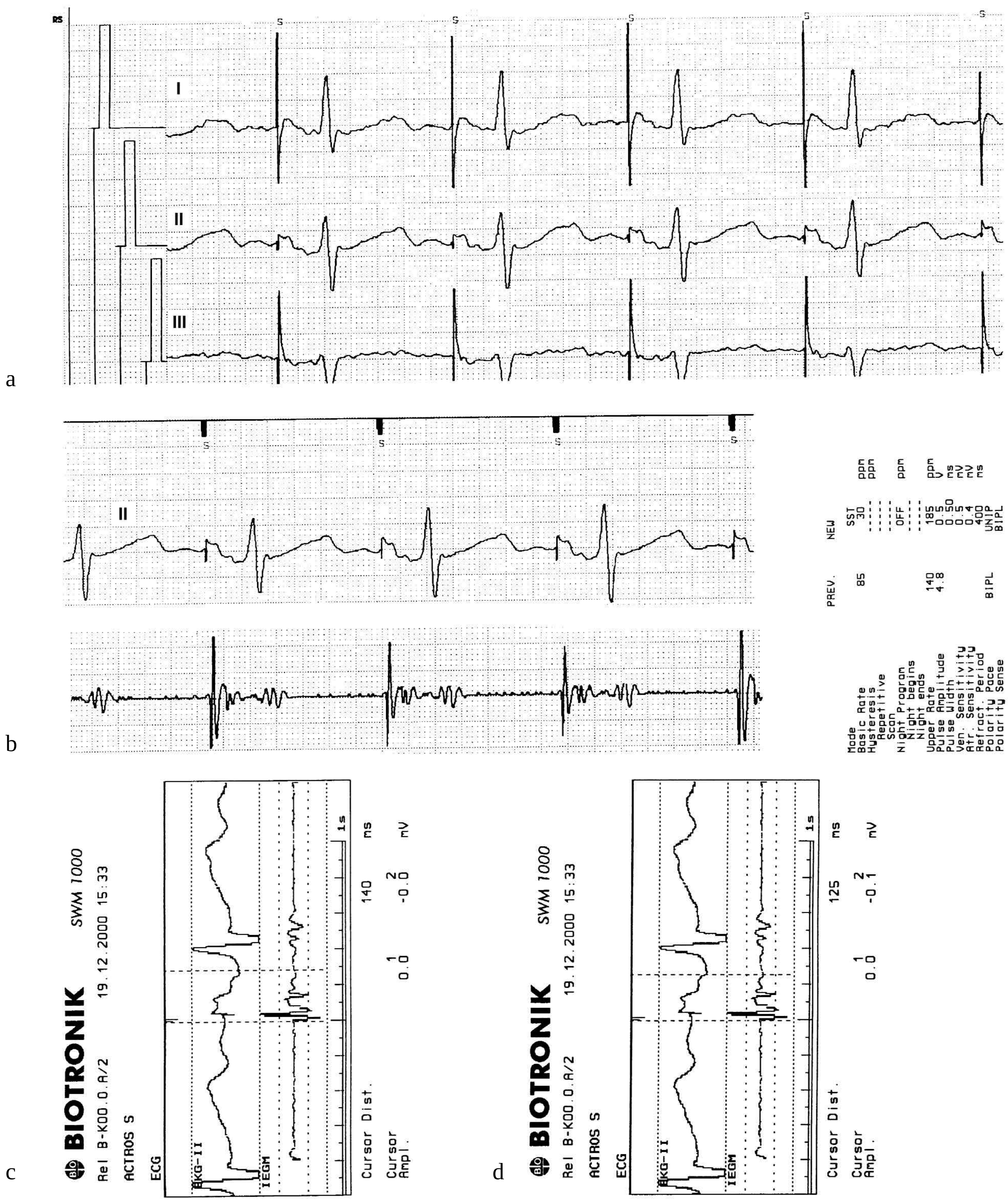


Figure 12. The same pacing program as in Figure 11, with pulse amplitude decreased to subthreshold values. Ineffective spikes do not change atrial activation in comparison to sinus rhythm, which is significantly different to effective septal pacing from Figure 11.

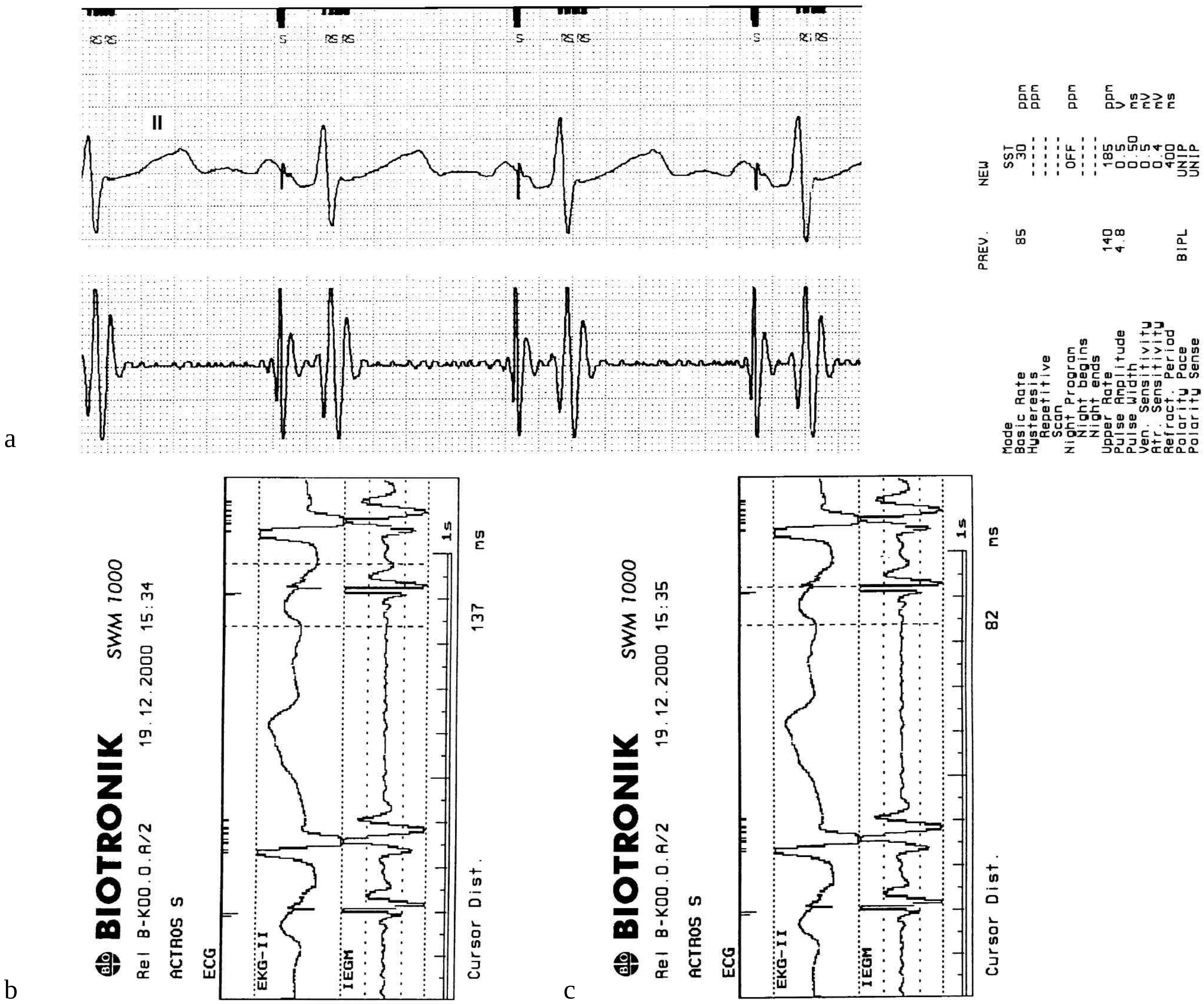


Figure 13. The same pacing program as in Figure 11, with pulse amplitude decreased up to subthreshold values and sense polarity reprogrammed to UP. Ineffective spikes indicate a delayed detection moment of the excitation front in the coronary sinus ostium region; pacing does not influence atrial activation in comparison to sinus rhythm, and significant differences cab be seen compared with in comparing the effective septal pacing from Figure 11.

[49-51]. Local potentials, e.g., sensed in RAA, are sufficient for driving ventricular pacing, but this advantage may pose a disadvantage for atrial resynchronization.

The proposed pacing system seems to be very promising. It combines all of the advantages of multisite atrial pacing systems (triggered pacing) with simple, single-site pacing systems. This proposed system facilitates very early detection of atrial excitation much better than multisite (driven with RAA potential) pacing systems can offer. This system allows for permanent (continuous) preexcitation of the triangle in the Koch region, the most common arrythmogenic area in the atria. These effects can be obtained using the simplest unit that offers triggered pacing (SST). Increasing the distance of the ring to the tip did not result in the deterioration of sensing or pacing conditions. Our first experience will have to be confirmed during electrophysiologic studies and in larger groups of permanently paced patients.

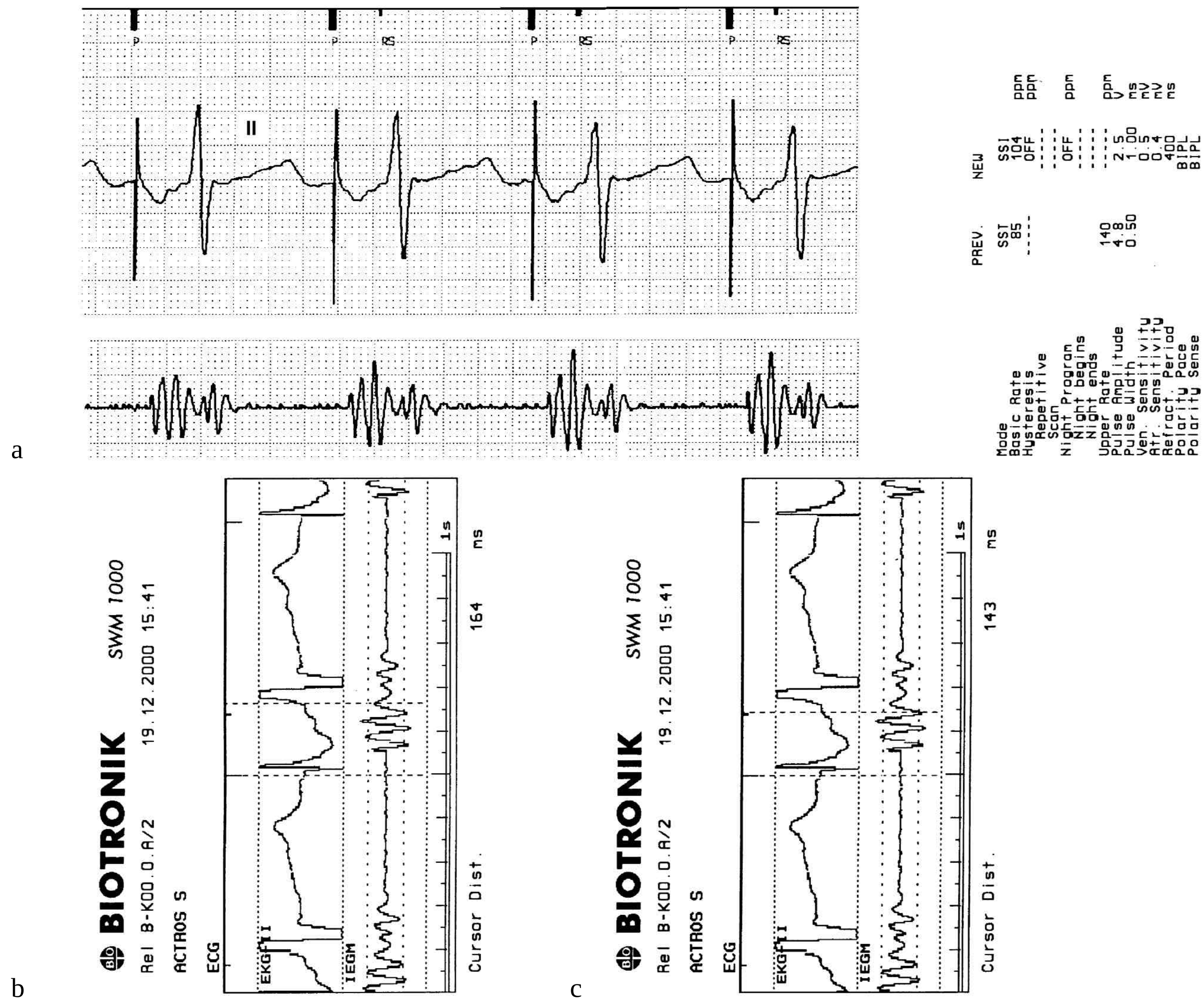


Figure 14. SSI (104 beats/min) septal (BP but unifocal) pacing above the sinus rate. P-wave duration is 140 ms and atrial activation time about 160 ms. Synchrony of atrial activation is not as good as during triggered septal pacing (compare to Figure 11). Atrial premature beats cannot trigger pacing due to the SSI programmed mode.

Conclusion

When a BP screw-in lead (with large distances between the tip and ring) is located in the CS ostium region, it may provide excellent, low posterior, septal pacing triggered with the onset of atrial excitation.

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