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Review Article

Perioperative Interrogation of Boston Scientific Cardiovascular Implantable Electronic Devices: A Guide for Anesthesiologists

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Key Words: pacemaker; cardiovascular implantable electronic device; implantable cardioverter defibrillator; subcutaneous implantable cardioverter defibrillator; anesthesia; Boston Scientific

TO INCREASE FAMILIARITY with cardiovascular implantable electronic devices (CIEDs) and their perioperative management, this review describes the creation and interpretation of Boston Scientific (Marlborough, MA) interrogation reports. This review of Boston Scientific CIEDs is intended to supplement and build on the other articles in this series.[1] This review should not be interpreted by the reader as evidence that elective interrogation and programming of CIEDs should be performed by untrained practitioners. Rather this series of articles is intended to inspire anesthesiologists to seek education and training in CIED management and serve as a resource for those interested practitioners.

In an effort to increase the knowledge base with Boston Scientific transvenous and subcutaneous CIEDs among anesthesiologists, basic programming of a Boston Scientific cardiac resynchronization therapy (CRT) device and subcutaneous implantable cardioverter defibrillator (S-ICD) is described. Because the background knowledge on dual-chamber pacemakers and defibrillators previously has been discussed in the review article on St. Jude Medical devices,[1] a Boston Scientific CRT device with defibrillator capabilities (ie, CRT-D) was chosen for this review because of its dual function (ie, pacemaker and defibrillator) and the new background it presents.[1] Finally, the Boston Scientific S-ICD is discussed because of its unique capabilities, perioperative management challenges, and programming.

Boston Scientific CIEDs

The indications for CIED implantation are vast, with varying levels of evidence for specific situations. However, permanent pacing can be indicated in sinus node dysfunction, acquired atrioventricular block, chronic bifascicular block, hypersensitive carotid sinus syndrome, neurocardiogenic syncope and after acute myocardial infarction. CRT, or biventricular pacing, uses a specific type of pacemaker that is indicated for patients with a reduced ejection fraction and a widened QRS. The goal of CRT is to improve cardiac output and symptoms by synchronizing contraction of the left ventricle (LV). Implantable cardioverter defibrillators (ICDs), which include CRT-D devices, have pacing capabilities but also are indicated for the primary or secondary prevention of cardiac death.[2] The S-ICD is a specific type of ICD that is indicated in the treatment of malignant ventricular

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Table 1
Boston Scientific Devices: Potential Responses to Magnet Application

Device Setting	Response to Magnet Application
Pacemakers	
Pace async or asynchronous (default)	Asynchronous pacing at 100 bpm with the rate decreasing to 85 bpm at ERI and <85 bpm at EOL.
Off	No response to magnet application.
Patient-triggered monitor or store electrogram mode	No change in pacemaker settings but the device collects data. After one electrogram is stored, the magnet response will automatically revert to "asynchronous" (see above).
Defibrillators	
On (default)	Tachyarrhythmia therapies are disabled and pacemaker settings are left unaltered. Beep or tone emitted.
Off	Magnet application has no effect on tachyarrhythmia therapies or pacemaker settings. No beep or tone emitted.
Subcutaneous defibrillator	
Therapy On (default)	Tachyarrhythmia therapies are disabled and postshock pacing is disabled (this device has no regular pacing settings). Beep is emitted with each R wave for 60 s (expected but not guaranteed response).
Therapy Off	Postshock pacing is disabled. Beep is emitted with each R wave for 60 s (expected but not guaranteed response).

Abbreviations: EOL, end of life; ERI, elective replacement indicator.

tachyarrhythmias in patients with no need for antitachycardia or bradycardia pacing.[3]

To determine the potential responses to magnet application (Table 1), contact the company (ie, 1-800-CARDIAC or 1-800-227-3422) or obtain an interrogation with the appropriate device programmer (eg, Zoom Latitude Programming System, Model 3120; Boston Scientific); a practitioner must first correctly identify the device company (Table 2).[4] A Boston Scientific device can be identified by characteristic device shapes or an alpha numeric code on chest radiograph (Fig 1).[5]

Table 2
Boston Scientific Devices

Boston Scientific CIEDs	
Pacemaker	Accolade, Essentio, Altrua, Vitalio, Accolade MRI, Essentio MRI
ICD	Dynagen EL, Inogen EL, Inogen Mini, Energen, Incepta, Perciva, Momentum EL, Resonate EL, Vigilant EL
S-ICD	Emblem MRI
CRT-P	Valitude X4, Intua, Invive
CRT-D	Dynagen X4, Inogen X4, Energen, Incepta, Resonate X4, Vigilant X4, Momentum X4

Abbreviations: CIEDs, cardiovascular implantable electronic devices; CRT-D, cardiac resynchronization therapy-defibrillator; CRT-P, cardiac resynchronization therapy-pacemaker; EL, extended longevity; ICD, implantable cardioverter defibrillator; MRI, magnetic resonance imaging; S-ICD, subcutaneous implantable cardioverter defibrillator.

Boston Scientific (Zoom Latitude Programmer)

Before discussing the interpretation of a report or programmable features that are applicable to anesthesiologists, it is important to become familiar with the Zoom Latitude Programmer. The Zoom Latitude Programmer Model 3120 currently is in circulation; however, Boston Scientific will release a new version in 2018, the Model 3300. The interface of the Model 3300 will be very similar to that of Model 3120, and thus the information presented in this review should apply to both models.

The Zoom Latitude Model 3120 programmer is a portable programming system specifically designed to interact with Boston Scientific implantable devices and leads. The Model 3120 user interface is a touch screen display that interacts with a tethered stylus. Therefore, the Zoom Latitude programmer cannot be used to interrogate devices manufactured by other companies. In addition to communicating with Boston Scientific devices via a telemetry wand, the Zoom Latitude Programmer is capable of radiofrequency communication.

The power cable inserts into the power receptacle on the back left side of the Model 3120. Once connected, locate the on/off switch and open the screen display via the latch on the front (Fig 2). The telemetry wand can be connected via the port on the right side of the programmer. Place the wand over the Boston Scientific transvenous CIED generator and select the Quick Start button on the touch screen display (Fig 3). Even though the information contained in an interrogation report can be obtained by navigating the touch screen display, an initial interrogation report should be obtained to document the device settings, which may facilitate subsequent interrogations and programming.

Zoom Latitude Programming Keys

The Model 3120 is equipped with programming keys, which are located on the base of the programmer (see Fig 2). These programming keys—stat shock, stat pace, divert therapy, program, and interrogate—can be used to emergently pace or deliver shock therapy.

The stat shock key allows the clinician to deliver maximum energy shocks, assuming the presence of a high-voltage coil, at any time during a communication session regardless of programmed parameters or detection status. While the stat shock is committed, which means the therapy will not be diverted automatically if the arrhythmia has terminated, it can be manually diverted by the clinician. Note that the stat shock key has to be pressed 2 times to deliver a shock, the divert therapy key must be pressed twice to cancel a shock, and the divert therapy key does not terminate stat pacing.

The stat pace key has to be pressed twice to initiate pacing. When initiated, the device will pace at 60 bpm in a VVI mode. If the device possesses an active left ventricular lead, then stat pacing will result in biventricular pacing at 60 bpm. To cancel stat pacing, the practitioner can select "View Changes - Load Initials" and then "Program" via the main screen.

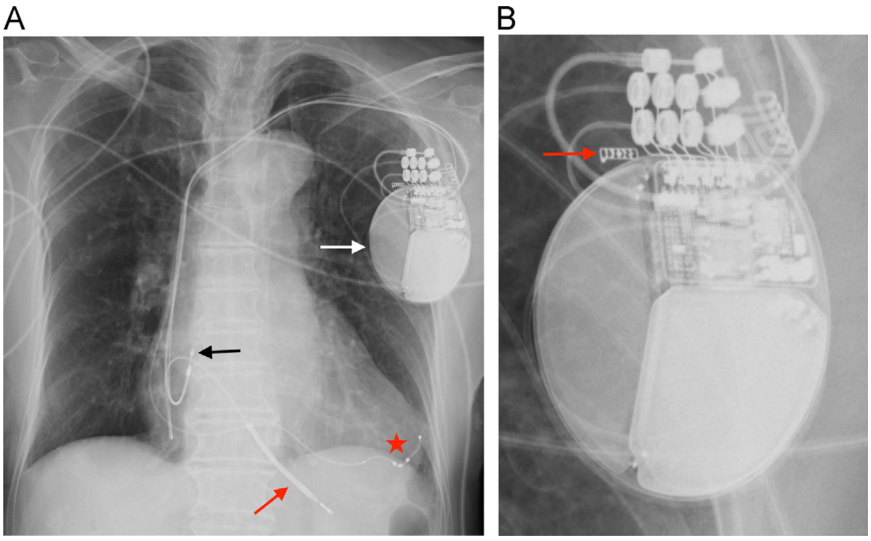


Fig 1. (A) Chest radiograph. A Boston Scientific transvenous cardiac resynchronization therapy device (Dynagen X4 CRT-D) with the generator in the left pectoral location (*white arrow*) and leads in the right atrium (*black arrow*), right ventricle (*red arrow*), and coronary sinus (*red star*). (B) Chest radiograph with magnification of the generator displaying the characteristic shape, battery, and alpha numeric code (*red arrow*) of a Boston Scientific device.

Interrogation Report (Boston Scientific Dynagen X4 CRT-D)

The following discussion pertains to a Boston Scientific CRT-D device, which was implanted in a patient with a severely reduced ejection fraction, New York Heart Association class III symptoms, left bundle branch block, and symptomatic sinus pauses (Fig 4). Even though the data conveyed in a device interrogation report is vast, much of the basic information required for perioperative management can be located on a few pages of the report (Table 3).

Patient/Device Identification

First, it is important to confirm that the report is current and correctly associated with the patient. Patient information and the type of device, last interrogation, and any alerts can be found at the top of the device follow-up report (Fig 5).

Indication

Additional patient-specific information such as the indication for implantation can be found in the patient data report section. In the patient described here, the indication for implantation was CRT and the primary prevention of sudden cardiac death. The CRT-D device is designed to improve cardiac output and patient symptoms by synchronizing contraction of the interventricular septum and the lateral wall of the LV and to diagnose and treat malignant tachyarrhythmias.[6,7] CRT-D devices pose specific dilemmas for perioperative management because the devices provide close to 100% biventricular pacing, and the addition of a high-voltage coil indicates that magnet application will not result in asynchronous pacing. As displayed in the postimplantation electrocardiogram (Fig 6), CRT results in a paced rhythm. Although CRT patients often have an "adequate" underlying rhythm, the goal is ventricular synchronization via biventricular pacing, and inhibition due to electromagnetic interference (EMI) may result in a reduction in cardiac output. In essence, EMI-induced hypotension in the CRT patient population can result from the loss of biventricular pacing rather than asystole, which is a possible EMI effect in the pacemaker-dependent patient. Therefore, an asynchronous mode may be indicated during the perioperative period. The addition of a high-voltage coil, which implies the device is a defibrillator, indicates that magnet application will not affect the pacemaker settings (see Table 1) and interrogation/programming with a programmer would be required to institute an asynchronous mode.

Fig 2. Zoom Latitude Programmer with the on/off switch and programming keys highlighted by a *red* and *white arrow*, respectively.

However, placing a device in an asynchronous mode either via magnet application or programming is not necessarily benign because asynchronous pacing potentially can be pro-arrhythmic. For example, the R-on-T phenomenon can occur anytime an electrical stimulus is delivered during a period of repolarization and may result in a ventricular tachyarrhythmia or ventricular fibrillation.[8] Even though most of the R-on-T case reports involve temporary pacemakers, it is a possible consequence of synchronous pacing and a lack of sensing or asynchronous pacing.[8–10]

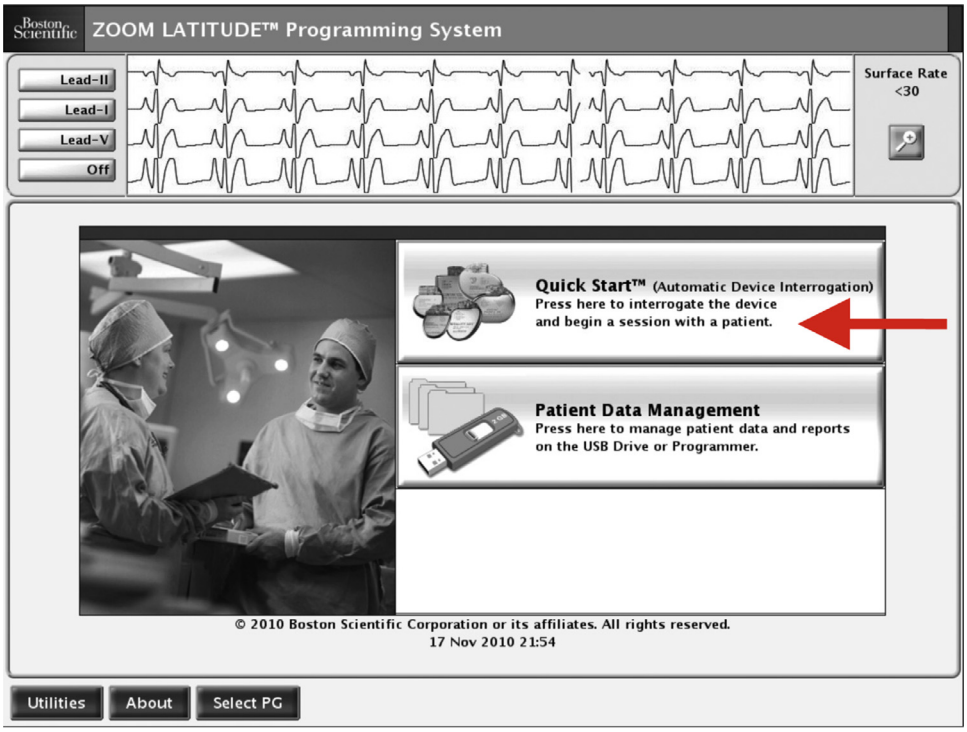


Fig 3. Startup screen displaying the Quick Start icon (*red arrow*).
With permission from Boston Scientific, Marlborough, MA.

Therefore, one should consider an assessment of the mode and underlying rhythm before pacing a patient asynchronously.

Magnet Application

Boston Scientific devices have a programmable response to magnet application (see Table 1). Therefore the magnet response should be confirmed before a practitioner relies upon magnet application for the temporary discontinuation of ICD tachyarrhythmia therapies or asynchronous pacing in a pacemaker during the perioperative period. This important piece of information, located on the device setting report page under the "Magnet and Beeper" section (Fig 7), also is dependent on the interrogation report being recent and accurate. The Heart

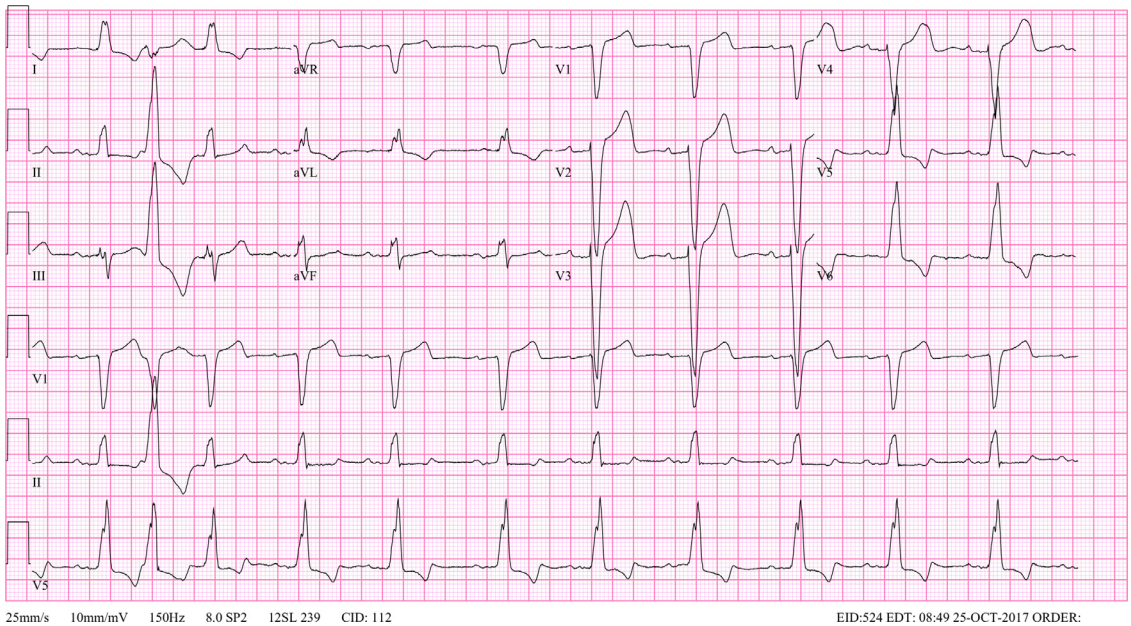


Fig 4. Preoperative 12-lead electrocardiogram displaying sinus rhythm with a first-degree atrioventricular block, occasional premature ventricular complexes, and a left bundle branch block (QRS of 156 ms).

Table 3
Boston Scientific Interrogation Reports

Transvenous CIEDs	
Pages	Pertinent Information
Device Follow-Up	Patient, type of device, last interrogation, alerts, AV delay, LV offset, battery life, pacing thresholds, lead impedances, sensitivities, rate response, bradycardia settings
Patient Data	Indication for implantation
Device Setting	Magnet response

Subcutaneous ICD	
Pages	Pertinent Information
Summary Report	Patient, mode, date of interrogation, battery status, electrode impedance status, postshock pacing, number of episodes/shocks

Abbreviations: AV, atrioventricular; CIEDs, cardiovascular implantable electronic devices; ICD, implantable cardioverter defibrillator; LV, left ventricle.

Rhythm Society (HRS) recommends that a pacemaker be interrogated within 12 months and ICD/CRT devices within 6 months of elective surgery in patients lacking medical problems that might adversely affect the function of the CIED.[11] However, the magnet response can be confirmed on the day of surgery in Boston Scientific devices. Boston Scientific pacemakers programmed to the default setting should respond to magnet application by pacing asynchronously at the predetermined rate (see Table 1). Boston Scientific ICD and CRT-D devices should notify the practitioner that magnet application has resulted in the suspension of tachyarrhythmia therapies by emitting a tone (see Table 1).

Even though pacemakers and CRT devices without defibrillator capabilities (ie, cardiac resynchronization therapy-pacemaker [CRT-P]) can respond to magnet application with asynchronous pacing, the settings are unlikely to be identical to the patient-specific programmed values. For example, magnet application to pacemakers and CRT-P devices results in a fixed asynchronous pacing rate with a 100 ms atrioventricular delay. This atrioventricular delay may be shorter or longer than the patient-specific settings and thus affect filling and cardiac output (see Fig 5). Furthermore, for CRT-P devices, magnet application results in the LV offset, which represents the time from the LV pacing pulse to the right ventricle pacing pulse, being set to 0 ms. Typically the LV offset is a negative number (eg, −20 to −80 ms) and conveys that the LV pacing pulse is delivered before the right ventricle pacing pulse.[12] Therefore, magnet-induced changes to the LV offset may affect synchronization and cardiac output.[13] These considerations represent yet additional arguments for perioperative interrogation/programming as opposed to reliance on a magnet.

Assuming magnet application results in asynchronous pacing, the heart rate response to a magnet also is dependent on battery life (see Table 1). Consequently, the battery life should be confirmed on the device follow-up report (see Fig 5) and compared with the HRS recommendation of battery longevity >3 months.[11]

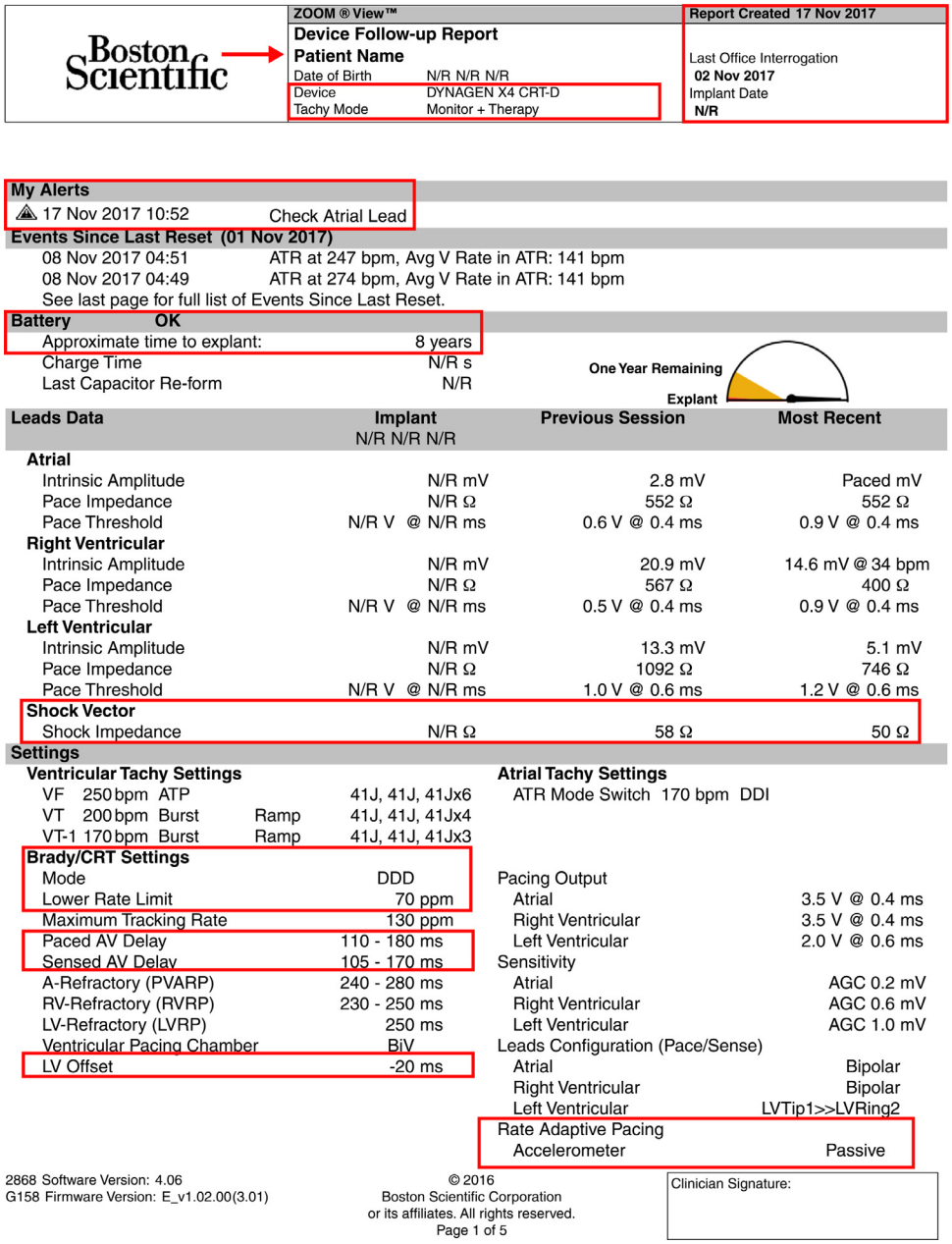
Pacing Threshold, Lead Impedance, and Sensitivity

General recommendations regarding pacing thresholds, lead impedances, and sensitivities have been discussed previously.[1] However, Boston Scientific specifically mentions that a chronic pacing threshold of >3 V can result in loss of capture and that a chronic defibrillation shock lead impedance value <20 or >200 ohms may indicate a problem with the high-voltage coil and should be investigated.[14] In addition, the Boston Scientific Dynagen technical manual also mentions that with respect to intrinsic amplitudes, an R wave amplitude <5 mV or P wave amplitude <2 mV can result in undersensing (Table 4).[14] Pacing thresholds, lead impedances, and sensitivities can be found on the device follow-up report page (see Fig 5).

Rate Adaptive Pacing

Accelerometer-based rate adaptive pacing or rate response is available in Boston Scientific devices including the CRT-D device being discussed in this article. When rate adaptive pacing is enabled, one or more sensors detect a change in the patient's activity level and increase the pacing rate accordingly. In the Boston Scientific CRT-D devices, an accelerometer detects motion or activity in a specific frequency range (eg, 1-10 Hertz) and increases the heart rate accordingly.[12] Practitioners can determine whether rate response is programmed as "on" by the mode (eg, DDDR) or by the accelerometer setting (eg, "on") (see Fig 5). A patient with a rate responsive mode (eg, DDDR) or accelerometer programmed to "on" may exhibit an increase in heart rate greater than the lower rate limit. Alternatively, programming to a nonrate responsive mode (eg, DDD) or the accelerometer to "passive" will disable this function. The intraoperative effects of rate adaptation are even more important in patients with a Boston Scientific pacemaker that monitors minute ventilation via thoracic impedance. Strong consideration should be given to disabling rate adaptive pacing during the perioperative period, especially in devices in which ventilation is the monitored parameter.[15] In fact, the American Society of Anesthesiologists (ASA) concluded that the majority of consultants agree that rate adaptive therapy should be disabled perioperatively.[16]

If rate adaptive pacing is electively continued perioperatively, the paced rate may inappropriately increase in response to factors including mechanical hyperventilation, external respiratory rate monitoring, electrocautery, succinylcholine-induced muscle fasciculations, and postoperative shivering. Intraoperative rate changes, which result from elective continuation of rate modulation, usually are benign. However, an increase in heart rate may be hemodynamically significant; unfavorable for certain comorbidities (eg, coronary disease); or misinterpreted as patient discomfort.



Boston Scientific

ZOOM ® View™

Device Follow-up Report

Patient Name

Date of Birth N/R N/R N/R

Device DYNAGEN X4 CRT-D

Tachy Mode Monitor + Therapy

Report Created 17 Nov 2017

Last Office Interrogation
02 Nov 2017
Implant Date
N/R

My Alerts

17 Nov 2017 10:52 Check Atrial Lead

Events Since Last Reset (01 Nov 2017)

08 Nov 2017 04:51 ATR at 247 bpm, Avg V Rate in ATR: 141 bpm

08 Nov 2017 04:49 ATR at 274 bpm, Avg V Rate in ATR: 141 bpm

See last page for full list of Events Since Last Reset.

Battery OK

Approximate time to explant: 8 years

Charge Time N/R s

Last Capacitor Re-form N/R

One Year Remaining

Explant

Leads Data	Implant N/R N/R N/R	Previous Session	Most Recent
Atrial			
Intrinsic Amplitude	N/R mV	2.8 mV	Paced mV
Pace Impedance	N/R Ω	552 Ω	552 Ω
Pace Threshold	N/R V @ N/R ms	0.6 V @ 0.4 ms	0.9 V @ 0.4 ms
Right Ventricular			
Intrinsic Amplitude	N/R mV	20.9 mV	14.6 mV @ 34 bpm
Pace Impedance	N/R Ω	567 Ω	400 Ω
Pace Threshold	N/R V @ N/R ms	0.5 V @ 0.4 ms	0.9 V @ 0.4 ms
Left Ventricular			
Intrinsic Amplitude	N/R mV	13.3 mV	5.1 mV
Pace Impedance	N/R Ω	1092 Ω	746 Ω
Pace Threshold	N/R V @ N/R ms	1.0 V @ 0.6 ms	1.2 V @ 0.6 ms
Shock Vector			
Shock Impedance	N/R Ω	58 Ω	50 Ω

Settings

Ventricular Tachy Settings

VF	250 bpm	ATP	41J, 41J, 41Jx6
VT	200 bpm	Burst Ramp	41J, 41J, 41Jx4
VT-1	170 bpm	Burst Ramp	41J, 41J, 41Jx3

Brady/CRT Settings

Mode	DDD
Lower Rate Limit	70 ppm
Maximum Tracking Rate	130 ppm
Paced AV Delay	110 - 180 ms
Sensed AV Delay	105 - 170 ms
A-Refractory (PVARP)	240 - 280 ms
RV-Refractory (RVRP)	230 - 250 ms
LV-Refractory (LVRP)	250 ms
Ventricular Pacing Chamber	BiV
LV Offset	-20 ms

Atrial Tachy Settings

ATR Mode Switch 170 bpm DDI

Pacing Output

Atrial	3.5 V @ 0.4 ms
Right Ventricular	3.5 V @ 0.4 ms
Left Ventricular	2.0 V @ 0.6 ms

Sensitivity

Atrial	AGC 0.2 mV
Right Ventricular	AGC 0.6 mV
Left Ventricular	AGC 1.0 mV

Leads Configuration (Pace/Sense)

Atrial	Bipolar
Right Ventricular	Bipolar
Left Ventricular	LVTip1>>LVRing2

Rate Adaptive Pacing

Accelerometer Passive

2868 Software Version: 4.06
G158 Firmware Version: E_v1.02.00(3.01)

Page 1 of 5

Clinician Signature:

Fig 5. Device follow-up report from an interrogation report of a Dynagen X4 CRT-D device. Important information, as described in the article, is highlighted by *red boxes* and *arrows*.

Basic Programming (Boston Scientific Dynagen X4 CRT-D)

Familiarity with basic programming of a Boston Scientific CIED can be extremely useful for anesthesiologists. After formal education and institutional support, basic programming (ie, mode, rate, rate response, and tachyarrhythmia therapies) by anesthesiologists also could be useful in situations with a perioperative CIED team or when a CIED team member or device representative is not immediately available. However, the education and support required to adequately prepare a clinician to interrogate and program these devices cannot be overemphasized. For additional information, please consider the publications by Rooke et al. and Ellis et al., which provide excellent descriptions of the education approach to and subsequent results of anesthesia CIED services.[17,18]

In order to interrogate and program a device, follow the previously described steps to turn on the Zoom Latitude Programmer and connect with the CIED (see Fig 3).

Patient/Device Identification, Capture Threshold, Impedance, and Sensitivity

Once a connection has been established, the main screen (ie, the Summary tab) (Fig 8) will display much of the information contained in an interrogation report as previously discussed

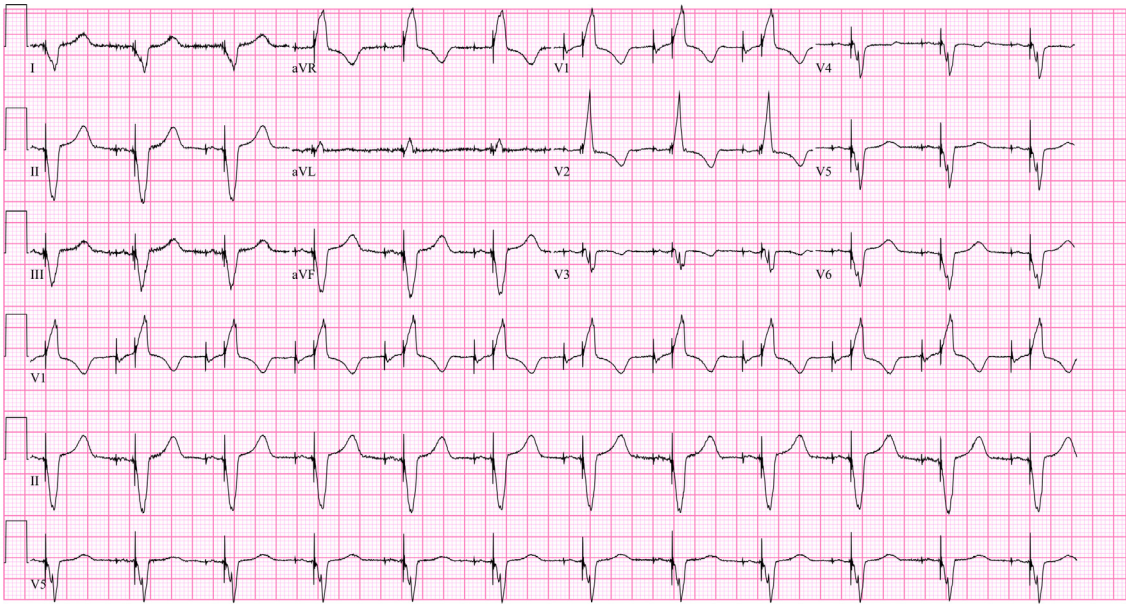


Fig 6. Postimplantation 12-lead electrocardiogram displaying a dual-paced rhythm.

(eg, patient name, device, battery life, percentage paced). In order to print a report, simply select the Reports tab on the lower portion of the main screen and print the desired report (see Fig 8).

Mode, Programmed Rate, and Rate Adaptive Pacing

In order to change the mode or rate for the perioperative period, which is pertinent to the CRT-D previously described,

ZOOM ® View™
Device Settings Report

Ventricular Tachy (Continued)			
VT-1 170 bpm (353 ms)			
Detection/Redetection		**ATP1**	Burst
Initial Duration	60.0 s	Number of Bursts	2
Redetection Duration	1.0 s	Pulses per Burst	
Post-shock Duration	1.0 s	Initial	8
Enhancements	Rhythm ID	Increment	0
VT-1 Detection	On	Coupling Interval	81 %
Initial Detection	On	Decrement	0 ms
Sustained Rate Duration	03:00 mm:ss	Burst Cycle Length	81 %
Post-Shock Detection	Off	Ramp Decrement	0 ms
Rhythm ID Setup		Scan Decrement	0 ms
Ambulatory update	On	Minimum Interval	220 ms
Temporary LRL	70 ppm	**ATP2**	Ramp
Common Parameters		Number of Bursts	1
Atrial Tachy Discrimination	On	Pulses per Burst	
AFib Rate Threshold	170 bpm	Initial	8
Stability	20 ms	Increment	0
RhythmMatch™ Threshold	94 %	Coupling Interval	81 %
		Burst Cycle Length	81 %
		Ramp Decrement	10 ms
		Minimum Interval	220 ms
		ATP Time-out	01:00 mm:ss
		Shocks	
		Shock 1	41 J
		Shock 2	41 J
		Shock 3 -5	41 J
Ventricular Tachy Therapy Setup			
ATP		**Shock (All Shocks)**	
RV ATP Amplitude	5.0 V	Waveform	Biphasic
RV ATP Pulse Width	1.0 ms	Committed Shock	Off
LV ATP Amplitude	5.0 V	Lead Polarity	Initial
LV ATP Pulse Width	1.0 ms	Shock Lead Vector	RV Coil to Can
Magnet and Beeper			
Magnet Response	Inhibit Therapy		
Beep During Capacitor Charge	Off		

Fig 7. Selected portion of the device settings report from an interrogation report of a Dynagen X4 CRT-D device. A *red box* highlights the magnet response, which is under the magnet and beeper section.

Table 4
Specific Perioperative Considerations for Boston Scientific CIEDs

Preoperative	
Capture threshold (chronic)	<3 V
Sensitivity (chronic)	P wave >2 mV R wave >5 mV
High-voltage lead impedance (chronic)	>20 ohms and <200 ohms
Magnet response	Confirm the device response to magnet application
S-ICD	Lacks bradycardia and antitachycardia pacing therapies
Intraoperative	
ICDs	Tone emitted in response to magnet application
S-ICDs	Tone emitted in response to magnet application
Pacemakers	The magnet-induced asynchronous pacing rate is 100 bpm with the rate decreasing to 85 bpm at ERI and <85 bpm at EOL Magnet application results in fixed asynchronous pacing rate with a 100 millisecond (ms) AV delay For CRT-P devices magnet application results in a left ventricle offset of 0 ms

Abbreviations: AV, atrioventricular; CIED, cardiovascular implantable electronic device; CRT-P, cardiac resynchronization therapy-pacemaker; EOL, end of life; ERI, elective replacement interval; ICDs, implantable cardioverter defibrillators; S-ICD, subcutaneous implantable cardioverter defibrillator.

either select the magnifying icon to the left of "Settings Summary" on the main screen (ie, Summary tab) or select the Settings tab (see Fig 8). From the Settings tab the practitioner can adjust the lower rate limit (LRL) via the slide board or open the "Brady/CRT" settings via the magnifying icon adjacent to "Normal Settings" (Fig 9). The "Brady/CRT -Normal" tab allows the practitioner to adjust the mode, LRL, and rate adaptive pacing (Fig 10). These adjustments are extremely relevant to the perioperative period because asynchronous pacing, a rate change, and the temporary discontinuation of rate adaptive pacing often are desired.

Rate adaptive pacing can be disabled in one of two ways. The mode can be changed from a rate response mode (eg, DDDR) to a nonrate response mode (eg, DDD) or the accelerometer setting can be changed from "on" to "passive." Either of these techniques will disable rate adaptive pacing. However, in order to implement any desired changes, the practitioner must remember to program the device via the "Program" tab at the bottom of the screen (see Fig 10).

Disabling Tachyarrhythmia Therapies

If disabling tachyarrhythmia therapies is preferred to magnet application for perioperative management, this also can be accomplished after some formal training via the main screen (see Fig 8). Once "Tachy Mode" is selected at the top of the main screen (see Fig 8), the practitioner will be prompted to change the device mode (Fig 11). The tachyarrhythmia therapies then can be programmed "Off" and finalized by selecting "Apply Changes" (see Fig 11).

Alternatively, the electrocautery protection mode can be enabled (see Fig 11). If available, the electrocautery protection

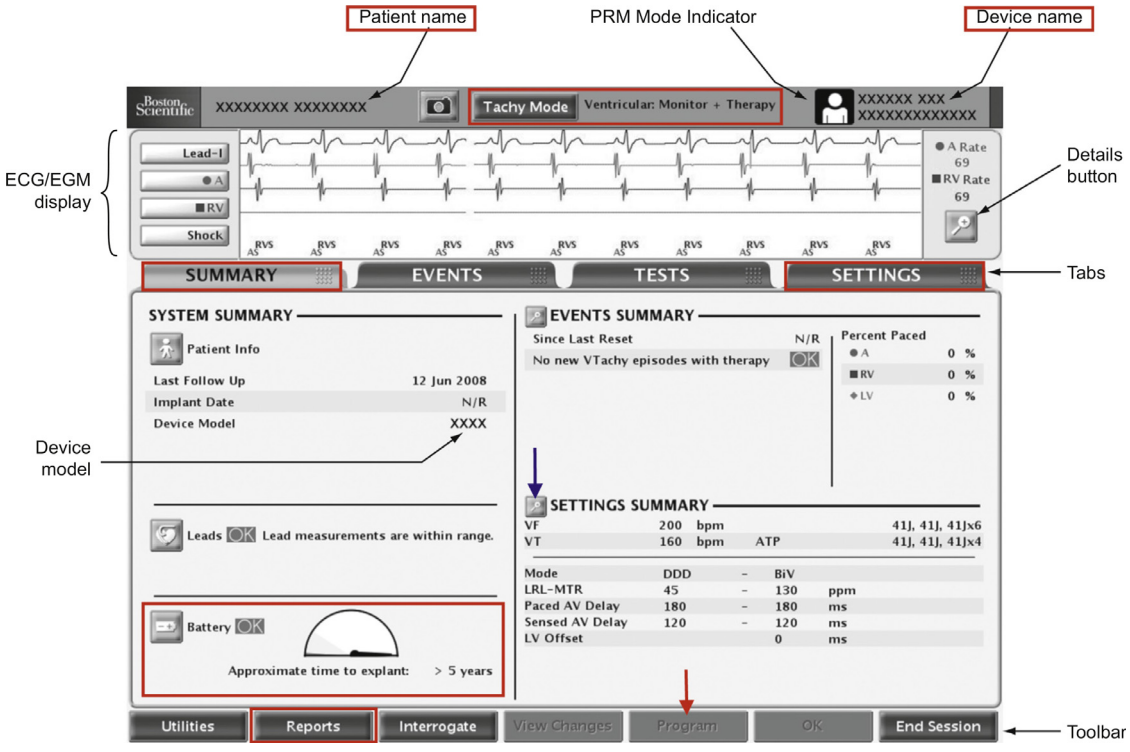


Fig 8. Generic Zoom Latitude Programmer main screen (ie, Summary tab) with important information, as described in the article, highlighted by *red boxes*. In addition, the "Program" tab is delineated by a *red arrow* and the "Settings Summary" icon by a *blue arrow*.
With permission from Boston Scientific, Marlborough, MA.

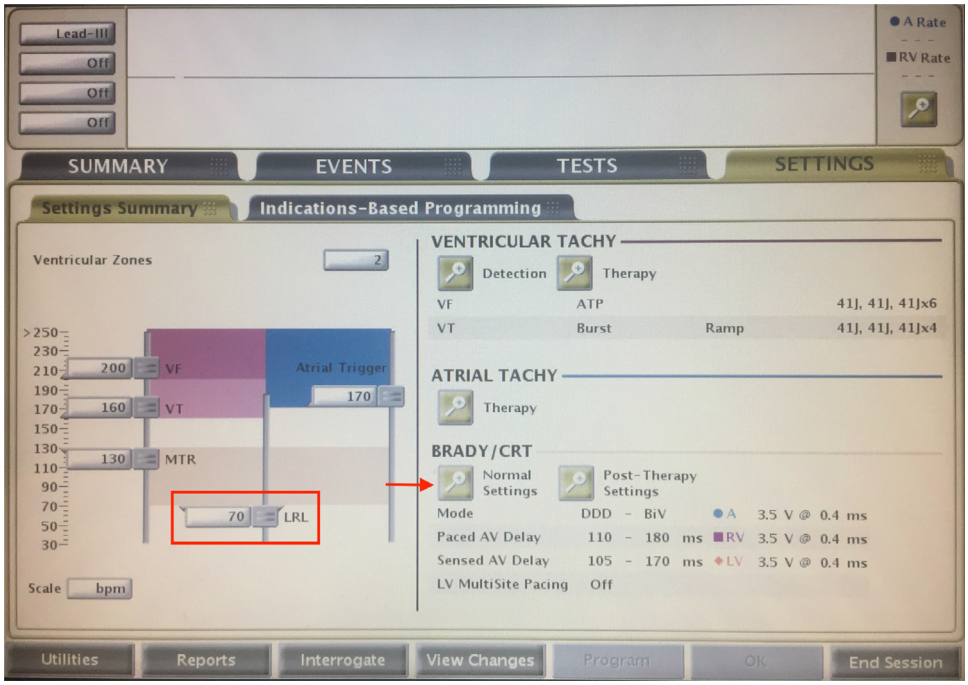


Fig 9. Zoom Latitude Programmer main screen (ie, Settings tab) with the lower rate limit slide bar highlighted by a *red box* and "Brady/CRT - Normal" settings button delineated by a *red arrow*.

mode provides asynchronous pacing at the programmed outputs and LRL and disables tachyarrhythmia detection and therapies. Even though this mode may accomplish all the desired perioperative goals (eg, asynchronous pacing and disable tachyarrhythmia therapies), it is dependent on the underlying bradycardia settings. Therefore, if bradycardia pacing is programmed "off," then the electrocautery protection mode will not result in asynchronous pacing.[12] It is worth mentioning that alternative means for the treatment of a malignant arrhythmia (eg, external pads and a defibrillator) should be readily available whenever tachyarrhythmia therapies are disabled. At the conclusion of the procedure, the "Tachy Mode" can be re-enabled via the main screen. A report should be printed and placed in the patient's chart any time changes are made to a

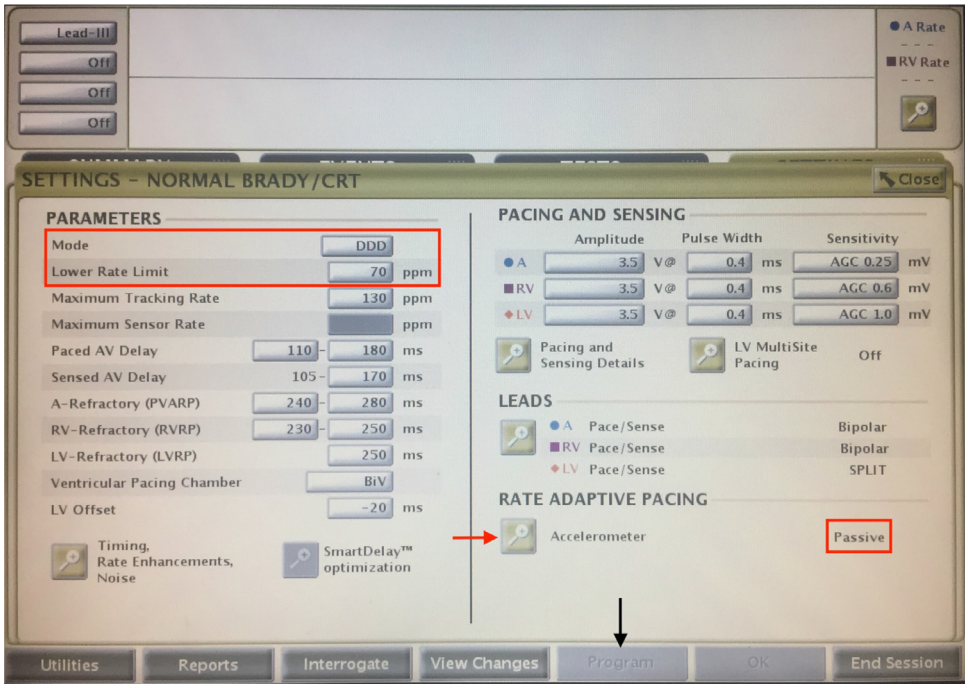


Fig 10. Zoom Latitude Programmer settings displaying the "Brady/CRT - Normal" tab,) with the mode, lower rate limit, and accelerometer information highlighted by *red boxes*. In addition, the program and accelerometer selection buttons are delineated by *black* and *red arrows*, respectively.

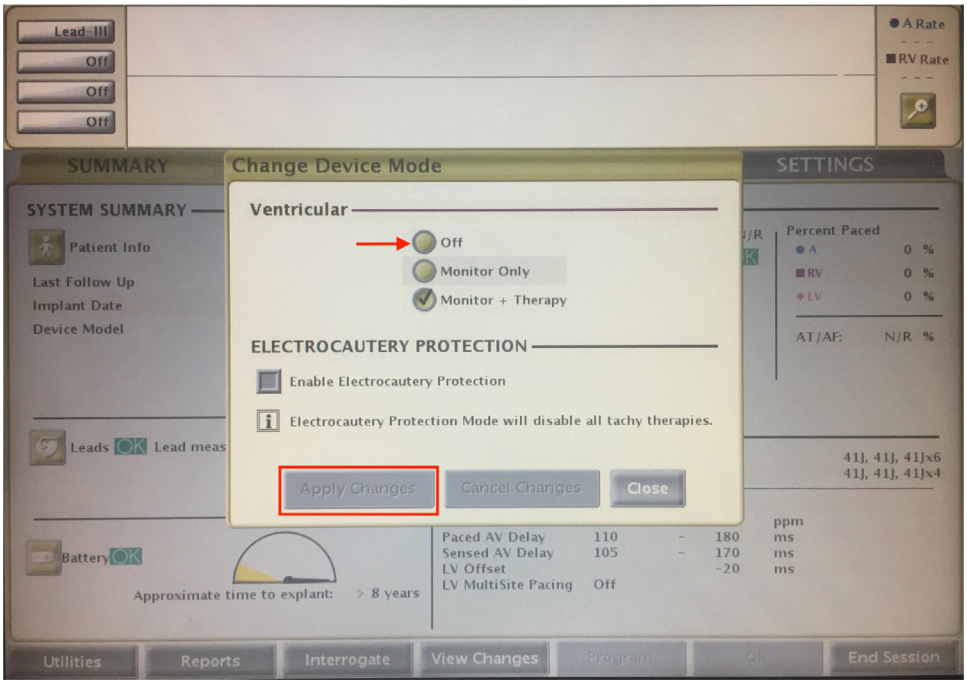


Fig 11. Zoom Latitude Programmer, displaying the "Tachy Mode" tab, with the tachyarrhythmia therapies "Off" radio button highlighted by a *red arrow* and "Apply Changes" button by a *red box*.

device's settings. This practice permits the review of previous settings and may help to avoid perioperative reprogramming errors.

Emblem S-ICD

The Emblem MRI S-ICD system (Boston Scientific) consists of a single subcutaneous electrode and a pulse generator (Fig 12) that are implanted for the prevention of sudden cardiac death in select patients.[19–22] The S-ICD provides sensing, detection, and defibrillation therapy (synchronous, biphasic shock of 80 Joules) of malignant ventricular tachyarrhythmias in patients who have no need for antitachycardia or bradycardia pacing. It is important to note that despite the lack of permanent pacing capabilities, the S-ICD can be programmed to provide transient bradycardia pacing at 50 bpm for a maximum duration of 30 seconds, in the event that postshock bradycardia occurs.[3]

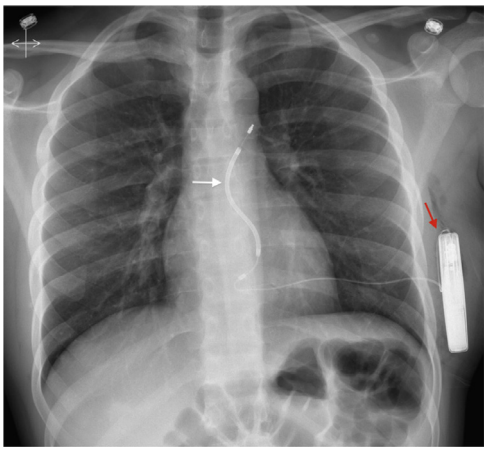


Fig 12. Anteroposterior chest radiograph demonstrating subcutaneous implantable cardiac defibrillator system in situ with the single subcutaneous electrode (*white arrow*) and pulse generator delineated (*red arrow*).

Although there is a lack of societal recommendations regarding perioperative management of the S-ICD, the wider sensing region and increased susceptibility to EMI of the subcutaneous device strongly favors deactivation of shock therapy during the perioperative period. A standard doughnut-shaped magnet can be used to temporarily deactivate the device; however, magnet application to the S-ICD is different from that used for transvenous ICDs. The manufacturer recommends magnet placement over the header or over the lower edge of the pulse generator, which typically is located in the 6th intercostal space along the left midaxillary line to suspend therapy (see Fig 12).[22] Optimal S-ICD suspension with a magnet occurs if the device emits a beeping tone for 60 seconds after magnet application (see Table 1).[19] However, even proper magnet application may not elicit the standard tone emission in patients with a "deep implant" or those previously exposed to a strong magnetic field (eg, magnetic resonance imaging). Even though the lack of tone emission may indicate a lack of interaction with the device (eg, "deep implant"), it also may merely represent defective tone emission from previous magnetic resonance imaging exposure.[22] Another possible explanation is the option to disable tone emission via the S-ICD programmer. If magnet application does suspend therapies successfully, then magnet removal will restore arrhythmia detection and shock therapy.

Alternatively, the S-ICD can be programmed to the "Therapy Off" mode before surgery to prevent EMI-induced inappropriate shock therapy. Given that even proper magnet

application may be ineffective (eg, patients with a "deep implant") or inconclusive (ie, lack tone emission), the authors prefer programming for perioperative management. As always, an alternative means of treating malignant arrhythmias (eg, external defibrillator) should be available if the device therapies are programmed off.

Interrogation Report (Emblem S-ICD)

Even though an interrogation report for a device in a patient with significant arrhythmia burden may be extensive, the majority of information pertinent to the perioperative period is conveyed on the summary report page (Fig 13).

Patient Identification and Follow-Up Date

First, it is important to confirm that the report is correctly associated with the patient, which can be found at the top of the Summary Report page (see Table 3). Second, the date of the interrogation/report should be compared with societal recommendations (see Fig 13). The HRS recommends that an ICD be interrogated within 6 months of elective surgery.[11] The date of the report speaks to the accuracy of the information. If the report date is remote from the day of surgery, then it may not reflect the current CIED settings and a reinterrogation may be warranted.

Battery Life and Electrode Status

The battery status of the device is depicted in the lower left of the Summary Report (see Fig 13). Per the manufacturer, the device's longevity is dependent on the number of shocks delivered yearly (eg, 3 annual full energy charges corresponds to an average longevity of 7.3 yr). Once the ERI is reached, the device's battery life commonly is quoted to be approximately 3 months. Because the HRS recommends that battery longevity be at least 3 months, an S-ICD device at ERI still may be consistent with HRS recommendations.[11] However, this depends on the device use.

In addition to battery life, the electrode impedance status is defined in the lower right of the Summary Report page. The single subcutaneous electrode is assessed weekly via a subthreshold energy pulse. If the impedance is <400 ohms, then it is deemed "OK" (see Fig 13). Alternatively, an impedance value >400 ohms may signify dysfunction. As discussed in a

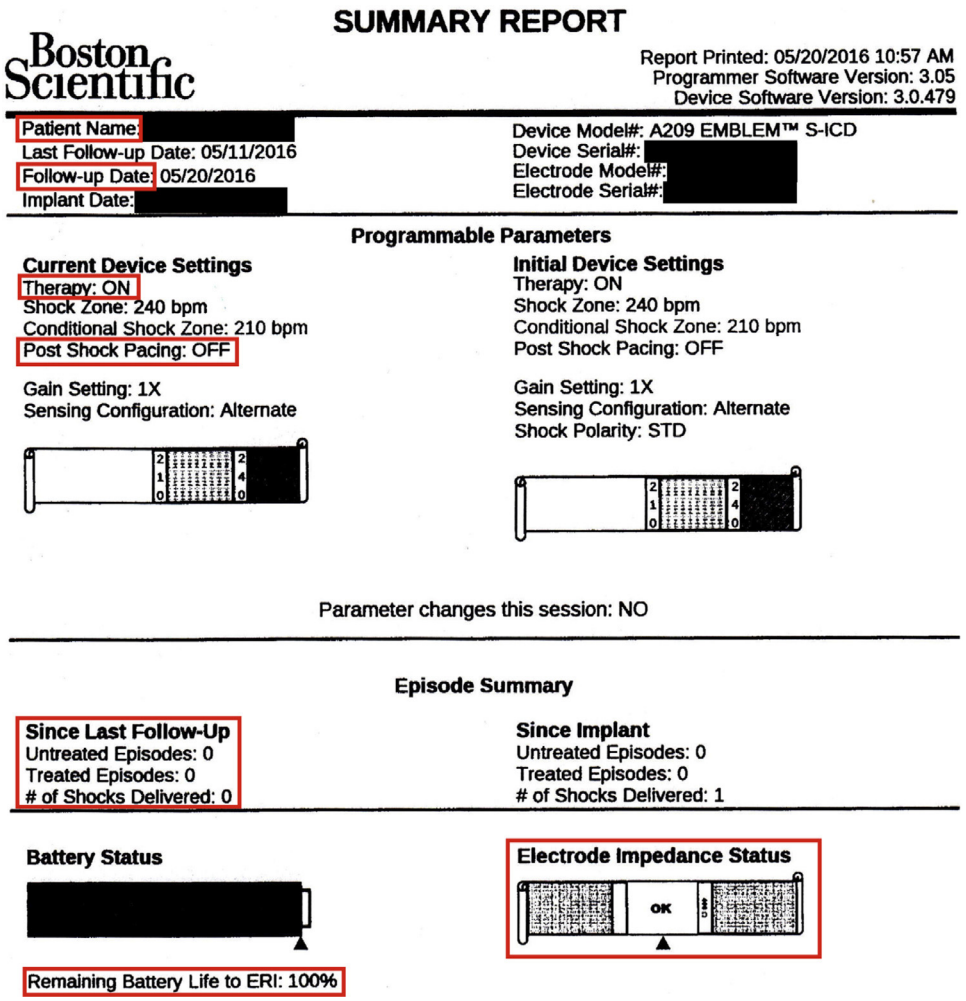


Fig 13. Selected page (ie, "Summary Report) from a sample interrogation report of an Emblem subcutaneous implantable cardiac defibrillator. Important information, as described in the article, is highlighted by *red boxes*.

previous publication, a recorded low (eg, <25 ohms) or high (eg, >200 ohms) impedance value from a delivered shock also may signify a problem and should be investigated before elective surgery.[1,23]

Device Settings

The Emblem pulse generator technically has 4 modes of operation; however, "Shelf Mode" is a low power consumption state used only for storage. "Therapy On" means the device will automatically detect tachyarrhythmias and deliver therapies if indicated. "Therapy Off" disables the automatic detection and treatment of ventricular tachyarrhythmias. "MRI Protection Mode" also will disable tachyarrhythmia therapies but is intended to be used only during a conditional magnetic resonance (MR) scan. The mode can be confirmed via the Summary Report page (top left) of the interrogation report (see Fig 13). In this example, the device is programmed to "Therapy On."

As previously stated, the Emblem S-ICD possesses the capability to transiently pace if therapy results in a bradyarrhythmia; however, postshock pacing can be programmed either "on" or "off." Therefore, a practitioner should not assume that the device will transiently pace the patient if perioperative device therapy is required. The postshock pacing settings can be confirmed in the Summary Report (see Fig 13).

Arrhythmia Burden

The number of episodes and shocks delivered since the last interrogation can be used by the anesthesia provider to determine the likelihood of encountering a malignant tachyarrhythmia in the perioperative period. This additional history regarding arrhythmia burden, which can affect perioperative management (eg, reprogramming *v* reliance on a magnet, postoperative monitoring), is located on the bottom left of the Summary Report page (see Fig 13).[19]

Basic Programming (Emblem S-ICD)

Interrogation

It is important to note that at this time the programmer required to interrogate or program the Boston Scientific S-ICD—the Model 3200 Emblem S-ICD programmer—is different than the programmer used for the Boston Scientific transvenous CIEDs (ie, Zoom Latitude Programming System - Model 3120). The current Emblem S-ICD programmer is a touch screen tablet that uses a radiofrequency telemetry wand (Model 3203) to communicate with the pulse generator, which also is unique to the S-ICD device.[23] It also is important to note that even though the Emblem MRI S-ICD is considered MR conditional, the Model 3200 programmer is MR unsafe.

After the telemetry wand is connected to the Emblem S-ICD programmer and the programmer is powered on (Fig 14), the telemetry wand can be placed over the pulse generator to establish a connection. The device status screen then will be displayed (Fig 15). Even though the information contained in an interrogation report can be obtained by navigating the touch screen display, an interrogation report should be printed to document the device settings, which may facilitate subsequent interrogations and programming. However, printing a pre-interrogation or post-interrogation report represents another nuance of the S-ICD because only the Boston Scientific–approved printer can communicate with the S-ICD programmer.

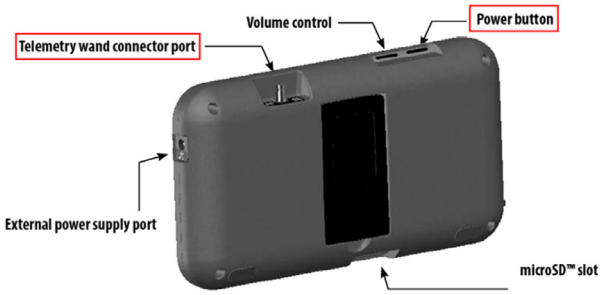


Fig 14. Posterior view of the subcutaneous implantable cardiac defibrillator programmer (Model 3200) with the power button and telemetry wand connector port highlighted (*red boxes*).
With permission from Boston Scientific, Marlborough, MA.

Device Status

The Device Status screen can be accessed by selecting the device status icon on the toolbar. The Device Status screen conveys important information such as the mode of operation, last interrogation, remaining battery life, number of episodes (treated and untreated), and shocks delivered since the last interrogation (see Fig 15). As previously discussed, these should be consistent with published recommendations regarding the interval of the last interrogation to the proposed procedure and battery life.

Modes of Operation

Even though anesthesiologists should be aware of all 4 modes, the "Therapy On" and "Therapy Off" modes are the most applicable to perioperative management with therapies being disabled preoperatively and re-enabled postoperatively. The mode of operation can be modified via the device settings icon and Device Settings screen (Fig 16). It is imperative that any changes be finalized by selecting the "Program" button on the Device Settings screen.

Shock and Conditional Shock Zones

The S-ICD possesses 2 programmable shock zones, with the shock zone being programmable between 170 and 250 bpm. The conditional shock zone is programmable between 170 and 240 bpm and is distinguished from the shock zone by automatically enabled enhanced tachyarrhythmia detection criteria. The enhanced detection criteria applied in the conditional shock zone are intended to reduce inappropriate therapies at

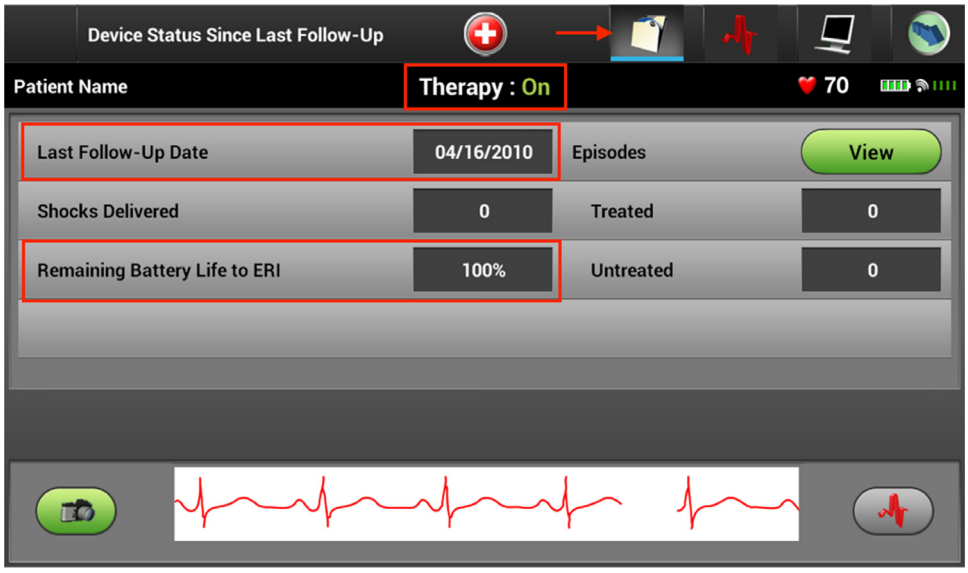


Fig 15. Device status screen displaying the device status icon (*red arrow*) and mode of operation, last interrogation, and remaining battery life highlighted (*red boxes*).

With permission from Boston Scientific, Marlborough, MA.

lower rates of detection (see Fig 16).[20] Although perioperative alterations to these zones are unlikely, knowledge regarding the rate at which therapies are delivered is important.

Summary: Boston Scientific CIEDs for Anesthesiologists

In summary, CRT devices are unique in that they attempt to improve cardiac output and patient symptoms by synchronizing contraction of the LV. The loss of synchronized contraction as a result of EMI-induced pacemaker inhibition may result in a reduction in cardiac output. The reduced cardiac output in these situations may result not from a complete lack of mechanical systole but rather from the suboptimal contraction induced by the patient's native rhythm. Although magnet application is expected to suspend tachyarrhythmia therapies in ICDs, which includes CRT-D devices, it will not affect the pacemaker settings. Therefore, programming would be required to pace asynchronously in CRT-D devices. In addition, Boston Scientific devices have a programmable magnet response (see Table 1). The magnet response can be confirmed by interrogation. Alternatively, the magnet response can be confirmed by magnet-induced asynchronous pacing at the anticipated rate for pacemakers or tone emission from ICD

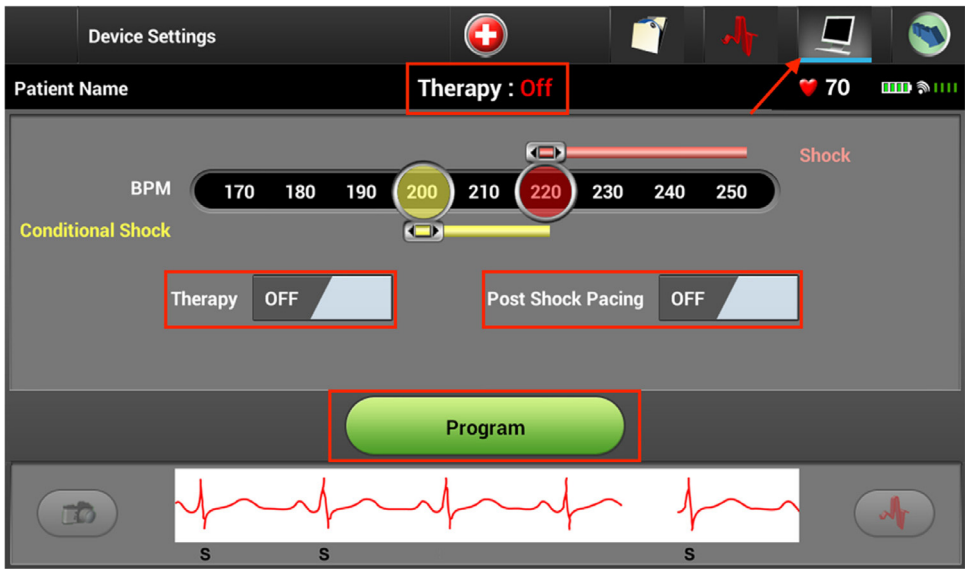


Fig 16. Device settings screen displaying the device settings icon (*red arrow*) and mode of operation, therapy on/off button, postshock pacing on/off button, and program button highlighted (*red boxes*).

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and CRT-D devices. The S-ICD also confirms proper magnet application with tone emission. However, because of the wider sensing region, increased susceptibility to EMI, and challenges of proper magnet application with S-ICDs, the authors prefer deactivation of shock therapy via programming for the perioperative period.

Conclusions

In conclusion, appropriate preoperative preparation and the effective interpretation of a CIED interrogation report are pivotal in determining perioperative management options and guiding the application of societal recommendations. After reviewing the potential responses to magnet application of Boston Scientific devices (ie, the programmable magnet responses inherent to Boston Scientific transvenous CIEDs and S-ICD), the authors prefer interrogation and programming over reliance on a magnet for perioperative management. As stated in prior publications, the authors are not advocating for untrained anesthesiologists to assume responsibility for CIED programming, but rather suggest that basic programming can be completed by anesthesiologists after formal training/institutional support and that improved patient care may result from increased knowledge and familiarity with CIED interrogation.[17] Hopefully, these reviews will serve as educational resources for institutions and departments that wish to educate anesthesiologists regarding the perioperative management of CIEDs.

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