PACEMAKERS, ICDs, AND CARDIAC RESYNCHRONIZATION

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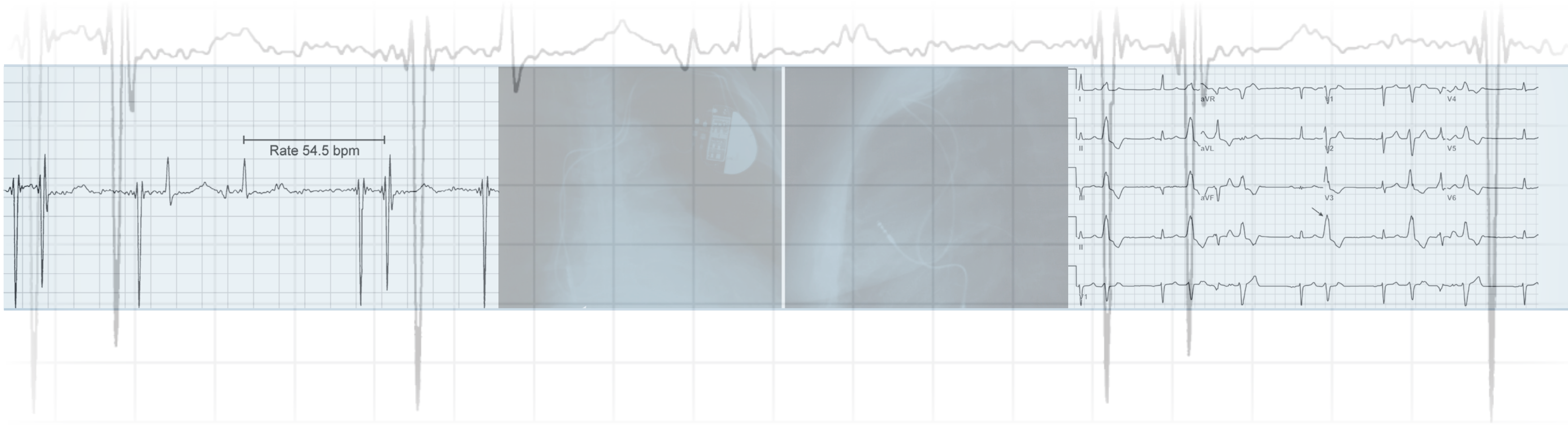
A Case-Based Approach to Pacemakers, ICDs, and Cardiac Resynchronization



Questions for Examination Review and Clinical Practice

Volume 3

Edited by

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Cardiotext Publishing, LLC
3405 W. 44th Street
Minneapolis, Minnesota 55410
USA

www.cardiotextpublishing.com

Any updates to this book may be found at: www.cardiotextpublishing.com/a-case-based-approach-to-pacemakers-icds-and-cardiac-resynchronization-volume-3/

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Library of Congress Control Number: 2011925451

ISBN: 978-1-935395-91-1

eISBN: 978-1-942909-09-5

Printed in the United States of America

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Preface

It is with great pleasure that we present the third volume of *A Case-Based Approach to Pacemakers, ICDs, and Cardiac Resynchronization: Questions for Examination Review and Clinical Practice*.

This book is the outgrowth of a weekly morning conference we established in 2008 for the purpose of presenting, discussing, and sharing interesting, challenging, and uniquely educational cases. Our meeting group went from a Mayo Clinic meeting to one that we now enjoy with colleagues from other hospitals, and indeed other countries, participating via interactive video. Learners include cardiology fellows new to the device practice, experienced nurses, and physicians, so the discussion sheds light on multiple facets of a case and tends to be of interest to caregivers at multiple levels.

We continued the format used in Volumes 1 and 2 in which cases are presented as a history with a pertinent image, which may include an x-ray or tracing. A question with multiple-choice answers is provided in order to encourage the reader to think through the differential diagnosis, the approach to clinical problems based on the information presented, and characteristics that make one answer preferable to another. In the subsequent pages, the answer is explained, and the rationale for its selection elaborated.

In light of the continued growth and the use of pacemakers, defibrillators, resynchronization devices, and the introduction of new technology, including subcutaneous defibrillators and leadless pacemakers, we hope that readers will find this a practical means of self-assessment, education, medical update, and of acquisition of clinical pearls. We additionally invite readers to share interesting cases with us and provide contact information below. Although the questions are designed in a multiple-choice format that may be useful for self-assessment for test makers, they are not formally validated board questions. This book is for any individual who sees patients with cardiac rhythm devices or who will be taking an examination related to device management.

How to Use This Book

As with previous volumes, cases generally progress from less to more complex, understanding that there will be individual variation in what constitutes a difficult case.

We intentionally excluded a table of contents because we specifically did not want to begin the book with a listing of the "diagnosis" for each case, which would limit the ability of the reader to approach the case as an unknown. However, for the reader interested in finding examples of a specific type of case (such as inappropriate shock, safety pacing, and so on), two resources are offered. The provided appendix identifies the major diagnostic dilemmas presented by each case, and the index will direct the reader to cases and discussions focusing on specific issues. However, we encourage readers to progress sequentially through the cases as unknowns to maximize learning and interest.

A new accompaniment to this third volume will be a multimedia component. This will include narrated slides, additional content, and verbal discussion highlighting key clinical pearls.

This text is the collective wisdom of numerous physicians, nurses, technicians, educators, and practitioners. We remain indebted to the entire Heart Rhythm Services team at Mayo Clinic for identifying and discussing cases and educating us with them. We have also benefited greatly from friends and colleagues at other institutions who have participated in the conference, kindly shared interesting cases with us, and permitted us to include them in this work. We are grateful for their generosity.

If you come across an interesting case that you would like included in a future edition of this book, we would love to discuss it with you. Email addresses are listed below for that purpose. Please enjoy the cases! We look forward to your feedback and future contribution.

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Abbreviations

A	atrial
AF	atrial fibrillation
APC	atrial premature contraction
AS	atrial sensed
ASD	atrial septal defect
AT	atrial tachycardia
ATP	antitachycardia pacing
AV	atrioventricular
AVNRT	atrioventricular nodal reentrant tachycardia
BBB	bundle branch block
CI	confidence interval
CRT	cardiac resynchronization therapy
CT	computed tomographic
DFT	defibrillation threshold
ECG	electrocardiogram
EGM	electrogram
EMI	electromagnetic interference
EP	electrophysiological
FFRW	far-field R wave
ICD	implantable cardioverter-defibrillator
IV	intravenous
J	Joules
LAO	left anterior oblique
LBBB	left bundle branch block
LV	left ventricle; left ventricular
LVEF	left ventricular ejection fraction
MRI	magnetic resonance imaging
OR	odds ratio
PA	pulmonary artery
PAC	premature atrial contraction
PMT	pacemaker-mediated tachycardia
PVARB	postventricular atrial blanking period
PVARP	postventricular atrial refractory period
PVC	premature ventricular contraction
RAO	right anterior oblique
RBBB	right bundle branch block
RV	right ventricle; right ventricular
RVOT	right ventricular outflow tract
SVT	supraventricular tachycardia
TARP	total atrial refractory period
TENS	transcutaneous electrical nerve stimulation
V	ventricular
VA	ventriculoatrial
VF	ventricular fibrillation
VRR	ventricular rate regulation
VS	ventricular sensed
VSD	ventricular septal defect
VT	ventricular tachycardia

A Case-Based Approach to Pacemakers, ICDs, and Cardiac Resynchronization

Questions for Examination Review and Clinical Practice **Volume 3**

Case 66

A 76-year-old male with a history of CHF, VT underwent implantation with a Boston Scientific Incepta CRT-D model # N161. His device tachy zones are programmed as defined in Figure 66.1.

Ventricular Tachy

VF 200 bpm (300 ms)			
Detection/Redetection		**Therapy**	
Initial Duration	2.5 s	QUICK CONVERT™ ATP	On
Redetection Duration	1.0 s	Shock 1	41 J
Post-Shock Duration	1.0 s	Shock 2	41 J
		Additional 41 J Shocks	6
VT 170 bpm (353 ms)			
Detection/Redetection		**ATP1**	**Off**
Initial Duration	9.0 s	**ATP2**	**Off**
Redetection Duration	1.0 s	**Shocks**	
Post-Shock Duration	1.0 s	Shock 1	Off
Atrial Tachy Discrimination		Shock 2	Off
Sinus Tachycardia Discrimination		Shock 3-6	Off
Initial Detection			
V Rate > A Rate	On		
AFib Rate Threshold	170 bpm		
Stability	20 ms		
	And		
Onset	9%		
Sustained Rate Duration	Off		
Post-Shock/Detection			
V Rate > A Rate	On		
AFib Rate Threshold	170 bpm		
Stability	20 ms		
Sustained Rate Duration	00:15 mm:ss		
Ventricular Tachy Therapy Setup			
ATP		Shock (All Shocks)	
RV ATP Amplitude	7.5 V	Waveform	Biphasic
RV ATP Pulse Width	1.0 ms	Committed Shock	Off
LV ATP Amplitude	7.5 V	Lead Polarity	Initial
LV ATP Pulse Width	1.0 ms	Shock Lead Vector	RV Coil to RA Coil and Can
Magnet and Beeper			
Magnet Response	Inhibit Therapy		
Beep During Capacitor Charge	Off		

Figure 66.1 Device settings.

66

An alert Latitude transmission was received with the following stored therapy delivered as found in Figures 66.2, 66.3, 66.4, and 66.5.

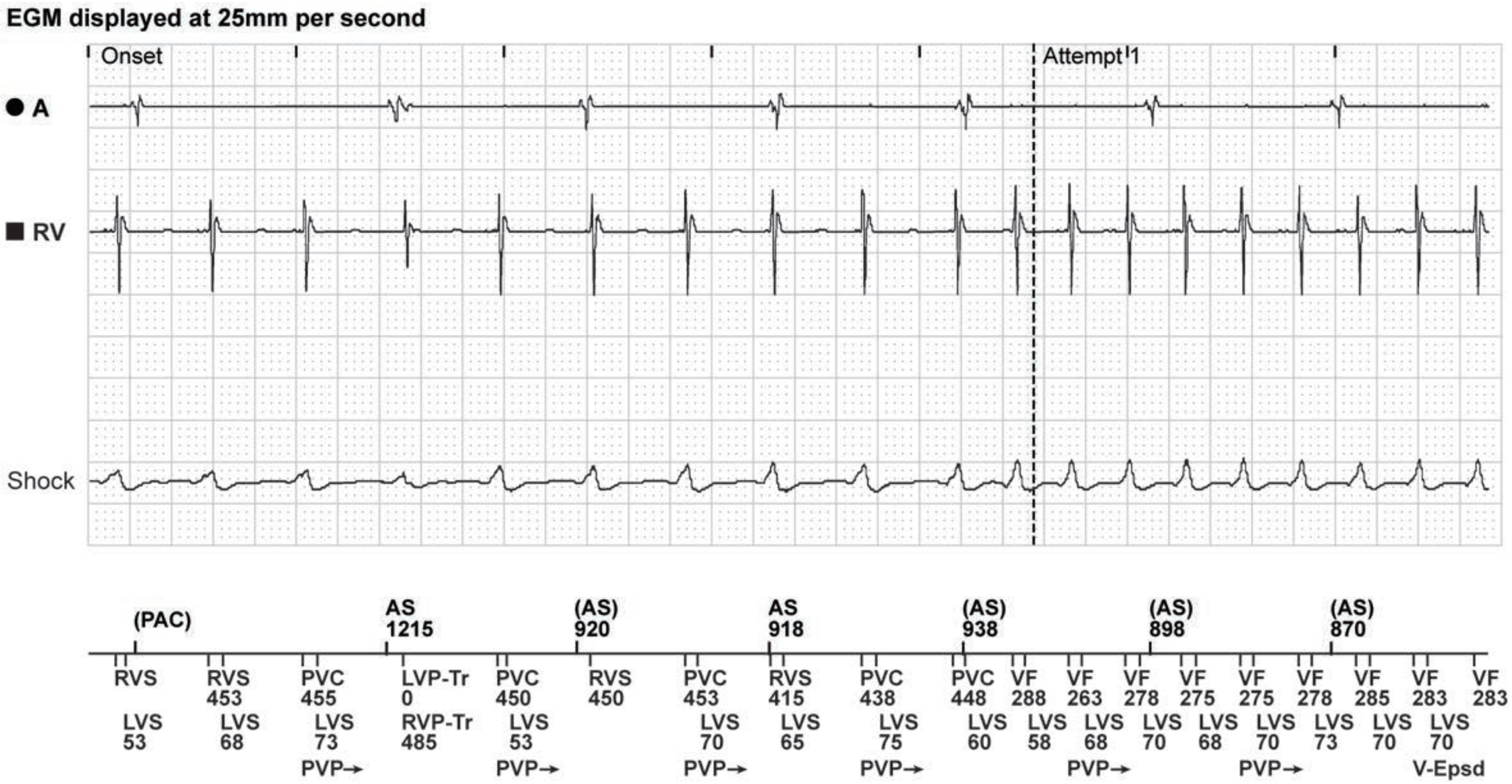

Figure 66.2 Episode EGMs.

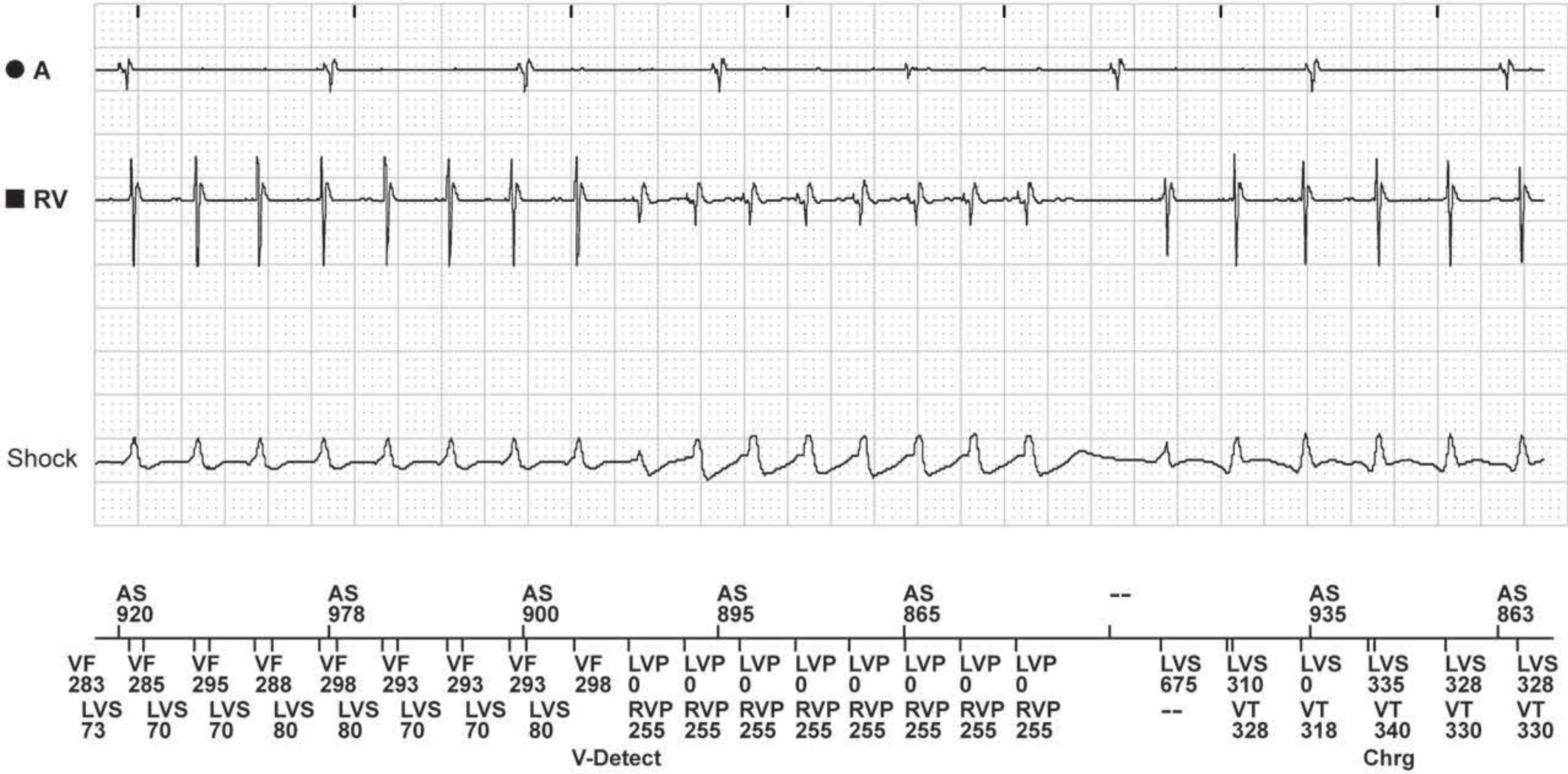

Figure 66.3 Episode EGMs.

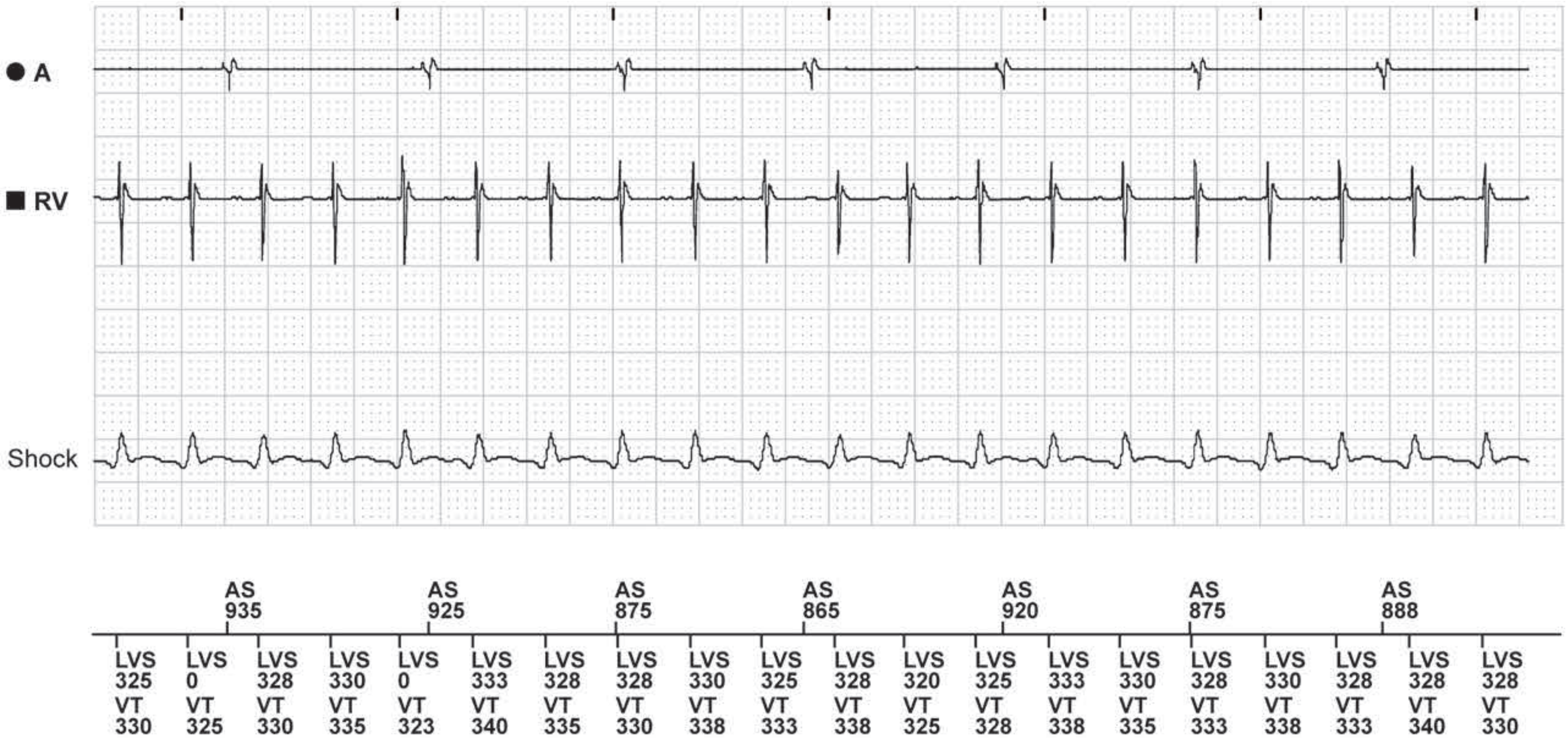

Figure 66.4 Episode EGMs.

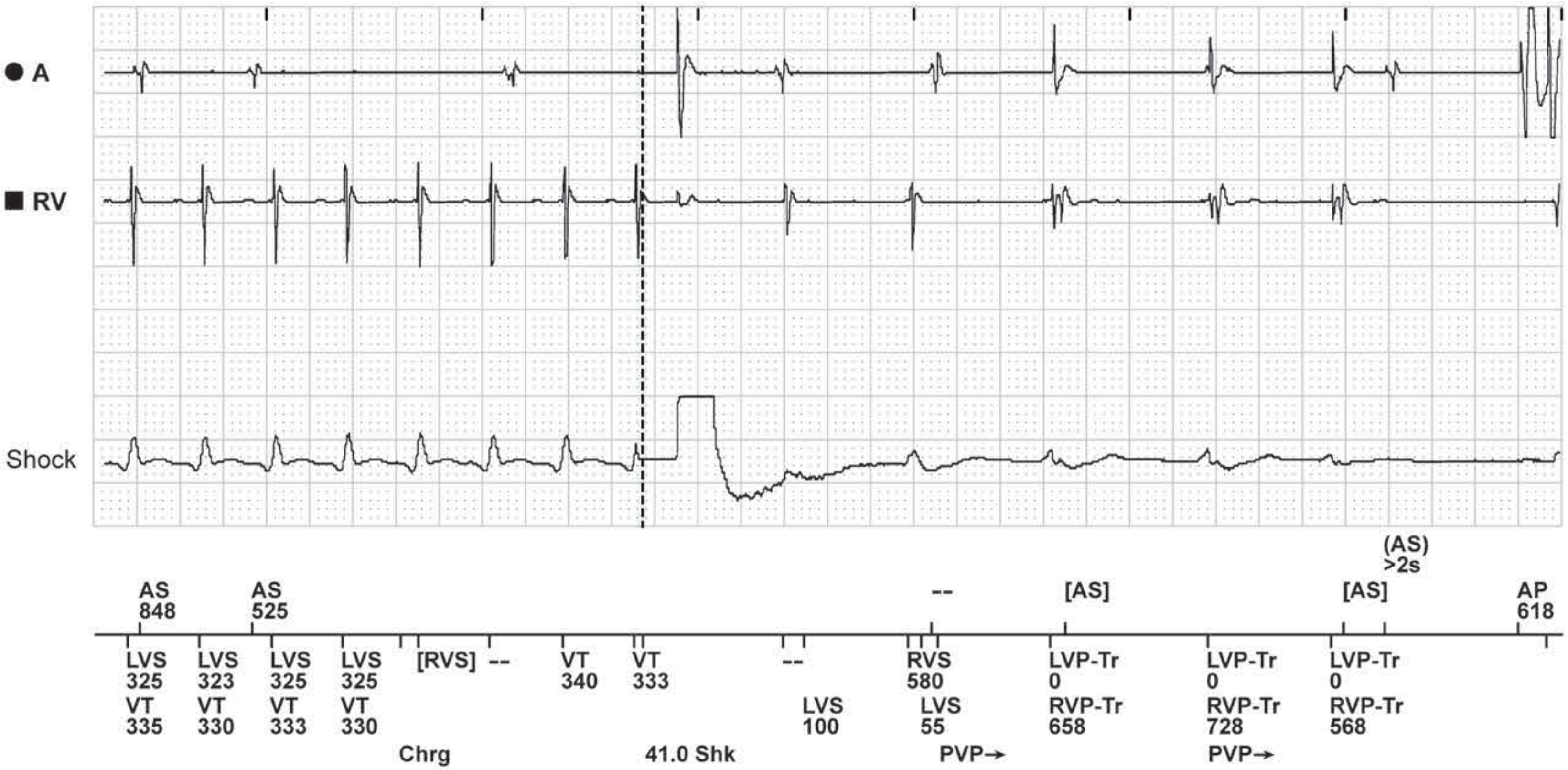

Figure 66.5 Episode EGMs.

Q:

Based on the provided tracing and settings, why did the patient receive a shock for VT that was in the monitor-only zone?

1. The shock was inappropriate due to oversensing of the T wave
2. The shock was a committed shock
3. Redetection in a Boston Scientific ICD includes rates at or above the lowest programmed detection rate, including monitor-only zones
4. Sustained-rate duration elapsed, indicating a shock was to be delivered

66

3. Redetection in a Boston Scientific ICD includes rates at or above the lowest programmed detection rate, including monitor-only zones

The stored EGM shows a ventricular tachycardia that is initially below even the VT monitor zone, which is programmed at 170 bpm. There is an abrupt increase in the rate of the VT, and a VF episode is declared after 8 of 10 beats are detected in the VF zone. There is then a 2.5-second VF initial duration timer started, in which 6 of the next 10 beats must remain in the VF zone to initiate a therapeutic shock. At this point, the device delivers Quick Convert ATP (ATP before charging). To minimize time to next therapy, when Quick Convert ATP is delivered, a reconfirmation count is initiated: if 2 of the 3 intervals following ATP are faster than the lowest rate threshold (in this case, 170 bpm), charging begins for the next programmed therapy, which in this case would be a 41-J shock, as no therapies are programmed in the VT monitor zone. After charging of the capacitors is complete, another 2-of-3 reconfirmation count is performed, and a 41-J shock is delivered, terminating the VT.

Answers 2 and 4 are incorrect, as rhythm discrimination and sustained rate duration do not apply in a 2-zone configuration when the lowest zone is monitor-only. Answer 1 is incorrect, as T-wave oversensing is not present.

Case 96

A 68-year-old gentleman with ischemic cardiomyopathy on optimal medical therapy undergoes BiV ICD implantation. He has good clinical improvement with reduction in the number of heart failure admissions. He undergoes a successful generator change after his device was noted at ERI. He has paroxysmal AF and has history of AV nodal ablation.

The device is programmed as follows:

Mode	DDDR
Lower rate	60 bpm
Upper sensor rate	130 bpm
CRT	Nonadaptive CRT
Mode switch rate	170 bpm
Mode switch behavior	DDIR
VT zone	180 bpm (treated with ATP followed by shocks)
AV delay	130 ms

The lead parameters at the time of device surgery are as follows:

	Sensing	Pacing Threshold	Impedance
RA	2 mV	Not tested due to AF	611 Ω
RV (integrated bipolar)	Paced	0.75 V @ 0.4 ms	585 Ω
LV (ring to RV coil)		0.75 V @ 0.4 ms	600 Ω

At 48 hours after discharge, the patient presents with symptomatic dizziness. The ECG obtained is shown below (Figure 96.1). Chest x-ray did not show any major abnormalities. Device interrogation shows RV and LV lead impedance at more than 3000 Ω. RV and LV thresholds are elevated. The patient was placed on bed rest, therapies were turned off, and the device was programmed to DOO mode. The next morning, lead parameters were back to baseline.

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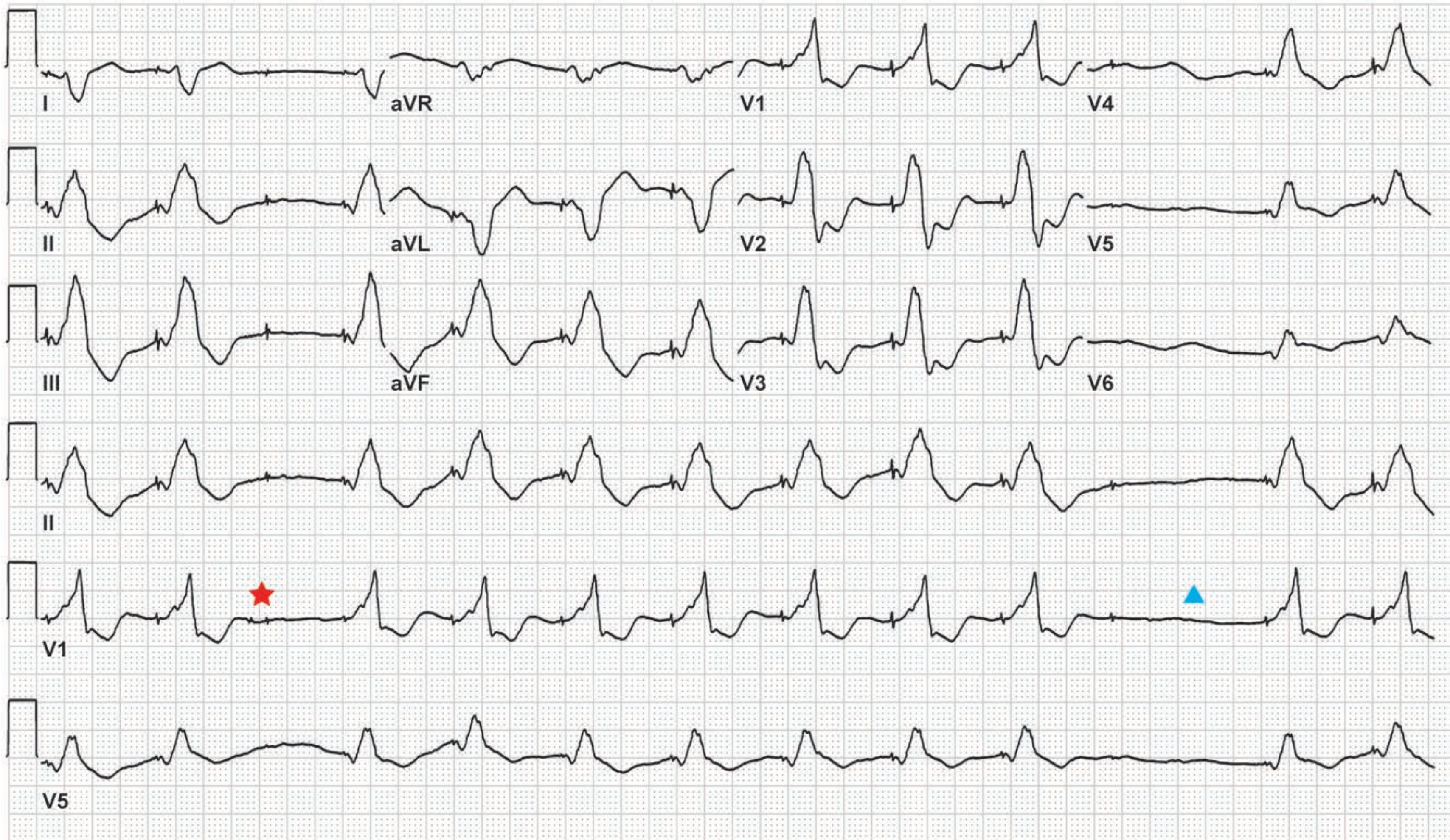


Figure 96.1 ECG on presentation.

Q:

Which of the following is the most likely cause of patient's symptoms?

1. Insulation break
2. Lead fracture
3. Set screw issue
4. Header bond fracture
5. Air in the header

3. Set screw issue

Lead impedance changes associated with noise in patients with recent device surgery are most likely secondary to connector problems. Insulation break is associated with decrease in lead impedance, making answer 1 incorrect. Lead fracture is associated with increase in lead impedance, but lead fracture in two leads is unlikely; thus, answer 2 is incorrect. Header bond fracture results in a change in function of all three leads, but here the impedances on the atrial lead is still preserved, so answer 4 is incorrect. Air in the header is associated with nonphysiologic signals on the lead without any significant changes in lead impedance, so answer 5 is incorrect. Noise due to air in the header is associated with escape of air from the sealant plugs. As this phenomenon is intermittent, device diagnostics may not reveal change in lead impedance.

Baseline ECG (Figure 96.2) suggests chronic atrial fibrillation with biventricular pacing. During presentation, there is only LV pacing, and RV pacing is not evident. Corresponding intracardiac tracings show atrial fibrillation, intermittent loss of RV capture, and R-wave double counting with LV pacing (Figure 96.3). The device detects this as noise, and tachycardia detection is withheld.

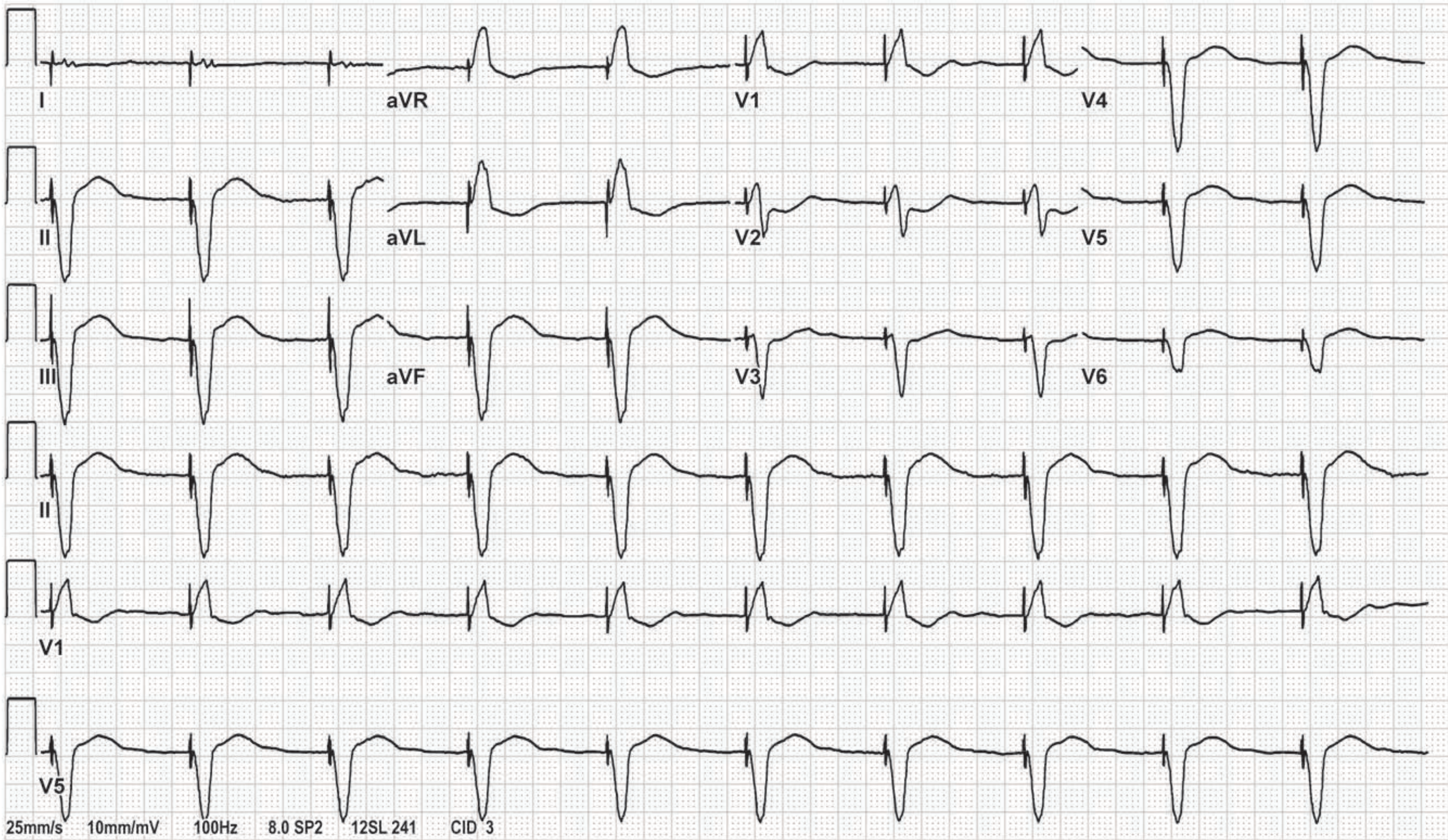
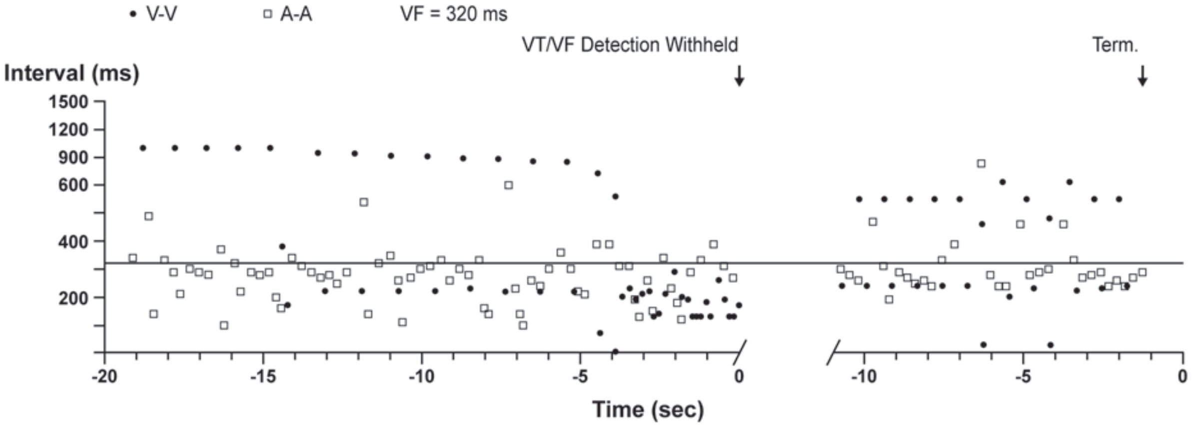


Figure 96.2 ECG prior to device surgery.

96

Type	ATP Seq	Shocks	Success	ID#	Date	Time hh:mm	Duration hh:mm:ss	Avg bpm A/V	Max bpm A/V	Activity at Onset
V. Oversensing-Noise				13	04-Jul-2015	15:42	:25	188/400	261/---	Rest



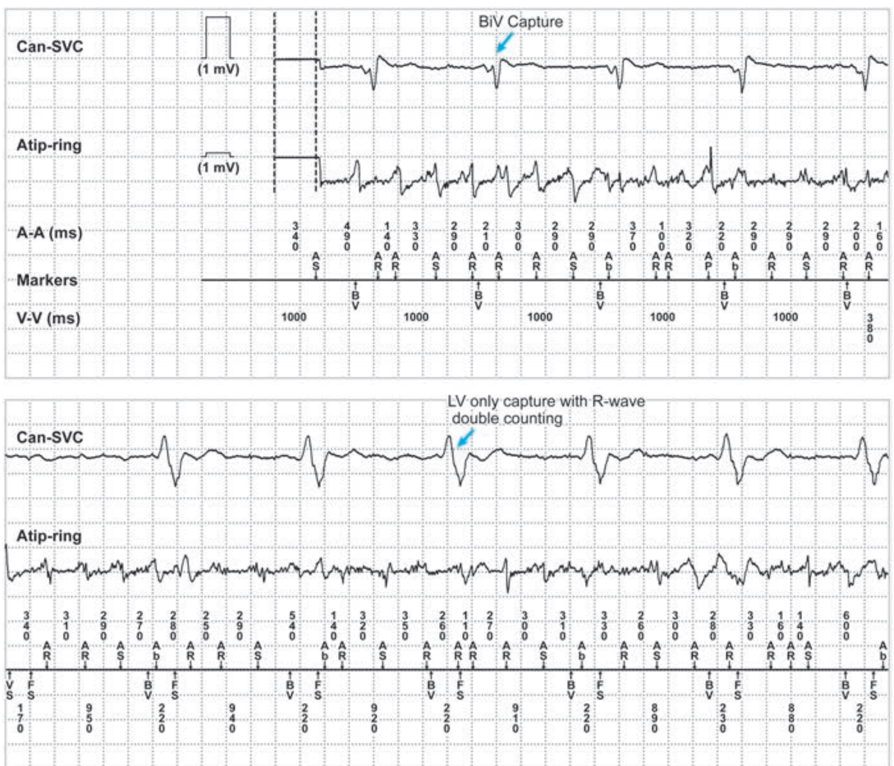


Figure 96.3 Interval plot shows several short V-V intervals (**circles**) prior to time zero. The device recognizes the signals as noise and tachyarrhythmia detection is withheld. EGM at the time of presentation shows underlying atrial fibrillation. When there is biventricular capture (BV) the ventricular complex on Can-SVC channel appears narrow. With LV-only capture the QRS complex looks wide with resulting delay to the RV channel. This delayed signal is annotated as “FS” on the marker channel.

Q:

Which of the following is the most likely reason for phenomenon denoted by star on the presenting ECG (see Figure 96.1)?

1. Atrial pacing followed by safety pacing
2. VV delay
3. Threshold testing
4. Failure to output from the ventricular leads

1. Atrial pacing followed by safety pacing

On the tracing (Figure 96.1), when there is constant ventricular pacing, the cycle length is around 800 ms. This is not a sensor-indicated rate, as the patient was resting. The R-wave double counting during LV-only pacing has consistently reset the VA timing cycles. In Medtronic devices, atrial refractory periods are dynamic. The device calculates the sensor rate (1000 ms at rest) and subtracts the programmed AV delay (130 ms) to get the PVARP (870 ms). The last 350 ms are used for sensing in the PVARP interval (870 ms). If there is no sensed event, VA timing cycle expires and atrial pacing occurs. This results in the initial pacing spike on the ECG. However, noise (no QRS on the far-field channel) is detected during the cross-talk alert window, resulting in safety pacing (Figure 96.4B). In Medtronic devices, safety pacing occurs only on the RV channel, which does not capture the myocardium. There is also noise that is oversensed, as denoted by the triangle on ECG 1, with no pacing (Figure 96.4A). If the device is programmed to VVIR, after mode switch, atrial pacing behavior would not occur.

Answer 2 is incorrect because there was no set VV delay programmed on the device, as is clear by simultaneous capture of LV and RV in Figure 96.2. Threshold testing (evoked response testing) is commonly performed in the middle of the night, so answer 3 is incorrect. We see pacing spikes on the tracing, so failure to output (answer 4) is incorrect.

Figure 96.4 EGMs demonstrating noise and device inhibition. Notice that there are several short intervals on the marker channel without correlating ventricular complexes on the far-field channel. Atrial pacing occurs when there are no sensed atrial events in the terminal 350 ms of the PVARP interval. Safety pacing occurs as noise is detected in the cross-talk alert window. Safety pacing does not capture the ventricle as no ventricular events are seen on the far-field channel.

Phenomenon	Association
Lead Fracture	↑ Impedance, Noise
Insulation Break	↓ Impedance, Noise
Functional Behavior	↑ Impedance
Set screw issue	Mostly post procedure
Air in the header	Transient noise
Header bond fracture	All leads are effected

Table 96.1 Troubleshooting lead and device malfunction.

Troubleshooting of lead malfunction is critical skill needed in current day electrophysiology practice (see Table 96.1). Connector problems can be detected by radiography (Figure 96.5). Analysis of leads after extraction shows that there is a potential for connector problems misdiagnosed as lead fracture. Intraoperative high-resolution fluoroscopy (Figure 96.5A) or analysis of markers on the lead provides clues for diagnosis. (Figure 96.5B shows set screw marks on a lead that was inserted well into the header. Figure 96.5C shows set screw marks on a lead that is not completely inserted into the header).

Air trapped in the header typically presents with nonphysiologic noise without any change in lead impedances. Header bond fracture (Figure 96.5D) results in malfunction of all affected leads and is usually seen with subpectoral implants.

In our patient, the set screw for RV lead was not tightened during intraoperative evaluation. Use of extended configuration for LV pacing (LV Ring to RV coil) resulted in intermittent loss of capture from both the leads.

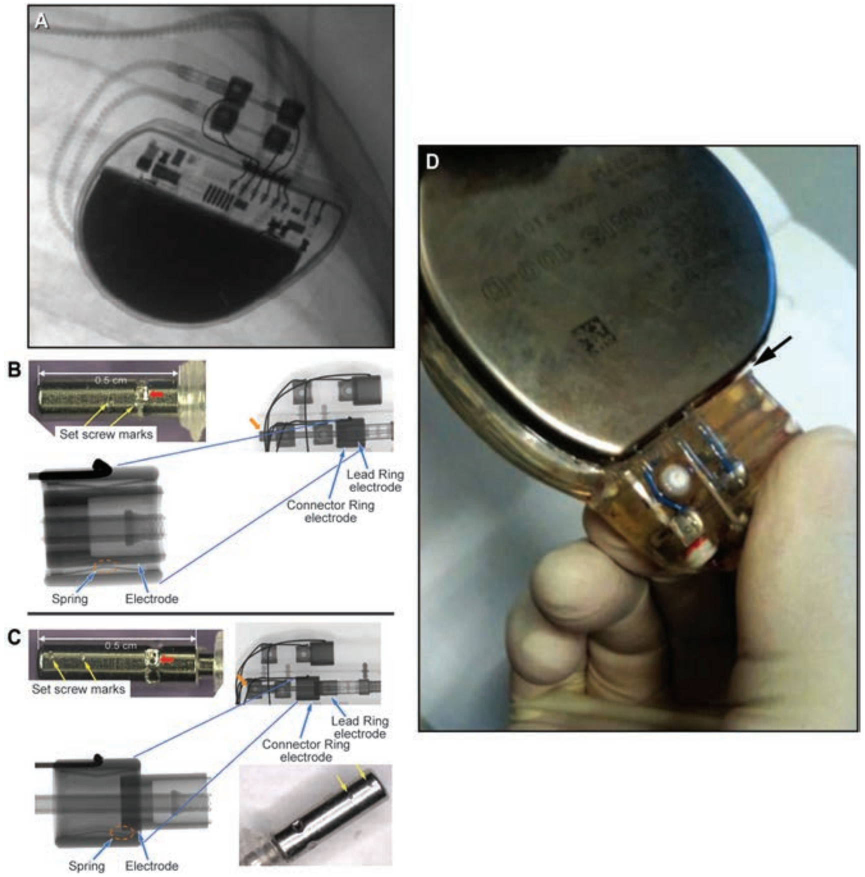


Figure 96.5 Connector problems associated with CIEDs. **Panel A:** Incomplete insertion of atrial lead pin is noted in the header. Marker analysis on the lead often provides clues to incomplete pin insertion. In **Panel B**, marker analysis suggest adequate pin insertion while **Panel C** suggests incomplete pin insertion. *Source for Panels B and C:* Reproduced with permission from Swerdlow C. *JACC*. 2011;57(23);2330–2339. **Panel D:** Header bond fracture is associated with abnormalities of all leads. *Source:* Reproduced with permission from Hayat SA. *J Cardiovasc Electrophysiol*. 2013;24:351–355.