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The Cardiothoracic Anaesthetic Society of South Africa practice advisory for the perioperative management of pacemakers and implantable cardioverter defibrillators in South Africa

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Pacemakers (PM) and implantable cardioverter defibrillators (ICDs) are likely to be encountered by anaesthetists in South Africa in everyday practice because of increasing rates of implantation of these cardiac implantable electronic devices (CIEDs) for an expanding group of conditions that qualify for their use. These devices are becoming increasingly sophisticated and anaesthetic perioperative management is changing with these developments. Traditionally, PM functions have been changed preoperatively to asynchronous modes because of the fear that electromagnetic interference (EMI) from the electrosurgical unit (ESU or diathermy) may cause oversensing and loss of pacing in patients who are PM-dependent. ICDs have had their anti-tachyarrythmia modes deactivated preoperatively to prevent inadvertent shocks delivered as a result of the misinterpretation of EMI as ventricular tachycardia (v-tach) or ventricular fibrillation (v-fib). Programming these devices in this manner may result in patient harm due to R-on-T phenomenon in PM set in asynchronous mode and in ICDs, undiagnosed v-tach and v-fib going untreated in patients who have anti-tachyarrythmia therapies switched off. Depending on the site of surgery, PM-on and ICD-on strategies may be acceptable. Magnet use intraoperatively can be used safely to change PM and ICD settings with the advantage that reversal to normal settings can be achieved by removal of the magnet once EMI is no longer in use. Intraoperative magnet use mandates that the device is interrogated preoperatively and that the results of magnet application are known to the anaesthetist in advance. Where management protocols stated may be controversial, the American Society of Anesthesiologists (ASA) survey of an expert consultant panel as well as member anaesthetists is published, as well as the Cardiothoracic Anaesthetic Society of South Africa (CASSA) committee responses to these controversies.[1]

Keywords: anaesthesia management, pacemaker, defibrillator

Background

Approximately 7 500 pacemakers (PMs) and implantable cardioverter defibrillators (ICDs) are implanted into South African patients every year.[2] This number is likely to increase in the future because of the recent addition of atrial fibrillation and pathway ablation to the indications for PMs. With longevity rates increasing, it is becoming more likely that anaesthetists in South Africa will encounter patients with cardiac implantable electronic devices (CIEDs) in their daily practice. Medical technologists who specialise in these devices provide a vital service perioperatively, specifically interrogating the device preoperatively and making changes to the device settings as necessary, and, as important, postoperative re-interrogation and resetting devices that have been altered preoperatively. Anaesthetists should work closely with these medical technologists to ensure optimal patient management of CIEDs perioperatively, mindful that the anaesthetist is responsible for prescribing changes to the device settings as well as directing the technologist to restore the settings postoperatively.[3]

Perioperative considerations

PMs: The anaesthetist has to decide on whether to leave a PM with its usual settings (PM-on policy) or ask the technologist to change the settings to DOO or VOO mode (see Appendix for PM codes). The problem with a PM left in DDD mode is that the sensitive device may register electromagnetic interference (EMI) as a normal heart beat and inhibit the following paced beat. This oversensing may result in periods of asystole in PM-dependent patients when exposed to prolonged bursts of EMI. Oversensing due to EMI is unlikely if the operation site is more than 15 cm from the PM generator or PM leads and if the diathermy dispersal pad is placed distal to the operation site (for example, in hip replacement surgery, the pad should be placed on the ipsilateral thigh to draw current away from the PM and leads). Operation sites below the iliac crest have been shown to have zero EMI

during diathermy.[4] Modern PMs may have algorithms that sense EMI and either ignore it completely or temporarily change the PM setting to VOO as a safety precaution. If a PM-on policy is to be followed, it is important that the anaesthetist has access to a magnet in theatre and knows the effects of magnet application for that particular PM. Incorrect placement of the diathermy dispersal pad has been reported to cause periods of asystole in PM-dependent patients under the influence of EMI, even if the operation site is below the iliac crest. If this is picked up during surgery, the anaesthetist has the choice of placing a magnet on the PM to temporarily change the mode to DOO.

If the operation site is less than 15 cm from the PM or leads, and especially if the patient is PM-dependant, it may be necessary to change the PM settings to an asynchronous mode preoperatively. Ideally, this should be carried out immediately before surgery and reversed as soon as EMI is no longer required. The patient should be closely monitored for R-on-T phenomenon while the PM is in asynchronous mode. R-on-T is a phenomenon that occurs when the PM delivers a pacing spike that coincides with the refractory period of the heart and may cause torsade de pointes which may progress to ventricular fibrillation. A PM-on strategy may be followed if the operation site is less than 15 cm from the PM leads or generator, if bipolar diathermy, plasma blade diathermy or a harmonic scalpel are to be used by the surgeon. In addition, if short bursts of unipolar diathermy are to be used, the EMI generated is unlikely to have an effect on the PM or ICD function. Bipolar diathermy functions with current travelling a very short (1–2 mm) distance between the electrodes. Generalised EMI is not produced. The plasma blade (PB) is a diathermy designed specifically to be used in PM lead or generator replacement. The cauterising effect of the PB has a very superficial burn and does not damage leads or the generator. The harmonic scalpel does not generate EMI and functions by high-frequency sound waves which generate rapid oscillatory movement of a scalpel blade.

A PM-on policy avoids R-on-T because the PM senses the natural beat that may occur and inhibits the following PM discharge. Another advantage of a PM-on policy is that normal AV conduction and synchronous right and left ventricular contraction are allowed to occur. An example if this is a PM inserted for sick sinus syndrome (SSS). If the SA node is dysfunctional, the patient may experience syncope due to bradycardia. A PM is inserted and set on AAI to restore SA node function if it is needed. The current passes via a normal AV node and ventricular conducting system and ensures synchronous right and left ventricular contraction. The PM may revert to DDD if it senses abnormal conduction of current in the AV node or His bundle, to ensure normal AV conduction. The PM will then pace the atrium and then the right ventricle. Because the current then has to pass from the RV to the LV and this results in some degree of right and left ventricular dyssynchrony. This may result in a decrease in left ventricular function that may reduce cardiac output by up to 15%. If a PM for SSS is reprogrammed to an asynchronous DOO mode perioperatively, a reduction in myocardial function may be expected.

CRT-P devices: Cardiac resynchronisation therapy (CRT) devices are CIEDs that are implanted for patients with heart failure due to poor left ventricular function and have a left bundle branch block. The device has an atrial lead and a right ventricular lead, as well as a lead that is placed in the coronary sinus, as far laterally as possible to pace the left ventricle. The CRT device reads the atrial beat and then paces the right and left ventricles at the same time, thus restoring the synchronous right and left ventricular contraction. The intended effect of CRT is to improve left ventricular ejection by approximately 15%. CRT-P includes a PM function if needed and CRT-D an ICD function.

ICDs and anti-tachycardia pacing (ATP)

Patients with recurrent ventricular tachycardia and/or ventricular fibrillation or those at risk for developing these arrhythmias may have an ICD placed in the left subclavian region. The ICD senses the R-R interval and if the interval reduces to a predetermined level, the device algorithm reads this as ventricular tachycardia and can deliver a repetitive sequence of eight rapid paced beats to try to break the re-entry condition of v-tach. If this fails to cardiovert the v-tach, the capacitor in the ICD generator is charged and a high voltage shock is delivered. See Figure 1. An ICD consists of a generator and PM leads around which coils are incorporated in the portion of the leads in the right atrium and right ventricle. The shock is delivered from the coils towards the generator in a triangulated vector to include the left ventricle. (The high voltage coils around the PM leads act as the cathode and the pulse generator acts as the anode.) Most modern ICDs will utilise a biphasic shock which reduces the total energy required for successful cardioversion. ICDs recognise supraventricular tachycardias (SVTs and AF) via atrial sensing, but cannot cardiovert them. This is designed to prevent unnecessary shocks. An ICD may act as a PM, delivering anti-bradycardia therapy if required to do so. A magnet applied to an ICD will generally disable the anti-tachycardia therapy while it is in situ, but will have no effect on anti-bradycardia therapy or rate responsiveness. It is important to note that the ICD needs time to read the R-R interval, deliver the ATP, repeat the assessment, deliver the ATP, altogether three times, each of which takes 10–15 seconds, before the ICD charges and then delivers a shock. Altogether, about 40 seconds to try ATP and then charge and deliver, 15 seconds, in total the ICD takes just under a minute of continuous v-tach to deliver a shock. If short bursts of monopolar diathermy are used, the chances of shock delivery are minimal. For example, electrocautery used for polyps in colonoscopies is generally of 1–2 second duration and will not cause inadvertent shocks in a patient where ICD-on protocol is followed[4] (Figure 1).

ICDs are potentially problematic during surgery because prolonged use of EMI may be interpreted by the device as v-tach or v-fib and antitachycardia treatment may be instituted, resulting in unnecessary repeated shocks from the ICD. It has been shown that ICDs do not respond to EMI if the surgery is below the iliac

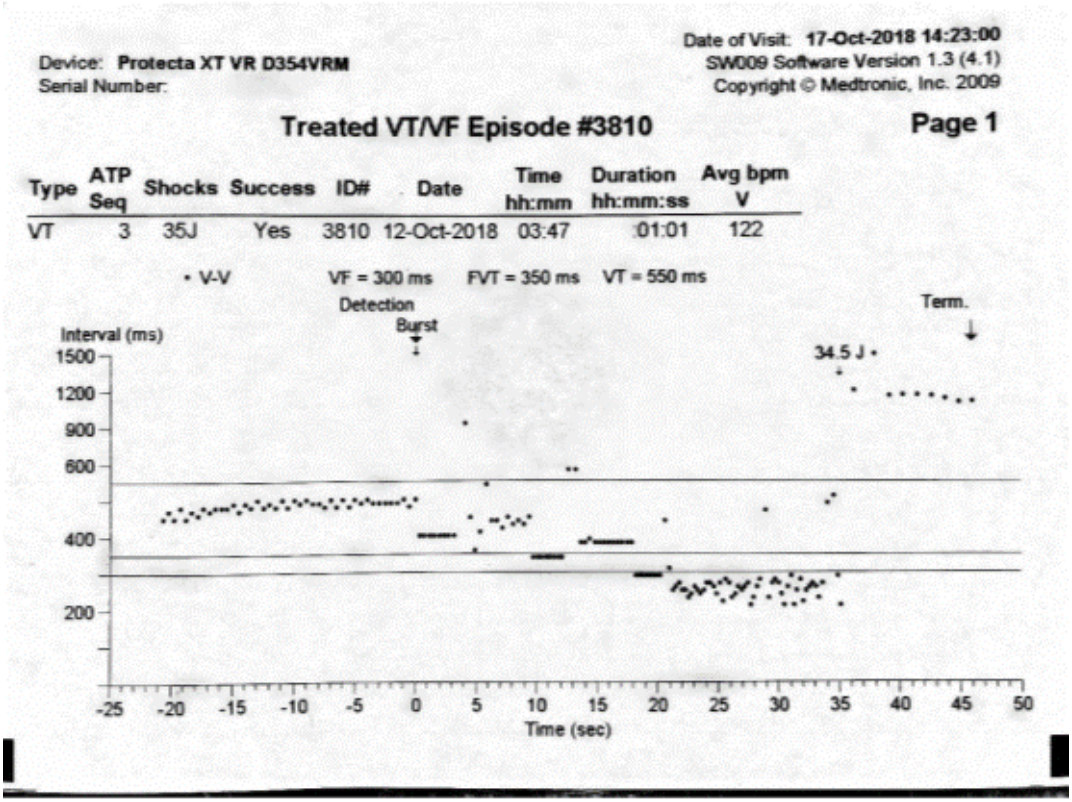

Figure 1: De-identified printout from a patient's ICD showing an episode of v-tach with attempted anti-tachy pacing (ATP) followed by successful 34.5 J defibrillation. Image supplied by Medtronic SA.

crest and the diathermy dispersal pad is placed at a site to lead current away from the device or leads.[4] If the anti-tachycardia modalities are disabled during surgery, it is imperative to manage the patient in a high dependency unit perioperatively in order to treat v-tach and v-fib timeously. In addition, care must be taken to diagnose and treat these arrhythmias intraoperatively. Case reports have been published of patients dying at home from arrhythmias when the ICD has been inadvertently left in a disabled mode on discharge of the patient.

Preoperative pacemaker and ICD interrogation

Preoperative PM interrogation is considered to be the standard of care and should be scheduled during the week prior to surgery. The PM technologist should provide the information as shown in Figure 2 and in consultation with the technologist and cardiologist and taking into account the planned surgery, the anaesthetist should decide on the perioperative PM management. See Figure 4.

If a PM-on strategy is to be followed, it is vitally important that the effects of magnet application and removal to the specific PM are known. It may be advantageous to reset the base rate of the PM, even though a PM-on protocol is followed. For example, a base rate of 60 may be increased to 70 or 80 if haemodynamic challenges are expected, such as blood loss or neuraxial anaesthesia.

If the PM settings are to be changed, this should be done on the day of surgery and preferably reversed to the preoperative settings as soon as possible after the electrosurgical unit (ESU) is no longer required.

If an ICD-on strategy is to be followed, it is important to note that placing a magnet over the ICD will not change the underlying PM function and this has to be changed independently of the anti-tachyarrhythmia function. It must be stressed that during thoracic surgery where the left lung may be collapsed, as in both a double-lumen tube use and collapse during left internal mammary harvesting in cardiac surgery, both external transcutaneous and ICD shock delivery may be ineffective due to high impedance to the shock wave because of the collapsed lung. If ATP therapy is ineffective in this scenario, direct application of DC shock via internal paddles may be necessary.

CRT devices need to be checked within three months of insertion, because the coronary sinus leads have poorer contact compared to the right ventricular leads and higher thresholds are accepted. This may result in faster battery drain and thus reduce longevity.

Survey

1. Preoperative interrogation of cardiac implantable electronic devices (CIEDs) is considered to be the standard of care and ideally should be scheduled during the week prior to surgery.

   The CASSA committee strongly agrees with the above statement.

2. If a technologist is not available and the device card is available, it is reasonable to proceed if the device has been checked:

a. PM within a year

b. ICD within six months

c. CRT device within three months

The CASSA committee strongly agrees with the above statement.

3. If the device settings are to be changed perioperatively, ideally, this should be done on the morning of surgery and reversed as soon as possible after ESU is no longer required. The patient should be monitored in a high dependency unit if device settings are to be changed preoperatively.

The CASSA committee strongly agrees with the above statement.

ASA: The consultants and ASA members strongly agree with the recommendation to ensure that the patient is in a monitored environment before suspending the antitachycardia function of an implantable cardioverter-defibrillator.

Preoperative pacemaker interrogation is considered standard of care: Individual prescription ℞

Is tech available:
1. Type PM/ICD/CRT-P or D
2. Manufacturer and model
3. Indication and date of insertion
4. Pacemaker dependency
5. Battery life (BOL/EOL/RRT) – replace prior to surgery
6. Pacemaker settings and thresholds checked in new leads
7. Reject activity
8. Effects of magnet application (and removal)
9. Reset rate if scope of operation requires
10. Device or lead alert/recll status

Is tech unavailable in an emergency:
1. CXR
2. ECG for dependency
3. Patient card
4. Cardiologist
5. Manufacturer 24 hour helpline
6. Last interrogation PM < 12 months, ICD < 6 months, CRT-D or P < 3 months
7. Magnet application preoperatively to assess PM rate changes or ICD tones
8. Blind magnet application not recommended unless emergency

Figure 2: Preoperative PM interrogation

Response to magnet application

The response to magnet application in Medtronic PM and ICDs is shown in Figure 3. It is important to note that there is no uniformity across the industry, and each manufacturer has a different set of responses to magnet application. Some manufacturers (St Jude, Boston Scientific) allow the PM or ICD to be set in a "ignore magnet application" mode and clearly, this has to be reset if a magnet is going to be applied during anaesthesia and surgery. This makes it imperative that the anaesthetist is aware of the specific response of the patient's device before applying a magnet. An indication of the enormity of this problem is that in the USA, there are 1 440 different types of device models across the different manufacturers.[5] Modern PM and ICDs respond in a predetermined manner to magnet application, and therefore, each device interrogation must include response to a magnet. Many of the problems associated with magnet application in the past have been dealt with. Examples include resetting device programming under the influence of a magnet and concurrent EMI, and switching off anti-tachy functions in ICDs, which do not return once the magnet is removed. These problems do not occur in modern devices.

During surgery, magnet application needs to be carefully monitored. This is easily done in the patient with a PM, because magnet application will result in a fixed rate change, which is specific to the manufacturer. For example, Medtronic PMs change from the patient's usual settings to a rate of 85 beats per minute while the magnet is applied. This rate is 65 if the battery life is shortened (EOL) and the generator needs to be replaced (RRT). Therefore, as long as the heart rate is 85 bpm, the anaesthetist can be reassured that the magnet is correctly applied and that there is sufficient PM battery life.

Continued magnet application is less clear in the case of ICDs. The Medtronic ICDs emit a tone for 10 seconds when the magnet is applied, but after this initial signal, there is no indicator to the anaesthetist whether or not the magnet is still in place and exerting its effect on the ICD. The magnet has no effect on the PM function of the ICD, so heart rate changes cannot be used as an indicator. Some of the manufacturers, such as Biotronic, include a rate change function in ICDs when a magnet is applied. It would make sense for the manufacturers to provide the anaesthetist with an ongoing signal to determine correct placement of a magnet over an ICD. Simply changing the PM rate to 85 would solve this problem. Modern devices have Bluetooth functionality and an elegant way of dealing with this problem would be to have a smartphone application that can read the wireless signals from the device. Magnet use intraoperatively is not recommended by the ASA, but Canadian and European guidelines include the intraoperative use of magnets.[6,7]

	CIED	Response to magnet application
PM	Pacemaker	85 beats per minute (65 bpm if RRT) DOO, VOO or AOO and disables rate responsiveness
ICD	Implantable cardioverter-defibrillator	Suspends anti-tachyarrhythmia therapy and anti-tachycardia pacing (ATP) and has no effect on PM functions. 10s even tone Med
CRT	Cardiac resynchronisation therapy	85 beats per minute (65 bpm if RRT) DOO
CRT-D	Cardiac resynchronisation therapy with cardioverter-defibrillator	Suspends anti-tachyarrythmia therapy and anti-tachycardia pacing (ATP) and has no effect on PM functions
Leadless PM	VVi implanted directly into RV	Depends on manufacturer: Medtronic – no effect St Jude – VOO

Figure 3: Response to magnet application in Medtronic PM and ICDs

Survey

1. If a PM-on protocol is to be followed, it is reasonable to use a magnet intraoperatively to change the PM setting to DOO, if the situation arises where EMI from the ESU causes oversensing by the PM.

   The CASSA committee strongly agrees with this statement, with the exception of one member who agrees with the statement.

2. If an ICD-on protocol is to be followed, it is reasonable to use a magnet to disable the anti-tachycardia function if the situation arises where EMI from the ESU may cause the anti-tachycardia function to deploy.

   The CASSA committee strongly agrees with this statement, with the exception of one member who disagrees with the statement.

3. If a magnet is to be applied intraoperatively, interrogation of the device preoperatively should include the device response to a magnet.

   The CASSA committee strongly agrees with this statement, with the exception of one member who disagrees with the statement.

   ASA: The consultants are equivocal and ASA members agree with the recommendation to avoid the routine use of a magnet over an implantable cardioverter-defibrillator.

Operating theatre requirements

PM-on or CRT-P-on protocol suggests that the PM settings are not changed during the standard preoperative technologist interrogation of the device. PM-on protocol will avoid inadvertent development of R-on-T phenomenon and implies that magnet application is possible if the situation of oversensing caused by EMI develops. In addition to this, the anaesthetist is able to remove the magnet when EMI is no longer being used. It takes away the need for postoperative high dependency unit care and a repeat call out by the technologist to reset the PM. The successful PM-on protocol requires the anaesthetist to follow the algorithm in Figure 4. A magnet can disable the rate responsiveness function in a PM and this is useful to prevent unwanted increases in heart rate, for example, when the sternal saw is used in open-heart procedures, as the vibration of the saw may be misinterpreted as patient movement.

ICD or CRT-D-on protocol suggests that the anti-tachycardia therapy of the ICD is not switched off perioperatively and that the device is allowed to sense tachyarrhythmias and deliver anti-tachycardia pacing (ATP) and shock if necessary. This provides protection to the patient in the event of v-tach and/or v-fib, which may occur at any time perioperatively. In order to prevent unnecessary ATP or shocks due to EMI being incorrectly read by the generator, a magnet should be available to place over the ICD to change the setting to ATP and shock off. It is important to note that the anaesthetist should know exactly what happens to the specific ICD under the influence of magnet application and removal, that the patient position is such that the magnet can be properly secured during surgery and that the tone emitted by the generator is recognised. There are certain operating sites where it is safe to leave the ICD on and generally these are more that 15 cm (6 inches) from the generator and leads and below the umbilicus or iliac crest, as long as the ESU dispersal pad is sited away from the surgical site so that EMI is not directed towards the ICD.[3]

The anaesthetist should consider switching off the anti-tachy therapy of the ICD if:

1. The operation site is within 15 cm of the generator or leads, especially if long bursts of unipolar diathermy are to be used. The argon beam ESU cannot be used in short bursts and may cause long periods of EMI.
2. A magnet cannot be reliably secured over the generator, such as in the prone position.
3. Certain operations such as hand surgery and ophthalmic operations where inadvertent shocks may lead to patient or operator harm. This would include operations at these sites performed under local anaesthesia.[8]

If the patient is PM-dependent, the anaesthetist should follow the algorithm in Figure 4 and, if necessary, may consider asking the PM tech to change the PM settings to DOO as in the PM-on protocol. It is also advisable to turn off rate responsiveness, as this function is not changed by magnet application in ICDs.

It is important to note that if the anti-tachy function has been turned off (ICD-off), the settings must be restored as soon as possible after the procedure and the patient has to be observed in a high dependency unit until this has been achieved.

Whatever PM or ICD protocol is to be followed, standard operating theatre monitoring should be used and this should include evidence of peripheral pulsation as in pulse oximetry and/or intra-arterial blood pressure trace monitoring. External pads should be applied to deliver pacing or DC cardioversion if required.

Survey

1. It is reasonable to follow a PM-on policy if the operation site is > 15 cm from the device or the leads or below the umbilicus and/or the iliac crest as long as the diathermy dispersal pad is situated distal to the operation site.

   The CASSA committee strongly agrees with this statement.

   ASA: The consultants disagree, and ASA members are equivocal with the recommendation to alter the pacing function of a cardiac implantable electronic device to an asynchronous pacing mode in the pacing-dependent patient if monopolar electrosurgery (bovie) use is planned inferior to the umbilicus.

2. It is reasonable to follow an ICD-on policy if the operation site is > 15 cm from the device or the leads or below the umbilicus and/or the iliac crest as long as the diathermy dispersal pad is situated distal to the operation site.

   The CASSA committee strongly agrees with this statement.

The consultants agree and ASA members are equivocal with the recommendation to suspend an implantable cardioverter-defibrillator's antitachycardia function, when present, if monopolar electrosurgery (bovie) use is planned inferior to the umbilicus.

3. The patient should be in a monitored environment before suspending the anti-tachycardia function of an ICD.

The CASSA committee strongly agree with the above statement.

The consultants and ASA members strongly agree with the recommendation to ensure that the patient is in a monitored environment before suspending the anti-tachycardia function of an implantable cardioverter-defibrillator.

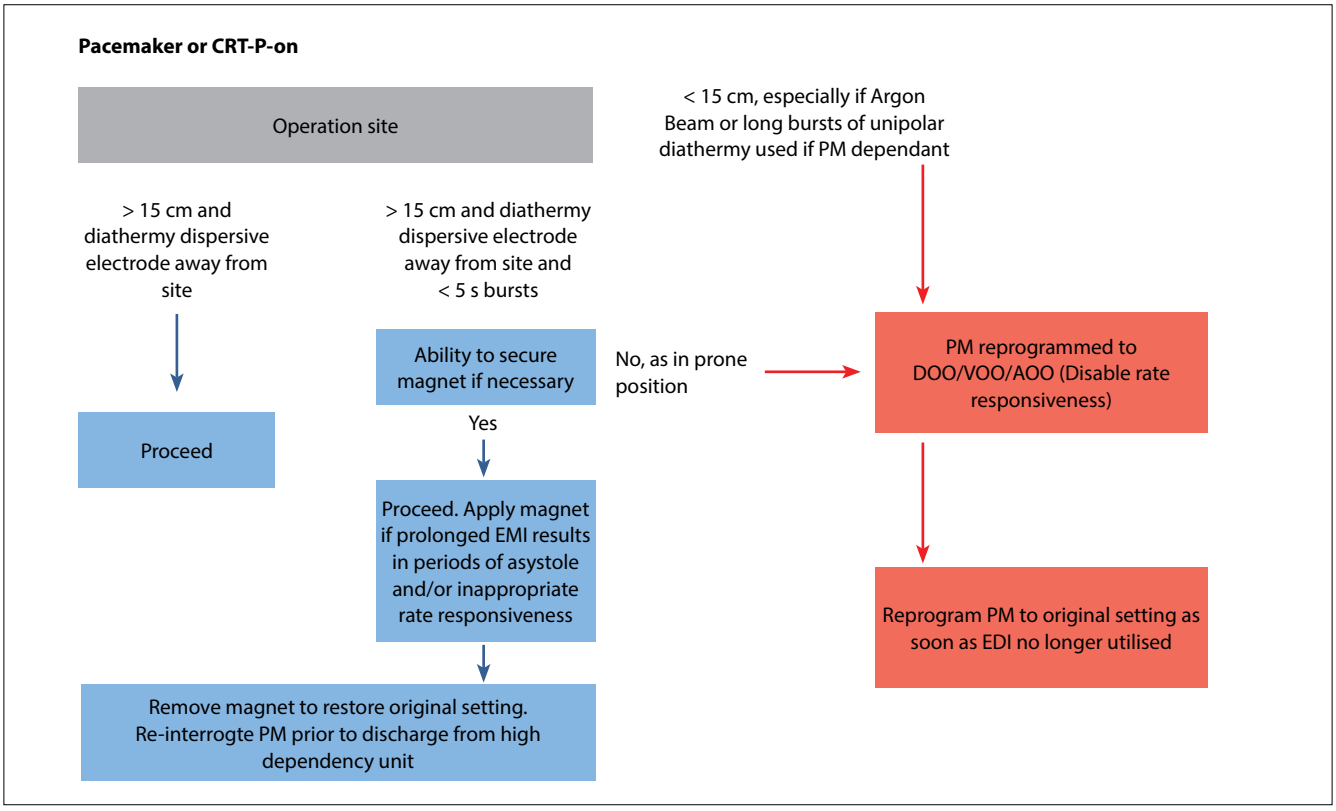

Figure 4: PM-on algorithm. It is safe to proceed with a PM-on protocol if the operation site is > 15 cm away and the diathermy dispersal pad is placed to draw current away from the PM generator and leads. It is unlikely that EMI will cause oversensing if this is the case, but in the event of EMI causing oversensing (for example, if the diathermy dispersal pad is misplaced on the patient's back) a request to the surgeon to limit the length of diathermy use should prevent periods of asystole. Alternatively, a magnet placed over the pacemaker will temporarily change to mode to DOO.

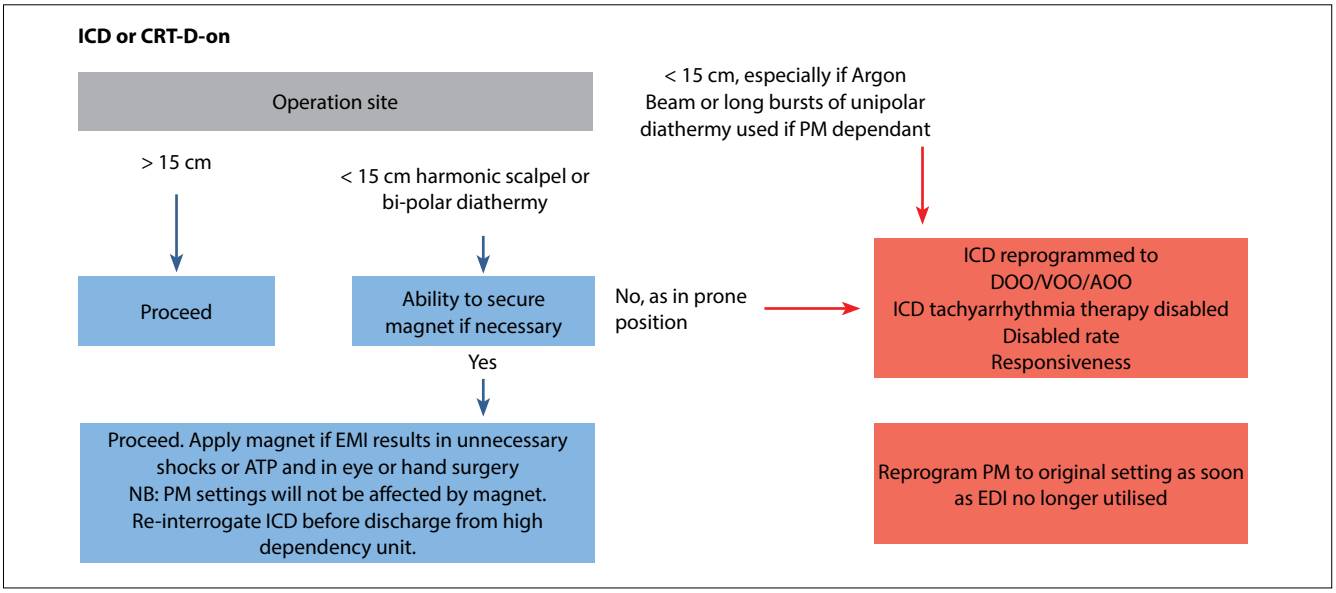

Figure 5: ICD-on algorithm: See figure 5 explanation, as EMI is unlikely to affect the ICD if the operation site is > 15 cm from the ICD generator or leads

Conclusion

It is reasonable to follow a PM-on or ICD-on policy as long as the basic principles of patient safety are adhered to. This includes routine interrogation of the device preoperatively and knowledge of the device response to application and removal of a magnet intraoperatively.

Conflicts of interest

The authors declare no conflicts of interest. The use of Medtronic PM and ICDs as examples is due to the 85% market share of the company in South Africa.

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Glossary of terms, abbreviations and acronyms

Anti-bradycardia therapy – Basic PM function to prevent symptomatic bradycardia

Anti-tachyarrythmia therapy – ICD function which includes ATP and DC shock

ATP – Anti-tachycardia pacing

BOL – Beginning of life

CIED – Cardiac Implantable electronic device

CRMD – Cardiac rhythm management device

CRT – Cardiac resynchronisation therapy

EOL – End of life

EOS – End of service (same as RRT)

ESU – Electrosurgical unit

ICD – Implantable cardioverter defibrillator

IPD – Implantable pulse generator

PM – Pacemaker

RRT – Recommended replacement time

Appendix[9]

Revised NASPE/BPEG Generic (NBG) Pacemaker Code

I	II	III	IV	V
Chamber(s) Paced	Chamber(s) Sensed	Response to Sensing	Rate Modulation	Multisite Pacing
O = None	O = None	O = None	O = None	O = None
A = Atruim	A = Atrium	T = Triggered	R = Rate Modulation	A = Atrium
V = Ventricle	V = Ventricle	I = Inhibited		V = Ventricle
D = Dual (A + V)	D = Dual (A + V)	D = Dual (T + I)		D = Dual (A + V)

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