Journal of Cardiothoracic and Vascular Anesthesia 000 (2019) 1–10

Contents lists available at ScienceDirect

Journal of Cardiothoracic and Vascular Anesthesia

journal homepage: www.jcvaonline.com

Review Article

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

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Biotronik cardiovascular implantable electronic devices, specifically Biotronik pacemakers, contain unique features that are relevant to perioperative management. For example, Biotronik pacemakers have a programmable response to magnet application, a default magnet response that does not result in sustained asynchronous pacing, and a unique method of rate adaptation (eg, closed loop stimulation). This review article focuses on these unique features; the interpretation of Biotronik interrogation reports; and the basic programming (eg, mode, rate, rate adaptation, tachyarrhythmia therapies) relevant to the perioperative management of Biotronik cardiovascular implantable electronic devices.
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Key Words: pacemaker; cardiovascular implantable electronic device; implantable cardioverter defibrillator; anesthesia; device programming; Biotronik; CLS; perioperative management

PREVIOUS PUBLICATIONS in this review series have focused on the interpretation of interrogation reports and basic programming pertinent to the perioperative management of Abbott (St. Jude Medical) and Boston Scientific cardiovascular implantable electronic devices (CIEDs).[1,2] This review article focuses on the interpretation of interrogation reports and basic programming (eg, mode, rate, rate modulation, and tachyarrhythmia therapies) related to the perioperative management of Biotronik (Lake Oswego, OR) CIEDs. As stated in previous publications, the information presented in this review series should not be interpreted as evidence for CIED programming to be completed by untrained and uncredentialed practitioners. CIED interrogation and programming should be performed only by practitioners who are appropriately trained and credentialed. Rather, the authors believe that the retention of relevant CIED information is facilitated by a thorough knowledge of the devices, programmers, reports, and management options. This review series hopefully serves as an introduction for interested individuals or as a resource for those in training. Whatever the motivation, it is important to recognize that when a consulting physician or licensed practitioner is not involved in the perioperative management, anesthesiologists are medicolegally responsible for these devices and their management in the perioperative period. Therefore, it behooves anesthesiologists to have a thorough knowledge of these devices, including programming options. In an effort to depict the clinical relevance of this

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https://doi.org/10.1053/j.jvca.2019.03.001
1053-0770/Published by Elsevier Inc.

information, a brief case description will precede the discussion of information relevant to the perioperative management of Biotronik CIEDs.

Case Report

An 88-year-old, 170 cm, 74 kg male with severe unilateral carotid stenosis was admitted for a right carotid endarterectomy. His medical history included essential hypertension, diabetes mellitus on insulin, Parkinson's disease, bladder cancer, prostate cancer, paroxysmal atrial fibrillation, second-degree atrioventricular block with bifascicular block, and a dual chamber Biotronik Eluna 8 DR-T pacemaker (Biotronik, Lake Oswego, OR), which was implanted after a recorded 10 second asystolic event that occurred 3 y prior. Preoperative device interrogation identified that he was atrially and ventricularly paced 28% and 98% of the time, respectively. After a preoperative history and physical examination were performed, an arterial line was placed and anesthesia was induced uneventfully with intravenous lidocaine (80 mg), fentanyl (100 μg), propofol (100 mg), and rocuronium (40 mg). The airway then was secured with a 7-0 endotracheal tube. Given his preoperative history, the perioperative recommendations provided by a cardiologist, and evidence of a ventricularly paced rhythm on an electrocardiogram (Fig 1), a magnet was placed over the CIED generator.

Anesthesia was maintained with infusions of remifentanil (0.15 μg/kg/min) and propofol (100 μg/kg/min) because of intraoperative neuromonitoring of somatosensory evoked potentials (SSEP) and electroencephalography. Blood pressure was maintained at or above the patient's baseline with the aid of an intravenous phenylephrine infusion (10-30 μg/min). The patient remained hemodynamically stable and displayed a paced rhythm. However, 1 hour into the surgical procedure the paced rate acutely increased and was maintained at 110 bpm. Rhythm strips of this acute increase in heart rate are not available. According to the practitioners, it was a ventricularly paced rhythm at a rate of approximately 110 bpm that coincided with monitoring of SSEP. The magnet position was confirmed but was not in an asynchronous mode. Review of the intraoperative anesthesia record by the practitioners revealed that the paced rate was not sustained at 90 bpm after the magnet was applied; therefore, the neuromonitoring technician was asked to alter the SSEP. The reduction in SSEP frequency and power resulted in a return to baseline—a paced rhythm at 60 bpm. The surgery was completed and the patient was extubated uneventfully. Postoperatively, the pacemaker was interrogated by an electrophysiologist and determined to be functioning normally.

Discussion

Medicolegal Responsibility

Even though anesthesiologists do not implant or chronically manage CIEDs, they often are responsible for patients with CIEDs in the perioperative period. Anesthesiologists are in a unique position to provide perioperative insights and information vital to formulating an appropriate perioperative CIED management plan with a consulting CIED physician or licensed practitioner. However, when a consulting physician (eg, electrophysiologist) or licensed practitioner is not involved in the perioperative management of a CIED, the medicolegal responsibility rests with the anesthesiologist.

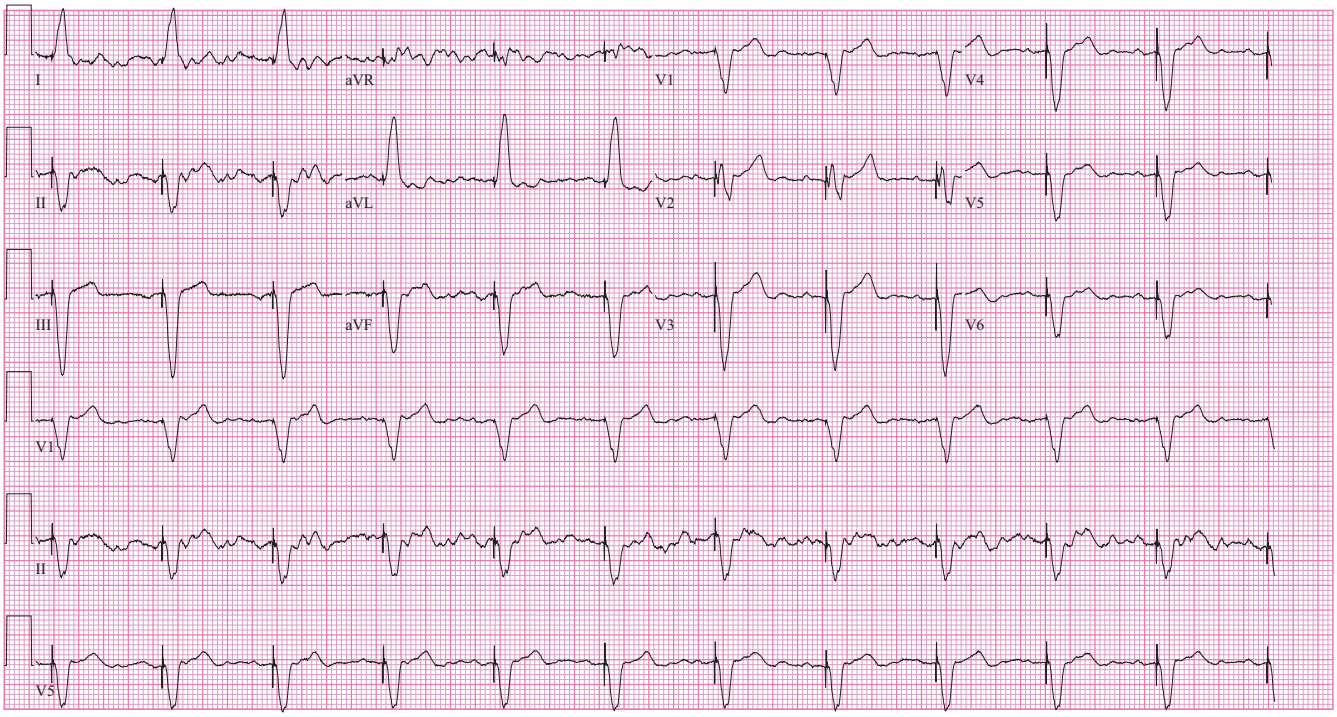

Fig 1. Preoperative 12-lead electrocardiogram displaying a ventricularly paced rhythm.

Even though anesthesiologists might find this statement unsettling, it is based on the fact that industry-employed allied professions (IEAPs) are not licensed or authorized to practice medicine. Rather, IEAPs interrogate, provide information, and ultimately reprogram CIEDs at the "request and direction of physicians."[3,4] Therefore, when an anesthesiologist requests IEAP support independent of another physician or licensed practitioner, then the anesthesiologist assumes the position of responsible physician. It was clearly stated by the North American Society of Pacing and Electrophysiology (NASPE) "that the physician has overall responsibility for the patient being treated and for the pacemaker/ICD [implantable cardioverter defibrillator] function and programming."[3] These sentiments were reiterated in 2008 by the Heart Rhythm Society (HRS), which stated that "the physician bears the responsibility for assessing effectiveness of device programming and any device malfunctions and recommending specific courses of action."[4] Even though these statements likely were intended for electrophysiologists, they also apply to anesthesiologists. In fact, their sentiments have been echoed in the anesthesia literature by Crossley et al., Rooke et al., and Ellis et al., who stated that IEAPs do not have the clinical privileges to determine the appropriate programming for surgery and that independent CIED management is beyond the scope of IEAPs.[5-7]

Biotronik CIEDs: Magnet Responses

Similar to Abbott (St. Jude) and Boston Scientific CIEDs, Biotronik pacemakers have a programmable response to magnet application (Table 1). In addition, the default response of Biotronik pacemakers is a brief period of asynchronous pacing followed by a return to the original settings at the lower rate limit. In the case described here, the anesthesia providers and consulted cardiologist were unaware that the magnet response was programmable and that the device response was programmed to "Auto" (Table 1).[8-10] Given that magnet application in the "Auto" setting changes the mode to asynchronous for only 10 beats and the original settings lacked rate response, a proposed mechanism for the intraoperative rate increase that occurred was inappropriate ventricular tracking of SSEPs as atrial activity.[11]

As illustrated by the present case, if magnet application is anticipated in the perioperative period, it is imperative that proper device identification (Table 2) and confirmation of the programmed magnet response, if applicable, occur in the preoperative period. As previously described, the Biotronik alpha numeric code, characteristic shape, and presence or absence of a high-voltage coil on a chest radiograph can aid the practitioner in identifying the device company and distinguishing between an ICD and pacemaker (Fig 2).[1,2,12,13] Once the device company has been identified, the company can be contacted (800-547-0394) and the Biotronik Renamic programmer (Biotronik, Lake Oswego, OR) can be used to interrogate the device and obtain a report. Ultimately, either the device programmer (Fig 3), an interrogation report (Fig 4), or sustained response to magnet application can be used to confirm the magnet response of a Biotronik pacemaker.

Table 2
Biotronik Devices

Biotronik CIEDs	
Pacemaker	Eluna 8 DR-T/SR-T, Etrinsa 8 DR-T/SR-T, Edora SR-T ProMRI, Edora DR-T ProMRI
ICD	Inventra 7 VR-T DX, Intica 7 VR-T DX ProMRI, Ilivia 7 VR-T ProMRI, Ilivia 7 DR-T ProMRI
CRT-P	Etrinsa 8 HF-T, Edora HF-T QP
CRT-D	Inventra 7 HF-T QP, Intica CRT-DX ProMRI, Ilivia HF-T QP ProMRI
Biotronik contact number	(800)-547-0394

Abbreviations: CIED, cardiovascular implantable electronic device; CRT-D, cardiac resynchronization therapy-defibrillator; CRT-P, cardiac resynchronization therapy-pacemaker; ICD, implantable cardioverter defibrillator.

Biotronik Renamic Programmer

Initiation of the Biotronik Renamic programmer is similar to that previously described for Abbott (St. Jude) and Boston Scientific device programmers.[1,2] To open the device programmer, depress the latches on both sides of the programmer. The power cord, which is stored in the rear compartment on the base, inserts on the back left of the Renamic programmer near the power button. After the device programmer is powered on and the programming head or wand is placed over the CIED pulse generator, the display can be manipulated with an untethered stylus. Although these steps and many aspects of CIED interrogation are similar across manufacturers (eg,

Table 1
Biotronik Devices: Potential Responses to Magnet Application

Device Setting	Response to Magnet Application
Pacemakers	
Auto (default)	10 asynchronous beats at 90 bpm followed by a return to the original settings at LRL. At ERI, 10 asynchronous beats at 80 bpm in VOO mode followed by VDD or VVI with the LRL reduced by 11%.
Asynchronous	Asynchronous pacing at 90 bpm. AV delay of 100 ms or the programmed AV delay, whichever is shorter. At ERI or EOL, asynchronous pacing at 80 pm in VOO mode.
Synchronous	Pacing continues in original programmed mode at LRL and an AV delay of 100 ms. At EOL, VDD or VVI with the LRL reduced by 11%.
Defibrillators	
	Tachyarrhythmia therapies are disabled and pacemaker settings are left unaltered. No beep or tone emitted.

Abbreviations: AV, atrioventricular; bpm, beats per minute; EOL, end of life; ERI, elective replacement indicator; LRL, lower rate limit.[8-10]

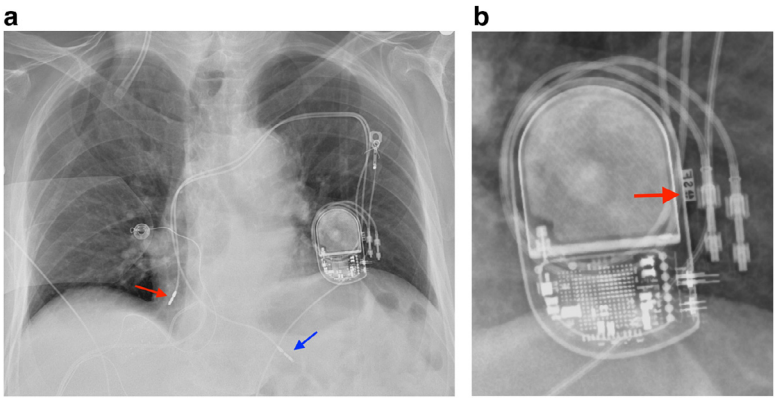

Fig 2. (A) Upright frontal chest radiograph. A Biotronik transvenous dual chamber pacemaker (Eluna 8 DR-T) with the generator in the left pectoral location and leads in the right atrium (*red arrow*) and right ventricle (*blue arrow*). (B) Chest radiograph with magnification of the generator displaying the characteristic shape, battery, and alpha numeric code (*red arrow*) of the Biotronik device.

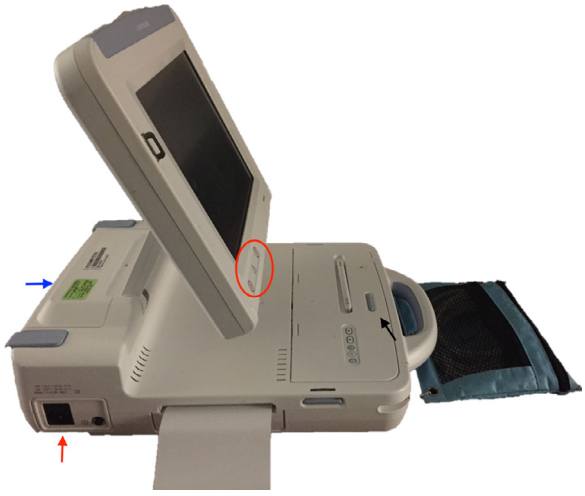

Fig 3. Biotronik Renamic programmer with the power receptacle and on–off switch (*red arrow*), rear storage compartment (*blue arrow*), safe programming and emergency shock buttons (*red oval*), and front storage compartment and untethered stylus (*black arrow*) highlighted.

radiofrequency telemetry requires that an initial connection be established with the programming head), there are 2 features of the Biotronik Renamic programmer that could be used in an emergency and therefore merit additional attention.

The Renamic programmer has an emergency pacing (ie, VVI) button (Fig 5) located in the lower left corner of the programmer just below the display (see Fig 3). After a connection has been established, safe programming or emergency pacing can be instituted with both pacemakers and ICDs via this button. The emergency pacing that ensues involves a VVI mode of 80 pulses per minute at a pulse amplitude of 7.5 volts and pulse width of 1.5 ms.[14] Once instituted, to stop emergency pacing, the practitioner is required to restore the previous settings by opening the parameters screen, selecting the desired settings, and programming the device (see the Basic Programming section that follows).[15]

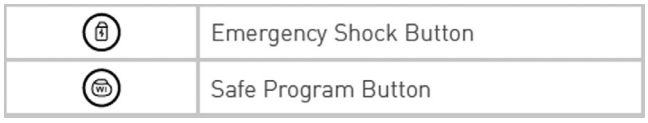

Fig 5. Emergency shock and the safe programming (ie, emergency pacing) buttons, which are located in the left lower corner of the programmer just below the display.

In addition to an emergency pacing button, the Biotronik Renamic programmer also has an emergency shock button (see Fig 5), which is similarly located in the lower left corner of the programmer just below the display (see Fig 3). Unlike the emergency pacing button, an emergency shock is only possible if the device is an ICD and a connection has been established. If an emergency shock is desired, and after the emergency shock button has been selected, "Emergency Shock" must be confirmed in a dialogue window. Once this 2-step process is complete, the device will charge and deliver a biphasic, synchronized, maximum energy, committed shock.[15]

Parameters - Bradycardia	(1st interrogation)
Mode	DDD
Basic rate/Night rate [bpm]	60/OFF
Basic rate [bpm]	60
Night rate [bpm]	OFF
Night begins	
Night ends	
Hysteresis [bpm]	OFF
Repetitive/Scan cycles	
Atrial overdrive	OFF
Magnet response	AUTO

Fig 4. "Parameters – bradycardia" portion of an interrogation report of an Eluna 8 DR-T pacemaker with the magnet response highlighted by a *red box*.

Basic Programming: Biotronik Pacemaker

In order to interrogate and program a device, the clinician should follow the previously described steps to turn on the Renamic programmer and connect with the pacemaker. Once a connection has been established, the main screen "follow-up" tab will display information also contained in an interrogation report (eg, patient information, device information, mode, rate, battery life, percentage paced) (Fig 6). Given that interpretation of this information has been discussed in previous publications, it is not be presented here.[1,2] However, it is worth reiterating that an initial interrogation report should be printed before any changes are made.

The mode, rate, and rate adaptive therapy can be manipulated via the "parameters" tab (Fig 7, A). Once the current mode is selected, the practitioner often is required to select "all modes" if an asynchronous mode is indicated (Fig 7, B). "Program" will finalize and implement any desired changes (see Fig 6).

In the authors' opinion, optimal management in the case presented here would have involved perioperative interrogation and programming to an asynchronous mode. However, a magnet could have been used if the device setting was asynchronous and the asynchronous rate was deemed appropriate for the patient by the management team (see Table 1). This magnet response could have been confirmed in the preoperative period by a recent interrogation report (see Fig 4), sustained asynchronous response to magnet application at the expected rate, or programming. The magnet response can be programmed by selecting the "basic rate/night rate" in the "parameters" tab (see Fig 7, A) and expanding the magnet response parameters. The desired magnet response then can be selected—"Async, Sync, or Auto" (Fig 8, A and B).[16] As always, any changes need to be programmed and a report should be printed for documentation.

The Biotronik pacemaker magnet response in the case report presented here was programmed to the "Auto" mode (see Fig 8, B). Therefore, as described in Table 1 and displayed in Fig 8, B, magnet application in the "Auto" mode only resulted in asynchronous pacing in the DOO mode at 90 bpm for the first 10 beats. As shown in Fig 8, B, the term "cycles" is used in place of "beats" on the Biotronik Renamic programmer and equates to a cardiac cycle. The heading "Magnet cycle 1-10" implies that after magnet application the pacemaker will be in a DOO mode at 90 bpm for 10 beats. With continued magnet application, after 10 beats or "magnet cycle 11" and greater, the device reverted to a DDD mode at the base rate of 60 bpm. In addition, had rate adaptation been active (eg, DDDR) the device would have used a rate adaptive mode (eg, DDDR) after 10 beats or "magnet cycle 11" and greater in the "Auto" mode. In summary, magnet application to Biotronik pacemakers in the "Auto" mode will not result in sustained asynchronous pacing.

Interrogation Report: Biotronik Pacemaker

The interpretation of information contained within a Biotronik pacemaker interrogation report (eg, indication for implantation, date of implantation, interrogation date, threshold, sensitivity, percentage paced) have been discussed in previous publications.[1,2] Features unique to Biotronik pacemakers include the potential responses to magnet application (see Table 1) and closed loop stimulation (CLS) rate adaptation.

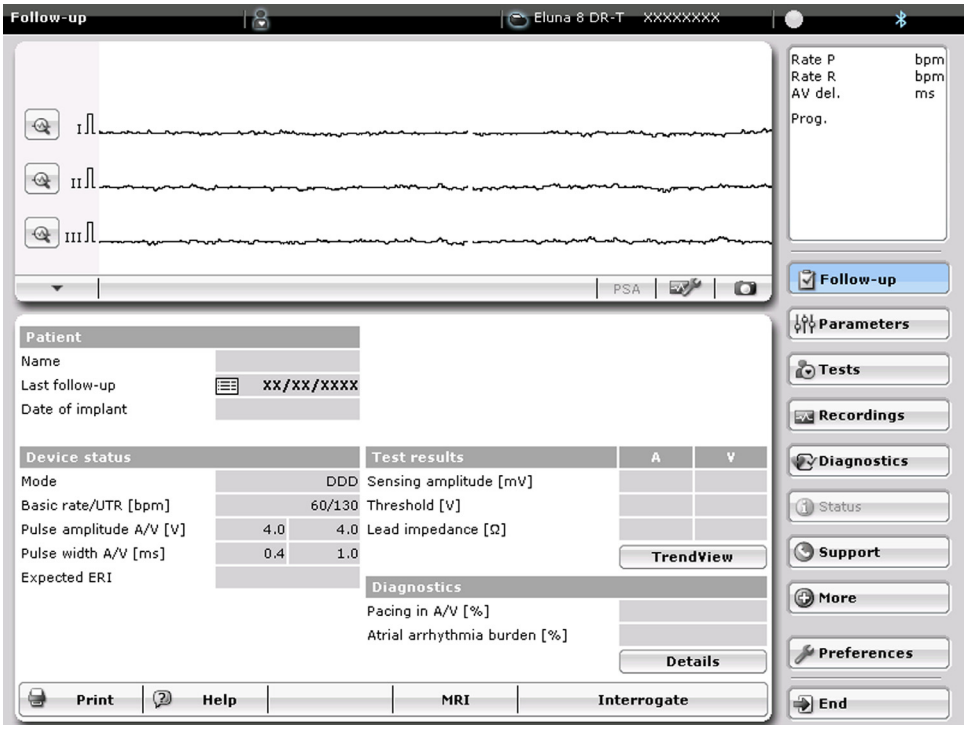

Fig 6. Renamic programmer main screen "follow-up tab" from a pacemaker (Eluna 8 DR-T) demonstration patient.

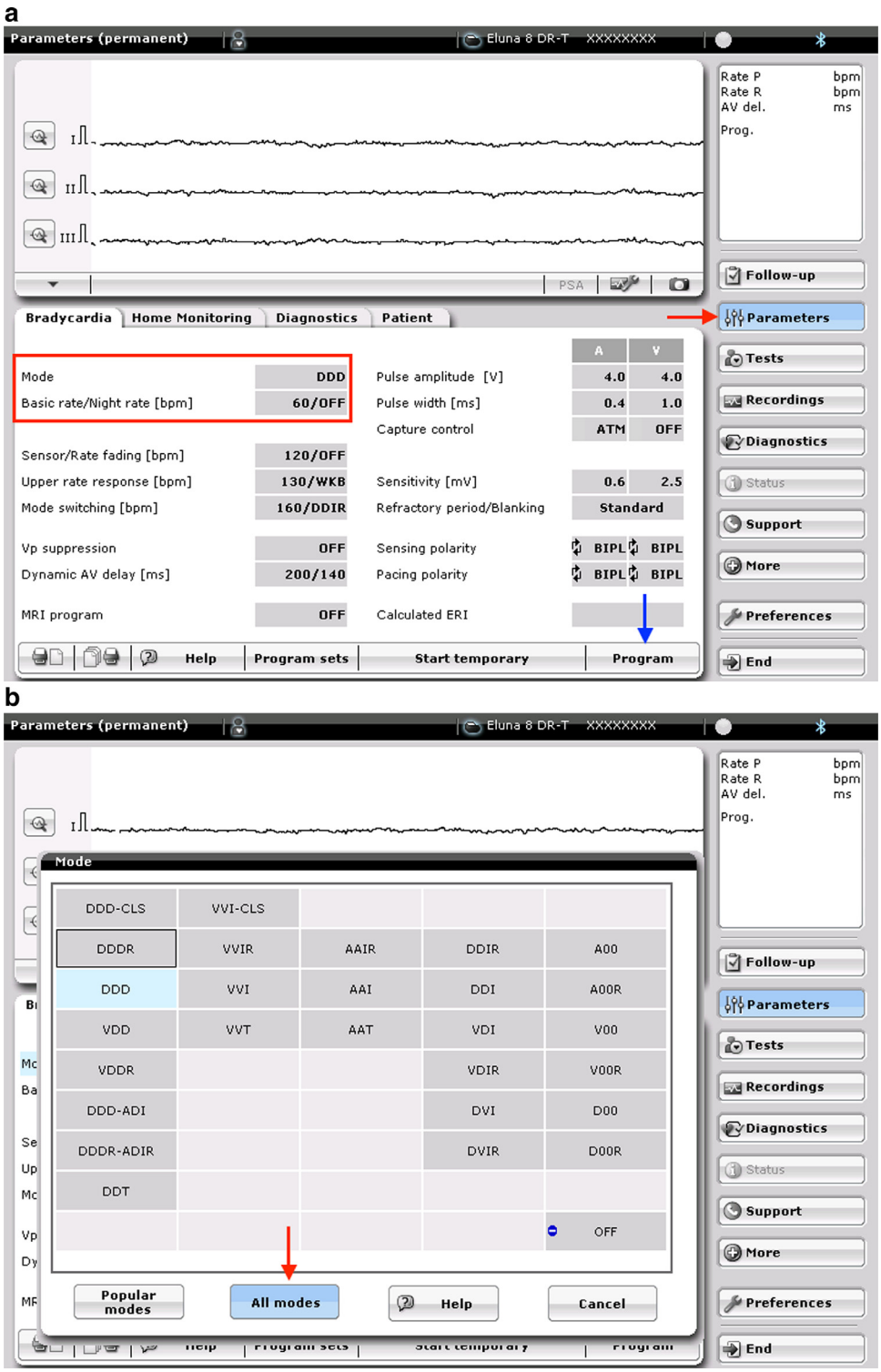

Fig 7. (A) Bradycardia settings of the Renamic programmer "parameters tab" (*red arrow*) from a pacemaker (Eluna 8 DR-T) demonstration patient with the mode and rate (*red box*) and program (*blue arrow*) buttons highlighted. (B) Renamic programmer available modes with "all modes" delineated by the *red arrow*.

The device response to magnet application can be found in the first section under the "parameters – bradycardia" heading (see Fig 4). This section also contains other information pertinent to perioperative management including the mode and basic rate or lower rate limit.

CLS is a form of rate adaptation that is related to the contractile state of the myocardium, predominantly involves the ventricular lead, and is unique to Biotronik devices. Given that this form of rate adaptation involves catecholamine stimulation and is based on intracardiac impedances at the lead tip, it

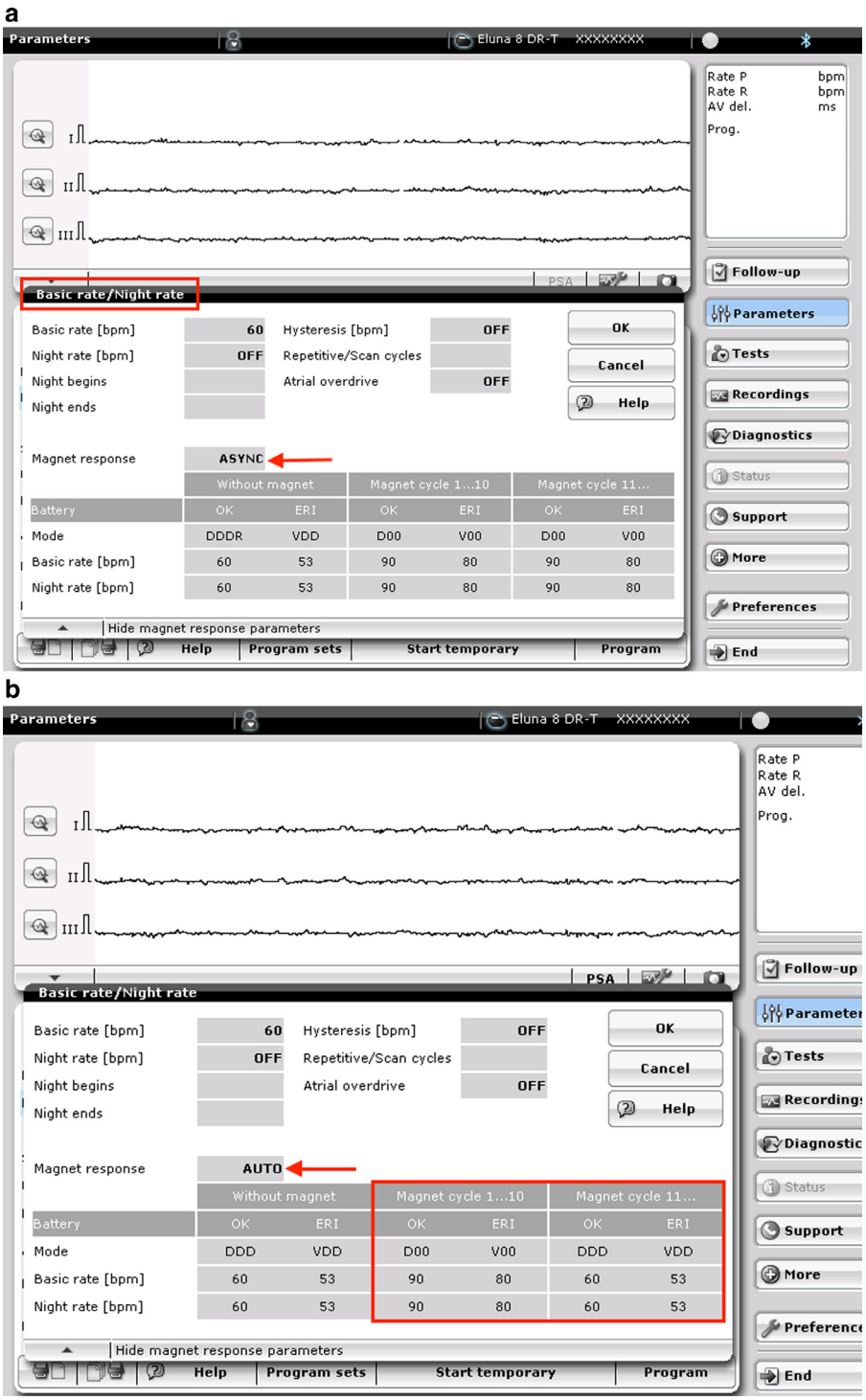

Fig 8. (A) Renamic programmer "parameters" tab from a pacemaker (Eluna 8 DR-T) demonstration patient with the "basic rate/night rate" (*red box*) selected and the magnet response delineated as "async" (*red arrow*). (B) Renamic programmer "parameters" tab from a pacemaker (Eluna 8 DR-T) demonstration patient with the "basic rate/night rate" selected. The magnet response—"auto"—is delineated by a *red arrow* and the "magnet cycles" is highlighted by a *red box*.

is reported to provide appropriate responses to not only exercise but also emotional stress.[17-19] Because these impedances are based on subthreshold unipolar pulses that are emitted after a sensed or paced event, the perioperative precautions and interactions (eg, electrocautery) of thoracic impedance rate adaptation devices also apply to devices with active CLS rate adaptation. Furthermore, CLS is theorized to be affected by myocardial ischemia and cardioactive medications.[18] Given the possible interactions and the recommendations by the American Society of Anesthesiologists (ASA) and HRS, the authors prefer that rate adaptation be suspended in the perioperative period.[7]

As implied by the available modes (see Fig 7, B), the monitored rate adaptation variable cannot be accelerometer and

CLS based. If rate adaptation is desired, then the device can be programmed to either a CLS (eg, DDD-CLS) or accelerometer (eg, DDDR) based mode. However, the accelerometer is used by the device to determine the baseline CLS waveforms, which are acquired during periods of inactivity.[18] Any changes in impedance associated with increased contractility are compared by the device with baseline waveforms by the device, and the pacing rate then is increased accordingly.

Interrogation Report: Biotronik ICD

The perioperative management of ICDs frequently hinges on asynchronous pacing, if indicated, and the temporary suspension of tachyarrhythmia therapies.[20-22] Even though tachyarrhythmia therapies frequently are suspended during the perioperative period, conversion to an asynchronous mode is dependent on the indication for implantation, underlying rhythm, and percentage paced. As previously described for Biotronik pacemakers, information regarding the indication for implantation, mode, rate, rate adaptation, and percentage paced can be obtained under the "follow-up" and "parameters – bradycardia" headings of a recent interrogation report. However, given their dual functionality, the information regarding tachyarrhythmia therapies and arrhythmia burden also should be ascertained before a surgical procedure. Tachyarrhythmia detection and the confirmatory criteria (eg, rate) and therapy (eg, antitachycardia pacing *v* shock) for ventricular tachycardia or ventricular fibrillation can be confirmed under the "parameters – overview" heading (Fig 9).

Basic Programming: Biotronik ICD

Temporary suspension of tachyarrhythmia therapies in Biotronik ICDs can be accomplished by applying a magnet (see Table 1). However, Biotronik ICDs do not emit a confirmatory tone in response to magnet application. Even though tachyarrhythmia therapies can be suspended by magnet application, some clinical situations (eg, inability to secure the magnet out of the surgical field) and practitioners prefer perioperative ICD programming. Tachyarrhythmia therapies can be disabled or enabled via the main screen on the Renamic programmer (Fig 10). As always, the desired settings must be programmed and an interrogation report should be printed for documentation. In addition, alternative means for the treatment of a malignant arrhythmia (ie, external pads and a defibrillator) should be readily available whenever tachyarrhythmia therapies are disabled, and the ICD should be reprogrammed "on" before the patient is discharged from the postanesthesia care unit.

The application of a magnet to a Biotronik ICD will not affect the bradycardia pacemaker settings (see Table 1). In other words, magnet application to a Biotronik ICD will not affect the pacing mode. Therefore, if an asynchronous mode is indicated or preferred, it must be programmed with the Renamic programmer. The mode, rate, and rate adaptation all can be modified under the "parameters" tab and "bradycardia" heading (see Fig 10) as previously described.

Postoperative Management

The 2011 HRS/ASA Expert Consensus Statement provided specific guidance on postoperative interrogation of CIEDs with the management recommendations being stratified into the following 3 groups: device evaluation before discharge from a monitored setting, postoperative device evaluation within 1 month, and routine follow-up. Postoperative interrogation and programming before discharge or transfer from a monitored setting were deemed necessary if the CIED was reprogrammed before the procedure (eg, tachyarrhythmia therapies were disabled). In addition, immediate postoperative interrogation is indicated when a surgery is hemodynamically challenging, remarkable for significant intraoperative events (eg, cardiac arrest, temporary pacing, cardioversion), or

Parameters - Overview			(1st interrogation)
Detection			
AT/AF rate [bpm]			200
VT1 rate [bpm]			150
VT2 rate [bpm]			171
VF rate [bpm]			231
Therapy		1. ATP	2. ATP
AT/AF		...	...
VT1		...	...
VT2		3*Burst	3*Ramp
VF		Burst	
	1st shock	2nd shock	3rd-nth shock
VT1 [J]	OFF		
VT2 [J]	40	40	6*40 J
VF [J]	40	40	6*40 J

Fig 9. "Parameters – overview" portion of an interrogation report of an Ilivia 7 HF-T biventricular implantable cardioverter defibrillator with the rate criteria for ventricular tachycardia zone 1 (VT1), ventricular tachycardia zone 2 (VT2), and ventricular fibrillation (VF) highlighted by the *red box*. In addition, initial antitachycardia pacing (ATP) and shock therapies for the different zones are delineated by the *red* and *blue arrows*, respectively.

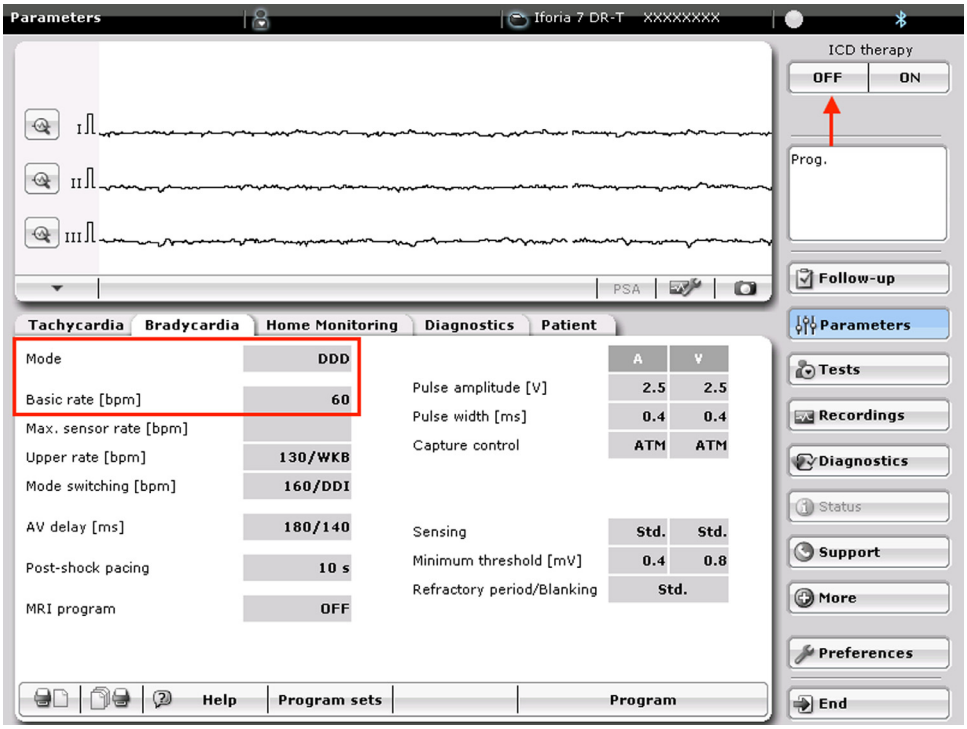

Fig 10. Bradycardia settings of the Renamic programmer "parameters" tab from an implantable cardioverter defibrillator (Iforia 7 DR-T) demonstration patient with the tachyarrhythmia "off" button delineated by a *red arrow*. In addition, the programmed mode and basic rate are highlighted by a *red box*.

emergency in nature or electromagnetic interference exposure occurred above the umbilicus or logistical challenges impedes the patient from being evaluated within 1 month. Finally, specific procedures including cardiothoracic surgery, external cardioversion, radiofrequency ablation, and therapeutic radiation were determined to be indications for interrogation before discharge or transfer from a monitored setting.[7]

A practice advisory released by the ASA in 2011 suggested that CIED postoperative management should include an interrogation in the postanesthesia care unit or intensive care unit. However, it was acknowledged that in low-risk situations (eg, no possibility of intraoperative electromagnetic interference, no blood products administered, no perioperative programming occurred, no perioperative complications, and appropriate preoperative CIED evaluation occurred), a postoperative CIED evaluation may not be required.[23]

Summary

In summary, Biotronik pacemakers possess a programmable response to magnet application when the default response is not sustained asynchronous pacing. If asynchronous pacing is indicated during the perioperative period, then the magnet response should be confirmed in the preoperative period or the device should be programmed to an asynchronous mode during the surgical period (Table 3). In the preoperative period, the magnet response can be confirmed by a recent interrogation report or a sustained asynchronous rhythm in response to magnet application.

Biotronik CIEDs also possess a unique method of rate adaptation, termed closed loop stimulation, or CLS. When enabled, CLS modulates the paced rate based on the contractile state of the myocardium. Despite its unique monitored parameter, the interactions and precautions applied to other rate adaptation technology (eg, thoracic impedance) should be extended to CLS-enabled devices and strong consideration should be given to a non-rate adaptive mode in the perioperative period.

Even though a magnet can be used to suspend tachyarrhythmia therapies temporarily in the perioperative period, Biotronik ICDs do not emit a confirmatory audible tone. In addition, if asynchronous pacing is desired in a patient with a Biotronik ICD in the perioperative period, then programming to an asynchronous mode is required because magnet application to an ICD does not affect the bradycardia pacemaker settings (see Table 3).

Conclusion

In conclusion, the authors are not advocating for untrained and uncredentialed anesthesiologists to assume total responsibility for CIEDs. However, anesthesiologists should be cognizant of the limited scope and responsibility of IEAPs as defined by the HRS. Based on these societal statements, one can conclude that the medicolegal responsibility for perioperative CIED management rests with the anesthesiologist when IEAP support is requested independent of a consulting physician or licensed practitioner. Therefore, anesthesiologists should either possess a thorough understanding of CIEDs in order to make educated, sound management decisions when independently supported by an IEAP or consult a CIED team member as defined by the HRS/ASA Expert Consensus Statement.[7]

Table 3
Specific Perioperative Considerations for Biotronik CIEDs

Preoperative	
Pacemakers	Determine pacemaker dependency • Indication for implantation, underlying rhythm, percentage paced Determine perioperative EMI risk Confirm the magnet response (eg, Auto, Async, Sync) • Auto and Sync: magnet application does not result in asynchronous pacing Consider a non-rate adaptive mode for the perioperative period • Biotronik CIEDs possess CLS and accelerometer based rate adaptation
ICDs	Determine pacemaker dependency (see the aforementioned description for pacemakers) Determine perioperative EMI risk
Intraoperative	
Pacemakers	Magnet application to devices programmed to the Auto and Sync magnet response modes does not result in sustained asynchronous pacing
ICDs	No tone is emitted in response to magnet application Magnet application will not result in asynchronous pacing
Postoperative	
Perioperative programming mandates postoperative interrogation	
2011 ASA practice advisory favors interrogation in the postoperative period, however, acknowledges that in "low-risk" situations it may not be needed	

Abbreviations: ASA, American Society of Anesthesiologists; Async, asynchronous; CIED, cardiovascular implantable electronic device; CLS, closed loop stimulation; EMI, electromagnetic interference; ICD, implantable cardioverter defibrillator; Sync, synchronous.

Conflicts of Interest: Dr. Michael Essandoh, MD, FASE has received consulting fees from Boston Scientific, INC in the past.

References

1 Cronin B, Essandoh MK. Perioperative interrogation of St. Jude cardiovascular implantable electronic devices: A guide for anesthesiologists. J Cardiothorac Vasc Anesth 2018;32:982–1000.
2 Cronin B, Birgersdotter-Green U, Essandoh MK. Perioperative interrogation of Boston Scientific cardiovascular implantable electronic devices: A guide for anesthesiologists. J Cardiothorac Vasc Anesth 2019;33:1076–89.
3 Hayes JJ, Juknavorian R, Maloney JD, et al. The role(s) of the industry employed allied professional. Pacing Clin Electrophysiol 2001;24:398–9.
4 Lindsay BD, Estes NA 3rd, Maloney JD, et al. Heart Rhythm Society policy statement update: Recommendations on the role of industry employed allied professionals (IEAPs). Heart Rhythm 2008;5:e8–10.
5 Rooke GA, Lombaard SA, Van Norman GA, et al. Initial experience of an anesthesiology-based service for perioperative management of pacemakers and implantable cardioverter defibrillators. Anesthesiology 2015;123:1024–32.
6 Ellis MKM, Treggiari MM, Robertson JM, et al. Process improvement initiative for the perioperative management of patients with a cardiovascular implantable electronic device. Anesth Analg 2017;125:58–65.
7 Crossley GH, Poole JE, Rozner MA, et al. The Heart Rhythm Society (HRS)/American Society of Anesthesiologists (ASA) Expert Consensus Statement on the perioperative management of patients with implantable defibrillators, pacemakers and arrhythmia monitors: Facilities and patient management this document was developed as a joint project with the American Society of Anesthesiologists (ASA), and in collaboration with the American Heart Association (AHA), and the Society of Thoracic Surgeons (STS). Heart Rhythm 2011;8:1114–54.
8 Rozner MA. Cardiac implantable electrical devices. In: Kaplan JA, ed. Kaplan's cardiac anesthesia: For cardiac and noncardiac surgery, Philadelphia: Elsevier; 2016:118–39.
9 Jacob S, Panaich SS, Maheshwari R, et al. Clinical applications of magnets on cardiac rhythm management devices. Europace 2011;13:1222–30.
10 Biotronik. Features suspended and active during interrogation and magnet placement. Lake Oswego, OR: Biotronik; 2017.
11 Rozanski JJ, Blankstein RL, Lister JW. Pacer arrhythmias: Myopotential triggering of pacemaker mediated tachycardia. Pacing Clin Electrophysiol 1983;6:795–7.
12 Jacob S, Shahzad MA, Maheshwari R, et al. Cardiac rhythm device identification algorithm using x-rays: CaRDIA-X. Heart Rhythm 2011;8:915–22.
13 Cronin B, Essandoh MK. Update on cardiovascular implantable electronic devices for anesthesiologists. J Cardiothorac Vasc Anesth 2018;32:1871–84.
14 Moses HW. A practical guide to cardiac pacing, ed 6. Boston: Little, Brown; 2007.
15 Biotronik. Renamic user's guide. Lake Oswego, OR: Biotronik; 2013.
16 Biotronik. Eluna SR-T/DR-T ProMRI pacemakers technical manual. Lake Oswego, OR: Biotronik; 2014.
17 Schaldach M, Hutten H. Intracardiac impedance to determine sympathetic activity in rate responsive pacing. Pacing Clin Electrophysiol 1992;15:1778–86.
18 Al-Ahmad A, Ellenbogen KA, Natale A, et al. Pacemakers and implantable cardioverter defibrillators: An expert's manual. Minneapolis, MN: Cardiotext Publishing; 2010.
19 Proietti R, Manzoni G, Di Biase L, et al. Closed loop stimulation is effective in improving heart rate and blood pressure response to mental stress: Report of a single-chamber pacemaker study in patients with chronotropic incompetent atrial fibrillation. Pacing Clin Electrophysiol 2012;35:990–8.
20 Stone ME, Apinis A. Current perioperative management of the patient with a cardiac rhythm management device. Semin Cardiothorac Vasc Anesth 2009;13:31–43.
21 Mahlow WJ, Craft RM, Misulia NL, et al. A perioperative management algorithm for cardiac rhythm management devices: The PACED-OP protocol. Pacing Clin Electrophysiol 2013;36:238–48.
22 Stone ME, Salter B, Fischer A. Perioperative management of patients with cardiac implantable electronic devices. Br J Anaesth 2011;107(Suppl 1):i16–26.
23 American Society of Anesthesiologists. Practice advisory for the perioperative management of patients with cardiac implantable electronic devices: Pacemakers and implantable cardioverter-defibrillators: An updated report by the American Society of Anesthesiologists Task Force on Perioperative Management of Patients with Cardiac Implantable Electronic Devices. Anesthesiology 2011;114:247–61.