BEHAVIOR OF AN AUTOMATIC PACEMAKER SENSING ALGORITHM FOR SINGLE-PASS VDD ATRIAL ELECTROGRAMS

J. Kim[1], S.H. Lee[1], S.Y.Yang[2], B. S. Cho[2], and W. Huh[1]
[1]Department of Electronics Engineering, Myongji University, Yongin, Korea
[2]Department of Information and Communication, Dongwon College, Kwangju, Korea

Abstract-**Single-pass VDD pacemakers have been used as a result of simple implantation procedures and generally reliable atrial tracking. However, there is a controversy over their reliabilities of atrial tracking. As a new sensing method for reliable atrial tracking, a simple automatic pacemaker sensing algorithm was implemented and evaluated to validate its benefits in sensing depolarization waves of single-pass VDD atrial electrograms. The automatic sensing algorithm had a predetermined sensing dynamic range and the sensitivity level was controlled as 50 % of the average of two most recently sensed intrinsic amplitudes. The behavior of the automatic sensing algorithm in the single-pass VDD atrial electrograms was analyzed and characterized. It was observed that the automatic sensing algorithm was more effective than a conventional fixed threshold method to accurately detect and track p-waves in SVDD electrograms.**
***Keywords* - Automatic sensing algorithm, pacemakers, single-pass VDD, electrogram**

I. INTRODUCTION

Single-pass VDD (SVDD) pacemaker systems have been used as a result of simple implantation procedures and generally reliable atrial tracking [1-2]. However, since in the single lead electrode the atrial sensing poles are floating, the signal amplitude may vary considerably. An optimal sensitivity level can not be determined using amplitude measurements of acute atrial electrograms because of the significant amplitude variations [3-4]. Individual patients may experience serious P-wave undersensing that may require sensing sensitivity reprogramming or may cause asynchronous pacing

There are several studies that suggest a highest sensitivity for P-wave sensing to compensate the amplitude variation, while there are contradictory studies that concern possible oversensing problems by the highest sensitivities [5-7].

In this study, a sensing method that adapts its sensitivity level to previous intrinsic amplitude variations, an automatic sensing algorithm, is implemented and evaluated to validate its benefits in atrial electrograms from SVDD leads. The automatic sensing algorithm had been developed for sensing of automatic implantable cardioverter defibrillator (AICD or ICD), and has been adopted by pacemakers recently [8-9]. It is expected that the automatic sensing algorithm in pacemakers will improve the sensing performance and remove the human intervention for choosing an optimal sensitivity level.

The purpose of this study is to characterize the behavior of an automatic sensing algorithm during SVDD P-wave sensing and compare its sensing performance to that of a conventional fixed sensitivity method.

II. METHODOLOGY

A simple automatic sensing algorithm was applied to 9 patients SVDD atrial electrograms obtained by Phymos™ 830-s lead (Medico), during several different body postures, deep respiration, and walking. The algorithm had a pre-determined sensing dynamic range of 0.25 - 2.25 mV and controlled the sensitivity level beat by beat as 50% of the average of two most recently sensed intrinsic amplitudes, as shown in Figure 1.

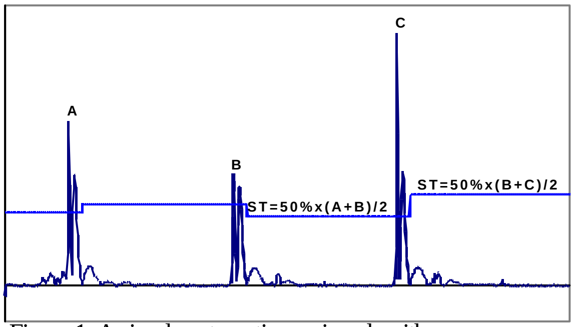

Figure 1. A simple automatic sensing algorithm.

In the figure, the sensitivity level (ST) after the second beat (B) of a rectified atrial electrogram, is calculated as 50% of the average of beats A and B. The behavior of the automatic sensing algorithm during SVDD P-wave sensing was characterized, and the sensing performance was compared to that of a conventional fixed sensitivity method.

Epochs (1-3 min.) containing the largest amount of amplitude variation and noise level were chosen from each electrogram and were applied to the automatic sensing algorithm. The algorithm was implemented on the epochs of electrograms by computer simulation.

Table 1 summarizes the p-wave amplitude characteristic of the 9 epochs. The signal amplitudes differ largely, depending on individual patient, and each patient also shows a considerable amplitude variation.

Table 1. The amplitude variation of SVDD electrograms used for algorithm simulation.

	Pt 1	*Pt 2*	*Pt 3*	*Pt 4*	*Pt 5*	*Pt 6*	*Pt 7*	*Pt 8*	*Pt 9*	*All*
Mean	0.33	0.62	0.68	0.52	0.45	1.86	4.55	1.06	1.58	1.29
SD	0.11	0.10	0.10	0.12	0.15	0.50	0.87	0.14	0.48	1.25
Max.	0.64	0.78	0.80	0.78	0.79	3.10	6.02	1.58	3.12	6.02
Min.	0.11	0.46	0.45	0.26	0.18	1.12	2.86	0.78	0.69	0.11

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Behavior of An Automatic Pacemaker Sensing Algorithm For Single-Pass VDD Atrial Electrograms	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Department of Electronics Engineering Myongii University Yongin, Korea	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-26, 2001 held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
2

Finally, the numbers of oversensed (false-positive) and undersensed (false-negative) beats by a conventional fixed sensitivity method at 0.25mV and the automatic sensing algorithm were compared.

III. RESULTS

The automatic sensing algorithm set the sensitivity level (ST) properly between p-wave and noise in all 9 patients without any human intervention. In Figure 2, the result of the automatic sensing algorithm was compared to that of the fixed sensitivity method. The algorithm reduced the malsensed beats by 46% in total, compared to the fixed sensitivity method. The oversensed beats by the fixed sensitivity method and the automatic sensing method were 3.9% and 0.5%, undersensed beats 4.7% and 3.0%, respectively. The reduction of oversensed beats was achieved in patients 5 and 7, while there was no difference by both methods in the remaining 7 patients. The reduction of undersensed beats was achieved in patients 1, 5, and 7, while there was no difference in the remaining patients. Not even one case was found that the fixed sensitivity method outperformed the automatic sensing method.

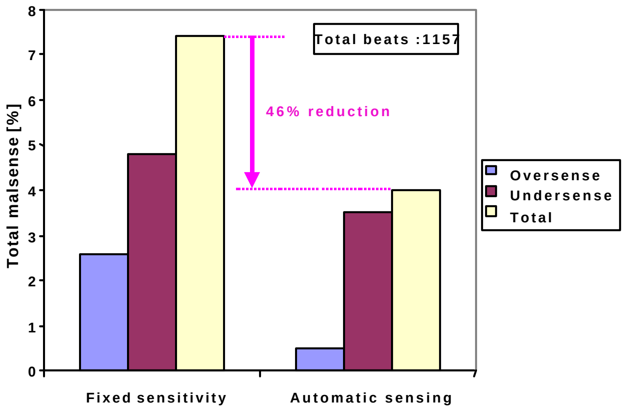

Figure 2. The percentages of malsensed beats by a fixed sensitivity method and the automatic sensing method.

IV. DISCUSSION AND CONCLUSION

Example of the behavior of automatic sensing algorithm is shown in Figure 3. The upper fluctuation shows the p-wave amplitude variation and the lower fluctuation shows the corresponding noise level. The algorithm sets the sensitivity level (middle fluctuation) properly between p-waves and noises. When p-wave amplitude becomes low, the automatic sensing algorithm chooses a higher sensitivity level. At worst case, the algorithm sets the sensitivity level at maximum sensitivity that is the same level as in the fixed sensitivity method, providing the same noise immunity. However, when the intrinsic amplitude becomes higher, the automatic sensing algorithm sets the sensitivity level higher, providing more noise immunity compared to the fixed sensitivity method.

The automatic sensing algorithm behaved to reduce the duration during which the system operated at high sensitivities by increasing sensitivity only when necessary. This explains how the automatic sensing algorithm has reduced the malsensed beats, particularly oversensed beats.

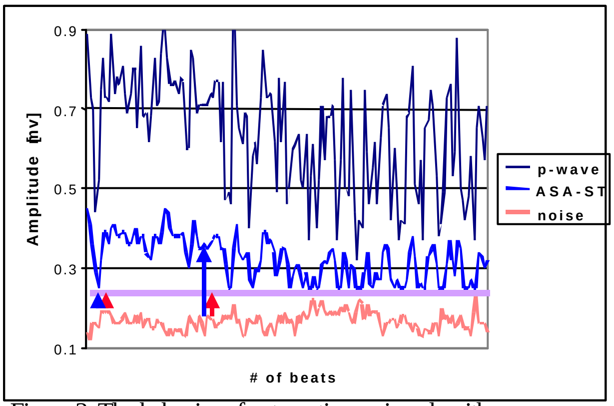

Figure 3. The behavior of automatic sensing algorithm.

Since an atrial amplitude of SVDD electrogram varies significantly and an optimal fixed sensitivity level is hardly obtainable by a couple of amplitude measurements during follow-ups, the automatic sensing algorithm is more effective than a conventional fixed threshold method to accurately detect and track p-waves in SVDD electrograms. To avoid detection of noise in an electrogram with a low signal to noise ratio, it is recommended that an automatic sensing algorithm have a noise level monitoring capability.

Automatic sensing algorithms are expected to increase pacemaker system ease of use by eliminating the need to measure P-wave amplitudes during routine follow-ups.

REFERENCES

[1] P. Curry, and D. Raper, "Single lead for permanent physiological cardiac pacing.," Lancet, vol. 2, pp.757-759, 1978.

[2] R. Brownlee, "Toward optimizing the detection of atrial depolarization with floating bipolar electrode," PACE, vol. 12, pp.431-442, 1989.

[3] E. Langford, R. Smith, W. McGrea, and R. Wainwright, "Determining optimal atrial sensitivity settings for single lead VDD pacing," PACE, vol.20, pp.619-623, 1997.

[4] Z. Sun, J. Stjernvall, P. Laine, and L. Toivonen, "Extensive variation in the signal amplitude of the atrial floating VDD pacing electrode," PACE, vol.21, pp.1760-1765, 1998.

[5] C. Lau, Y. Tai, S. Leung, W. Leung, F. Chung, and I Lee, "Long-term stability of P wave sensing in single lead VDDR pacing: Clinical versus subclinical atrial undersensing," PACE, vol.17, pp.1849-1853, 1994.

[6] D. Lellouche, C. Adamopoulous, O. Gartenlaub, F. Halimi, "Long term reliability of single-lead VDD pacing," Eur. J. C. P. E. vol. 6, no1, p243, 1996.

[7] U. Wiegand, J. Potratz, R. Schneider, F. Bode, A. Brandes, and K. Diederich, "Atrial sensing failures of a single-lead VDD pacemaker," Eur. J. C. P. E. vol. 6, no1, p249, 1996.

[8] J. Kim and P. Haefner, "An automatic pacemaker sensing algorithm using automatic gain control," Proceedings of the 20th Annual International Conference of the IEEE EMBS, Vol. 20, pp.423-425, 1998.

[9] B. Jones, J. Kim, Q. Zhu, J. Nelson, B. KenKnight, D. Lang, J. Warren, "Future of bradyarrhythmia therapy system: Automaticity," Am. J. of Cardiol., vol. 83, pp.192D-210D, 1999.