Original Article

Feasibility of Atrial AutoCapture™ to Detect Atrial Evoked Response: Experience from 102 Patients Implanted with Dual-chamber Pacemakers

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Abstract

Background: Atrial AutoCapture™ (ACap™) was a new technological development that confirmed atrial capture by analyzing evoked response (ER) with a new method – paced depolarization integral ER detection – and optimized energy output to changes in the stimulation threshold. The purpose of this study was to evaluate the clinical performance of ACap™ function.
Methods: This was a prospective, observational, nonrandomized two-center study. Between November 2008 and August 2014, 102 patients were enrolled from two different institutions. Data were collected by case report forms at enrollment, hospital discharge, and in-office follow-ups scheduled at 1, 2, 3, 6, and 12 months postimplantation.
Results: Ambulatory ACap™ function started to become available for 20.6% of patients at 1 day, then progressed to 30.4% at 7 days, 38.6% at 1 month, 41.6% at 2 months, 47.5% at 3 months, 53.5% at 6 months, and 63.4% at 1 year. The cause of the unsuccessful attempts to perform ACap™ threshold was ER/polarization <2:1. Availability for SD, BND, and HOCM indications had shown better results than AVB indication. For SD indication cases, feasibility was significantly better for SD with paroxysmal atrial fibrillation (pAF) than SD without pAF (78.4% vs. 35.0% at 1 year, $n = 71$, $P < 0.001$). At each stage of the clinical follow-ups, there had been a strict correlation between ACap™ measurements and those conducted manually with $P < 0.001$ ($n = 299$).
Conclusions: It has been concluded that ACap™ function was safe and effective to confirm atrial threshold and reduce energy output automatically. ACap™ function is unavailable for some patients at early stages of the implantation; however, availability has been progressively increasing during follow-up.

Key words: AutoCapture; Pacemaker; Pacing; Stimulation Threshold

Introduction

Automatic assessment of ventricular threshold by analyzing evoked response (ER) to confirm capture had been used in medical practice for more than 10 years.[1] Atrial threshold measurement by analyzing ER had been difficult because the amplitude of ER was too low to detect with the disturbance of polarization (POL).[2] For this reason, the manufacturer Medtronic had developed atrial automatic capture measurement (ACM) with a specific algorithm of introducing premature atrial pacing and sensing of atrial or ventricular responses according to the pacing modes to assess atrial threshold. ACM confirmed atrial capture depending on a stable sinus rhythm or a stable atrioventricular conduction (AVC), or it could not work normally. The results of this method had been previously published, and the ACM was unavailable for a part of patients.[3-5] Recently, the manufacturer St. Jude Medical had developed atrial AutoCapture™ (ACap™) technology

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by analyzing ER with a new method – paced depolarization integral (PDI) ER detection without limitations of stable sinus rhythm or AVC; however, the clinical outcomes of this method had not yet been studied extensively. The purpose of this study was to assess the clinical performance of the ACap™ management system of Zephyr5826 DR implantable pacemaker (St. Jude Medical, Minnesota, USA).

Methods

Ethical approval

The study was conducted in accordance with the *Declaration of Helsinki* and was approved by the Institutional Review Board at TEDA International Cardiovascular Hospital ((No. 2008-006, Tianjin, China) and Tianjin Chest Hospital (Tianjin, China) that participated in the study. Written informed consent was obtained from all participants.

Study protocol

This was a prospective, observational, nonrandomized two-center study. Between November 2008 and August 2014, 102 patients implanted with Zephyr 5826 DR pacemakers were enrolled over two different institutions. Indications of dual-chamber pacing were not selected *a priori* for enrollment. Transvenous leads were part of the inclusion criteria, and the lead selection was restricted. Data were collected by case report forms at enrollment, hospital discharge, and in-office follow-ups scheduled at 1, 2, 3, 6, and 12 months postimplantation. St. Jude Merlin programmer device (St. Jude Medical, Minnesota, USA) was used to perform pacemaker interrogations. Before ACap™ management started to function, ACap™ Confirm Setup test must be performed to determine the area ER sensitivity. The area ER sensitivity must be determined, and ACap™ management function could be recommended only if ER/POL >2:1. If ER/POL was <2:1, the ACap™ function must not be turned on. Manually measured atrial threshold data using atrial amplitude autodecrement test with a voltage step of 0.25 V were compared with the atrial pacing threshold data assessed by ACap™ Immediate Test using the same pulse width (0.4 ms) and an amplitude autodecrement with a voltage step of 0.125 V. Clinical equivalence was defined as such that the difference between ACap™ and manual thresholds must be within −0.125 V to +0.125 V in tolerance. The physician performing manual testing was aware of the results of the ACap™ Confirm Setup test and the ACap™ Immediate Test. For other parameters and the atrioventricular (AV) delay values, in particular, programming was left to the discretion of the physician.

Description of the atrial AutoCapture™ measurement algorithm

ACap™ measurement function operated in DDD/DDDR mode with bipolar pacing configuration only. It measured atrial pacing threshold automatically and regularly every 8 or 24 h for out-of-clinic use and immediately by user initiated threshold search for in-clinic use. All atrial pacing thresholds data were stored in the device memory and could be plotted into graphs if needed. The atrial pacing voltage was adjusted based on the last measurement. The pacemaker applied the fixed amplitude safety margin to the amplitude threshold value measured at a 0.4 ms pulse width to determine the target amplitude [Table 1]. If the operating amplitude was above the target, the pacemaker would adjust the amplitude down toward the target in one-step decrements. If the operating amplitude was below the target, the amplitude would immediately adjust to the target. A high-threshold warning would be issued if the amplitude threshold reached 3.0 V; the pacemaker would respond by adjusting to amplitude of 5.0 V and a pulse width of 0.4 ms.

Similar to the ventricular AutoCapture™ management, ACap™ management utilized the ER sensing to determine capture. Before ACap™ management function could be turned on, ACap™ Confirm Setup test must be performed to determine the area ER sensitivity. The area ER sensitivity needs to be determined, and ACap™ management function would be recommended if ER/POL >2:1. If the above-mentioned ratio was <2:1, ACap™ function must not be turned on and the possible reasons for ER/POL <2:1 would be shown.

ACap™ Confirm Setup test included three phases: atrial capture verification, atrial rate overdrive, and atrial threshold search. PDI detection was the only capture verification algorithm used to confirm atrial capture, which was based on the area under the signal waveform of captured beats. The calculated area value was then stored for threshold testing comparisons [Figure 1]. The test would only run if the patients' paced rate was below 120 beats/min. AV delay was <120 ms and default temporary values for the test were DDD/R and rate 90 beats/min.

Table 1: ACap™ function applied the fixed amplitude safety margin to the atrial threshold

Atrial threshold (V)	Voltage added to the atrial threshold (V)	Atrial pacing voltage (V)
0.125–1.500	+1.0	1.125–2.500
1.625–2.250	+1.5	3.125–3.750
2.375–3.000	+2.0	4.375–5.000
>3.000	Goes to 5.0	5.000

ACap™: Atrial AutoCapture™.

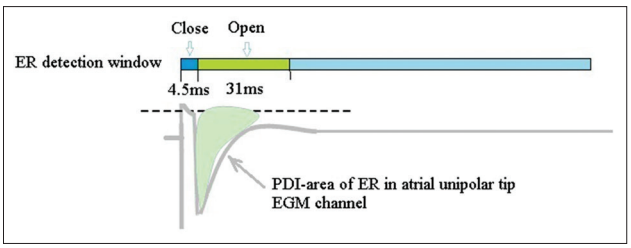

Figure 1: Paced depolarization integral detection of atrial evoked response. EGM: Electrogram; PDI: Paced depolarization integral; ER: Evoked response.

Implanted leads

The atrial leads were newly implanted in all 102 patients (100%), and the lead selection was restricted to IsoFlex S 1642T bipolar lead (St. Jude Medical, Minnesota, USA) with low POL. The lead location was the right atrial appendage.

Statistical analysis

Data were subjected to descriptive statistical analysis. Means and standard deviations were performed for quantitative variables, and frequency measurements (absolute frequencies and percentages) were performed for qualitative variables. Univariate analysis of the quantitative variables was performed using the Student's *t*-test if the distribution was normal. The Mann-Whitney *U*-test was used instead if the distribution was not normal distribution. The qualitative variables were analyzed using the Chi-square or the Fisher's exact test. Regression coefficient model was used to compare the manual threshold data with the ACap™ management output. In all cases, statistical significance was established as $P < 0.05$. The software package SPSS Version 17.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses.

Results

Patients

A total of 102 patients were enrolled in the study from two institutions in China. The mean age of the patient population was 69.2 ± 9.2 years with a slightly higher ratio of male (60%) patients.

Indications of pacing were sinus dysfunction (SD) or Brady-Tachy syndrome (70.0%), AV block (AVB, 21.0%), binodal disease (BND, 6.0%), and hypertrophic obstructive cardiomyopathy (HOCM, 3.0%). Fifty-two percent of patients had a history of paroxysmal atrial fibrillation (pAF); 55.0% of patients were known or likely to be pacemaker dependent; and 16.0% of patients had an ischemic cardiopathy history. All 102 patients were assessed at 1 and 7 days postimplantation, and 101 patients were assessed at 1, 2, 3, 6, and 12 months postimplantation. During the study, no clinical complications related to the pacemaker settings were observed.

Feasibility of atrial AutoCapture™ management function and manual atrial thresholds during follow-up

Table 2 shows that ambulatory ACap™ management function was available for 21 patients (20.6%) at 1 day, 31 patients (30.4%) at 1 week, 39 patients (38.6%) at 1 month, 42 patients (41.6%) at 2 months, 48 patients (47.5%) at 3 months, 54 patients (53.5%) at 6 months, and 64 patients (63.4%) at 1 year. Gain adjustment failure (95.4%) was the main cause of ER/POL <2:1, and other causes included high pacing threshold (0.2%), low ER (1.7%), and unstable safety range (2.7%). During the courses of the ACap™ Confirm Setup test and ACap™ Immediate Test, there were no atrial fibrillation and other tachycardia observed.

Manual atrial threshold data were available for all patients at follow-up

Table 3 shows the unavailability of ACap™ management function according to indications of pacing at each follow-up. Due to more frequent gain adjustment failure occurrence in AVB patients precluding atrial threshold assessment, availability was better for SD indication than for AVB with a gradually expanding difference during follow-up, but no statistical difference (23.6% vs. 9.5% at 1 day, $n = 93$, $P = 0.271$; 31.9% vs. 14.3% at 1 week, $n = 93$, $P = 0.190$; 40.8% vs. 19.0% at 1 month, $n = 92$, $P = 0.116$; 42.3% vs. 28.6% at 2 months, $n = 92$, $P = 0.259$; 47.9% vs. 33.3% at 3 months, $n = 92$, $P = 0.238$; 56.3% vs. 33.3% at 6 months, $n = 92$, $P = 0.064$; and 66.2% vs. 42.9% at 1 year, $n = 92$, $P = 0.054$) was observed.

Figure 2 shows that the percentage of patients with available ACap™ function varied progressively at each follow-up for different indications of pacing. Compared with the overall average, the availability level of ACap™ management was higher for HOCM, BND, and SD with pAF indications and was lower for AVB and SD without pAF indications. For SD indication as shown in Table 4, the availability of ACap™ function was significantly better for SD with pAF than SD without pAF with a gradually expanding difference during follow-up (26.9% vs. 15.0%, $n = 72$, $P = 0.449$, at 1 day; 38.5% vs. 15.0%, $n = 72$, $P = 0.103$, at 1 week; 49.0% vs. 20.0%, $n = 71$, $P < 0.05$, at 1 month; 51.0% vs. 20.0%, $n = 71$, $P < 0.05$, at 2 months; 56.9% vs. 25.0%, $n = 71$, $P < 0.05$, at 3 months; 68.6% vs. 25.0%, $n = 71$, $P < 0.001$, at 6 months; and 78.4% vs. 35.0%, $n = 71$, $P < 0.001$, at 1 year). For patients with pAF, the AF burden was 2.1 ± 2.7%. The percentage of atrial pacing was higher for SD with pAF and available ACap™ function than SD with pAF and unavailable ACap™ function (72.9 ± 27.2% vs. 54.8 ± 26.2%, $n = 51$, $P < 0.05$).

Chronology of atrial AutoCapture™ atrial threshold with regard to manual atrial threshold assessment

The manual test and ACap™ Immediate Test were performed successively for all patients with available ACap™

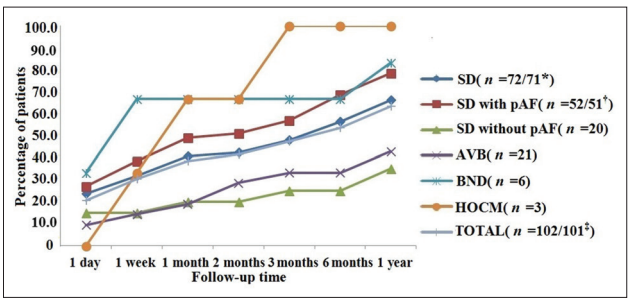

Figure 2: Percentage of patients with available atrial AutoCapture™ function varied progressively at each follow-up for different indications of pacing. *$n = 72$ at 1 day and 1 week, and $n = 71$ at 1, 2, 3, and 6 months and 1 year, †$n = 52$ at 1 day and 1 week, and $n = 51$ at 1, 2, 3, and 6 months and 1 year, ‡$n = 102$ at 1 day and 1 week, and $n = 101$ at 1, 2, 3, 6 months and 1 year. SD: Sinus dysfunction; AVB: Atrioventricular block; BND: Binodal disease; HOCM: Hypertrophic obstructive cardiomyopathy; pAF: Paroxysmal atrial fibrillation.

Table 2: Ambulatory feasibility of ACap™ management during follow-ups and the causes of unavailability

Patients	Possible cause of ER/POL <2:1	1 day (*n* = 102)	1 week (*n* = 102)	1 month (*n* = 101)	2 months (*n* = 101)	3 months (*n* = 101)	6 months (*n* = 101)	12 months (*n* = 101)
With available ACap™		21	31	39	42	48	54	64
With unavailable ACap™	Gain adjustment failure	80	68	58	55	51	44	35
	Unstable safety range	1	3	2	2	1	1	1
	ER is too low	0	0	2	1	1	2	1
	High pacing threshold	0	0	0	1	0	0	0
	Total	81 (79.4)	71 (69.6)	62 (61.4)	59 (58.4)	53 (52.5)	47 (46.5)	37 (36.6)
Loss of follow-up				1	1	1	1	1

Values are presented as *n* or *n* (%). ER: Evoked response; POL: Polarization; ACap™: Atrial AutoCapture™.

Table 3: Unavailability of ACap™ management function according to indications of pacing at each follow-up

Indication	Possible reason for ER/POL <2:1	1 day (*n* = 102)	1 week (*n* = 102)	1 month (*n* = 101)	2 months (*n* = 101)	3 months (*n* = 101)	6 months (*n* = 101)	12 months (*n* = 101)
SD (*n* = 72/71*)	Gain adjustment failure	54	48	39	39	36	29	22
	Unstable safety range	1	1	1	0	0	1	1
	ER is too low	0	0	2	1	1	1	1
	High pacing threshold	0	0	0	1	0	0	0
AVB (*n* = 21)	Gain adjustment failure	19	17	17	14	13	14	12
	Unstable safety range	0	1	0	1	1	0	0
BND (*n* = 6)	Gain adjustment failure	4	2	2	2	2	1	1
	Unstable safety range	0	0	0	0	0	1	0
HOCM (*n* = 3)	Gain adjustment failure	3	1	0	0	0	0	0
	Unstable safety range	0	1	1	1	0	0	0

Values are presented as *n* or percentage. *n = 72 at 1 day and 1 week, and n = 71 at 1, 2, 3, 6, and 12 months. *n* (column): Number of patients according to indications of pacing; *n* (row): Number of patients during follow-up. SD: Sinus dysfunction; AVB: Atrioventricular block; BND: Binodal disease; HOCM: Hypertrophic obstructive cardiomyopathy; ER: Evoked response; POL: Polarization; ACap™: Atrial AutoCapture™.

Table 4: Availability of ACap™ function was significantly better for SD with pAF than SD without pAF with a gradually expanding difference during follow-up

Indications	1 day (*n* = 72)	1 week (*n* = 72)	1 month (*n* = 71)	2 months (*n* = 71)	3 months (*n* = 71)	6 months (*n* = 71)	12 months (*n* = 71)
SD with pAF (*n* = 52/51*)	14 (26.9)	20 (38.5)	25 (49.0)	26 (51.0)	29 (56.9)	35 (68.6)	40 (78.4)
SD without pAF (*n* = 20)	3 (15.0)	3 (15.0)	4 (20.0)	4 (20.0)	5 (25.0)	5 (25.0)	7 (35.0)
χ^2	0.573	2.658	3.878	4.453	5.844	11.116	12.110
P	0.449	0.103	<0.050	<0.050	<0.050	<0.001	<0.001

Values are presented as *n* (%). *n = 52 at 1 day and 1 week, and n = 51 at 1, 2, 3, 6, and 12 months; *P* means SD with pAF versus SD without pAF. *n* (column): Number of patients according to indications of pacing; *n* (row): Number of patients during follow-up. SD: Sinus dysfunction; pAF: Paroxysmal atrial fibrillation; ACap™: Atrial AutoCapture™.

management function. There was only a few minutes delay between ACap™ Immediate Test and manual test, and as a result, the changes of atrial threshold with time were insignificant.

Correlations between atrial AutoCapture™ and manual thresholds

Values of ACap™ and manual atrial thresholds are summarized in Table 5. The difference in mean values between the two methods was 0.012 V at 1 day, 0.032 V at 1 week, 0.028 V at 1 month, 0.012 V at 2 months, 0.011 V at 3 months, 0.012 V at 6 months, and 0.006 V at 1 year. The mean of output voltage in ACap™ atrial pacing was 1.786 V at 1 day, 1.781 V at 1 week, 1.721 V at 1 month, 1.595 V at 2 months, 1.609 V at 3 months, 1.586 V at 6 months, and 1.541 V at 1 year.

As shown in Figure 3, excellent correlation was demonstrated between the two methods with a correlation coefficient of 0.9853 at 1 day, 0.8261 at 1 week, 0.9898 at 1 month, 0.9775 at 2 months, 0.9846 at 3 months, 0.9636 at 6 months, and 0.9901 at 1 year follow-up.

The differences between the two methods were observed as the following: For 100% of patients at 1 day, 96.8% at 1 week, 97.4% at 1 month, and 100% at 2, 3, 6, and 12 months, the difference was ≤0.125 V. The difference was 0.5 V for one patient (3.2%) at 1 week and 0.625 V for the same patient (2.6%) at 1 month follow-up. No

Table 5: Comparison between the values of ambulatory available ACap™ thresholds and those of manual atrial thresholds

Follow-up	Number of patients with available ACap™	Mean of ACap™ threshold (V)	Mean of corresponding manual threshold (V)	Difference of means (V)	Mean of output voltage (V)
1 day	21	0.786 ± 0.186	0.798 ± 0.203	0.012	1.786 ± 0.186
1 week	31	0.718 ± 0.185	0.750 ± 0.204	0.032	1.718 ± 0.185
1 month	39	0.696 ± 0.313	0.724 ± 0.405	0.028	1.721 ± 0.460
2 months	42	0.595 ± 0.170	0.607 ± 0.176	0.012	1.595 ± 0.170
3 months	48	0.609 ± 0.196	0.620 ± 0.200	0.011	1.609 ± 0.196
6 months	54	0.586 ± 0.159	0.598 ± 0.164	0.012	1.586 ± 0.159
12 months	64	0.541 ± 0.184	0.547 ± 0.188	0.006	1.541 ± 0.184
Total	299	0.623 ± 0.213	0.638 ± 0.239	0.015	1.627 ± 0.246

Values are presented as *n* or mean ± SD. SD: Standard deviation; ACap™: Atrial AutoCapture™.

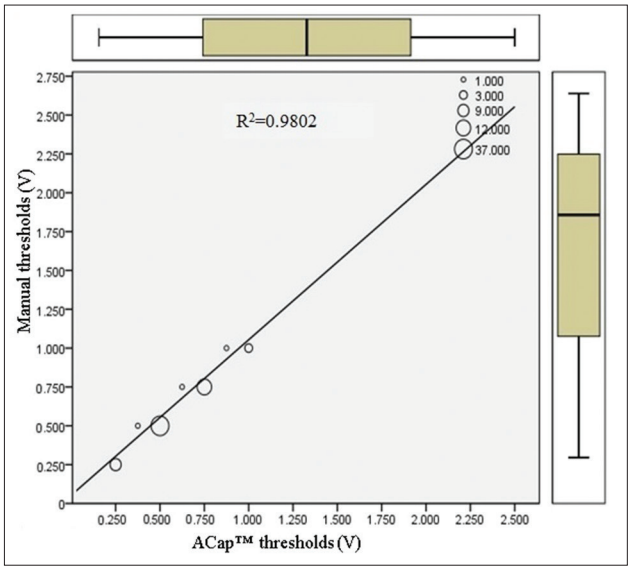

Figure 3: Regression coefficient between atrial AutoCapture™ and manual thresholds at 1 year ($n = 64$). Circle surface was proportional to the number of the same values.

difference >0.625 V between the two methods was observed. For the patient with a difference of 0.500 V and 0.625 V between ACap™ and manual thresholds, absolute pacing thresholds were 0.750 V, 2.375 V for ACap™ method and 0.25 V, 3.00 V for manual method, and automatic adjustment output voltage was 1.75 V, 4.375 V separately. The percentage of individual clinical equivalence for the two methods was 99.3% (297/299). The electrocardiogram and Holter monitoring of all patients showed a normal pacing function without loss of capture during follow-up. No atrial fibrillation and other tachycardia were observed during 299 tests in 64 patients.

The manual pacing threshold of patients with unavailable ACap™ function was 0.707 ± 0.201 V ($n = 410$), and the output voltage was 2.5 V with a 0.4 ms pulse width.

Patients with high atrial AutoCapture™ threshold

Of all 102 patients, only one demonstrated transient high atrial threshold superior to 1.5 V at 1 month: manual and ACap™ atrial thresholds were 3.0 V and 2.375 V, and the ACap™ output voltage was 4.375 V.

Discussion

Feasibility of atrial AutoCapture™ atrial threshold

In this prospective observational study, we found that (1) the availability of ACap™ function was progressively increasing during follow-up and (2) ACap™ atrial threshold assessment was still unavailable for a percentage of the patients (36.6%) after 1 year. Causes of the unsuccessful attempts to perform ACap™ threshold were gain adjustment failure, unstable safety range, low ER, and high pacing threshold [Table 2]. No other systemic study of ACap™ management function was previously published. In Rey *et al*.'s[5] study of Medtronic ACM feature, the feasibility of ambulatory ACM threshold assessment was 91.5, 97.3, and 95.7% at discharge, 2 months, and 8 months, which was very close to Sperzel *et al*.'s[3] study of ACM. Causes of the unsuccessful attempts to perform ACM threshold were atrial arrhythmias or permanent AP-VP.

The difference between the results of ACap™ and ACM methods was believed to be caused by the different algorithm. Unlike ACap™ management, ACM did not use ER sensing to determine capture, but introduced premature atrial pacing and sensed atrial or ventricular response according to the pacing mode to assess atrial threshold. ACM uses two methods to automatically determine the atrial threshold: atrial chamber reset and AVC. Before starting threshold measurement, the device evaluated the patient's rhythm and selected the more appropriate of both the methods. ACM confirmed atrial capture depending on a stable sinus rhythm or a stable AVC, or it would not work normally. ACap™ management confirmed atrial capture by analysis of ER regardless whether patients had stable sinus rhythm/AVC or not. It had been still too difficult to analyze ER for a percentage of the patients by PDI method due to the lower wave of ER and the disturbance of POL, which caused the lower feasibility of ACap™ atrial threshold than that of ACM threshold.

The study demonstrated that the feasibility was better for SD indication than AVB with a gradually expanding difference due to the greater occurrence of gain adjustment failure, but no statistical difference was observed during follow-up [Table 3 and Figure 2]. In Rey *et al*.'s[5] study, the

feasibility of ACM feature was statistically better for AVB indication than SD, in contrary to our results. The different capture verification algorithm was considered to be the cause. Figure 2 shows that the feasibility was significantly better for SD with pAF than SD without pAF with a gradually expanding difference during follow-up. It could possibly be due to atrial ion-channel remodeling caused by pAF.[6]

Correlation between atrial AutoCapture™ and manual atrial thresholds

Correlations were excellent at the seven stages of the study [Figure 3] with $P < 0.001$. In Sperzel *et al*.'s[3] study of Medtronic ACM feature, the difference in means of values was 0.012 V at discharge, 0.010 V at 1 month, and 0.018 V at 6 months, which was very close to the results.

In this study, the difference between ACap™ and manual atrial thresholds absolute values was equal to zero in 261 (87.3%) follow-up tests, 0.125 V in 36 (12.1%), 0.50 V in 1 (0.3%), and 0.625 V in 1 (0.3%). In Rey *et al*.'s[5] study of Medtronic ACM feature, results were lower with 48% of patients without difference between the two methods, 32% with a difference of 0.125 V, 13% with 0.250 V, 5% with 0.375 V, and 2% with 0.5 V. This could be caused by the fact that automatic and manual atrial thresholds were assessed with a delay of 1 day, much longer than that of this study. When they compared the ambulatory atrial threshold and the manual atrial threshold, the difference of the means was 0.032 V and 0.017 V which was more than that of this study.

Furthermore, it should be noted that the voltage step decrease was different for the two methods −0.125 V for the ACap™ capture algorithm and 0.250 V for the manual threshold test. Therefore, the difference within −0.125 V to +0.125 V between ACap™ and manual thresholds was defined as clinical equivalence. In the study, the clinical equivalence rate between ACap™ and manual thresholds was 99.3%, better than 98% in Sperzel *et al*.'s[3] study and 80% in Rey *et al*.'s[5] study.

Potential benefit of atrial AutoCapture™ threshold assessment

Of all 102 patients, only one with transient high atrial threshold >1.5 V at 1 month was appropriately assessed by ACap™ algorithm. The maximum difference between ambulatory ACap™ and manual thresholds was 0.625 V for one patient at 1 month (ACap™ threshold was higher than manual threshold), and automatic adjustment of atrial amplitude algorithm with a fixed amplitude as shown in Table 1 ensured safe atrial pacing. In Rey *et al*.'s[5] study of ACM function, more patients with high atrial threshold ≥1.5 V appeared and were appropriately assessed by ACM algorithm: 26 patients at discharge (7.4%), 25 patients at 2 months (8.4%), and 19 patients at 8 months (7.5%). However, our follow-up lasted only 1 year and a further increase of atrial pacing threshold could occur as demonstrated by Biffi *et al*.[7] for ventricular threshold in 6.8% of patients beyond 1 year. In this event, the automatic adjustment of atrial amplitude could improve safety for patients.

In Benezet-Mazuecos *et al*.'s[8] study, the estimated projected longevity was significantly extended with automatic ventricular threshold assessment and adjustment of amplitude with a St. Jude autocapture system, especially for patients with high stimulation (output over 2.5 V) or high percentage of ventricular stimulation. With another autocapture system of Biotronik pacemaker, Biffi *et al*.[9] demonstrated a significant increase of longevity using automatic atrial and ventricular amplitude adjustment versus fixed-output pacing during long-term follow-up.

In this study, the total mean of output voltage in ACap™ atrial pacing was 1.627 ± 0.246 V (n = 299). According to Joule›s law[10] ($W = U^2t/R$), 57.6% of the atrial pacing energy consumption was reduced compared with common output voltage (2.5 V, 0.4 ms), and 78.4% was reduced compared with high output voltage (3.5 V, 0.4 ms). Automatic adjustment of atrial pacing amplitude with periodic verification of atrial threshold could increase again the longevity of the pacing system, especially for patients frequently paced in the atrium. The study showed that in the case of a rise in the atrial threshold, safety of atrial capture was always assured by automatic algorithm amplitude adjustment.

Recently, St. Jude Medical developed ACap™ management function by analyzing atrial ER with a new method – PDI ER detection; however, no systemic study of ACap™ management had yet been published. The study was performed to analyzing the availability of the ACap™ function at different stage postimplantation and the correlation between ACap™ management and manual atrial thresholds. The study was performed according to the current medical practice in a nonselected and important population of patients, 102 patients were enrolled and 101 patients completed the follow-up of 1 year.

Comparisons were performed between ambulatory ACap™ threshold and manual atrial threshold, to assess the validity of ACap™ threshold assessment in replacing the manual atrial threshold in current practice.

Not being able to perform ACap™ threshold in a percentage of the patients was a limitation of the method. This involved 71 patients (69.6%) at 1 week, 62 patients (61.4%) at 1 month, 59 patients (58.4%) at 2 months, 53 patients (52.5%) at 3 months, 47 patients (46.5%) at 6 months, and 37 patients (36.6%) at 1 year, with progressively increased availability of ACap™ management demonstrated during follow-up [Figure 2]. ACap™ function needs to be improved to reduce its unavailability. One patient was lost to follow-up at 1 month, but it was an observational study in current medical practice.

In conclusion, ACap™ function was safe and effective to confirm atrial threshold and reduce energy output automatically. ACap™ function was unavailable for a percentage of the patients, but the availability was progressively increased during follow-up.

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Nil.

Conflicts of interest
There are no conflicts of interest.

References
1. Chen RH, Chen KP, Wang FZ, Hua W, Zhang S. Impact of automatic threshold capture on pulse generator longevity. Chin Med J 2006;119:925-9.
2. Hacioglu E, Mugnai G, Czapla J, Nijs J, Wellens F, Schoors D, *et al.* Predictors of successful atrial and ventricular auto capture pacemaker algorithm post implantation: Single-centre experience. Acta Cardiol 2016;71:612-5. doi: 10.2143/AC.71.5.3167506.
3. Sperzel J, Milasinovic G, Smith TW, Mead H, Brandt J, Haisty WK, *et al.* Automatic measurement of atrial pacing thresholds in dual-chamber pacemakers: Clinical experience with atrial capture management. Heart Rhythm 2005;2:1203-10. doi: 10.1016/j.hrthm.2005.07.023.
4. Yadav R, Jaswal A, Chennapragada S, Kamath P, Hiremath SM, Kahali D, *et al.* Effectiveness of Ventricular Intrinsic Preference (VIP™) and Ventricular AutoCapture (VAC) algorithms in pacemaker patients: Results of the validate study. J Arrhythm 2016;32:29-35. doi: 10.1016/j.joa.2015.07.004.
5. Rey JL, Quenum S, Hero M. Automatic assessment of atrial pacing threshold in current medical practice. Europace 2012;14:1615-9. doi: 10.1093/europace/eus076.
6. Lee HC. Electrical remodeling in human atrial fibrillation. Chin Med J 2013;126:2380-3.
7. Biffi M, Bertini M, Mazzotti A, Gardini B, Mantovani V, Ziacchi M, *et al.* Long-term RV threshold behavior by automated measurements: Safety is the standpoint of pacemaker longevity! Pacing Clin Electrophysiol 2011;34:89-95. doi: 10.1111/j.1540-8159.2010.02915.x.
8. Benezet-Mazuecos J, Iglesias JA, Rubio JM, Cortés M, de la Cruz E, de la Vieja JJ, *et al.* Limitations of the AutoCapture™ Pacing System in patients with cardiac stimulation devices. Europace 2014;16:1469-75. doi: 10.1093/europace/euu080.
9. Biffi M, Bertini M, Saporito D, Belotti G, Quartieri F, Piancastelli M, *et al.* Automatic management of atrial and ventricular stimulation in a contemporary unselected population of pacemaker recipients: The ESSENTIAL Registry. Europace 2016;18:1551-60. doi: 10.1093/europace/euw021.
10. Kutvonen A, Koski J, Ala-Nissila T. Thermodynamics and efficiency of an autonomous on-chip Maxwell's demon. Sci Rep 2016;6:21126. doi: 10.1038/srep21126.