American Society of Anesthesiologists®

These resources are intended to supplement the current **Practice Advisory for the Perioperative Management of Patients with Cardiac Implantable Electronic Devices: Pacemakers and Implantable Cardioverter–Defibrillators 2020** regarding new developments in the CIED field.

Perioperative Cardiac Implantable Electronic Device (CIED) Management Aid

Purpose: Advise/assist prudent decision making for patients with CIEDs having surgical procedures requiring monopolar electrocautery with <15cm distance between device and electrocautery unit, ground pad, or current path.

Abbreviations:

CIED	Cardiovascular Implantable Electronic Device
EMG	Electromyogram
ERI	Elective Replacement Time
ICD	Implantable Cardioverter Defibrillator
HR	Heart Rate
MRI	Magnetic Resonance Imaging
PM	Pacemaker
VT/VF	Ventricular Tachycardia/Ventricular Fibrillation

Definitions:

Asynchronous pacing: External cardiac pacing at a fixed rate which is neither triggered nor inhibited from other sources including the native cardiac electrical activity and electrocautery.

Synchronous pacing: External cardiac pacing which can be inhibited or triggered by other sources including native cardiac electrical activity and electrocautery.

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Programmable Device Magnet Responses by Manufacturer/Type

1. **Biotronik**
   a. PM
      i. "Auto" mode (nominal setting): Device paces 10 cycles at 90ppm followed by synchronous pacing at the device programmed rate. The device comes out of the box set in "Auto" mode and is usually programmed to asynchronous pacing "Async" at time of implantation. However, one study found 6 of 38 devices interrogated at the time of surgery were in "Auto" mode. (1)
      ii. "Async": The device paces asynchronously with magnet rate 90ppm. At ERI, the device will pace at its programmed lower rate minus 11%.
      iii. "Sync": There is no device magnet response. The device will not pace asynchronously with magnet placement. This is an uncommonly utilized programming. Additional programming can be applied to the device to store an EMG with magnet application in "Sync" mode. This is a rarely utilized programming option.
   b. ICD
      i. Suspend tachytherapies is the only magnet response option. Magnet application suspends tachytherapies for 8 hours.
      ii. The magnet must be removed and replaced after 8 hours to maintain suspension of tachytherapies. Alternatively, the device tachytherapies can be programmed off if needed for surgeries lasting longer than 8 hours.

2. **Medtronic**
   a. PM
      i. Asynchronous pacing is the only magnet response option at a rate of 85ppm and 65ppm at ERI.
      ii. Note: *Adapta, Sensia, Versa,* and *Attesta* require 1 hour between device interrogation and asynchronous magnet response unless the session is ended in a specific manner.
   b. ICD
      i. Magnet placement will suspend tachytherapies.

3. **Abbott/St. Jude**
   a. PM
      i. Asynchronous pacing (nominal setting) at a magnet rate of 100ppm gradually declining to 85ppm at ERI.
      ii. OFF. No magnet response. Magnet placement will not result in asynchronous pacing. This is a rarely utilized programming option.
      iii. Episode trigger. Episode trigger is a magnet response that can be programmed in addition to either asynchronous pacing or OFF. When programmed, an EMG is stored with magnet application. The device will then revert to asynchronous pacing if the magnet left in place or reapplied provided the magnet response is programmed to asynchronous pacing. If the magnet response is programmed to OFF, the device will revert to synchronous pacing if the magnet is left in place or reapplied. Use of Episode Trigger is uncommon in the modern era.

b. ICD
    i. Suspend tachytherapies (nominal setting) with magnet placement.
    ii. OFF. No device response to magnet placement. Magnet application will not suspend tachytherapies. This is a highly uncommon programming.
    iii. Episode Trigger. An EMG is stored upon magnet placement if Episode Trigger for magnet response is enabled. The device will revert to suspension of tachytherapies afterword if the magnet is either left in place or reapplied provided the magnet response was enabled. Utilization of this programming is uncommon in the modern era.

4. Boston Scientific

a. PM
    i. Asynchronous pacing (nominal setting) at magnet rate 100ppm, ERI 85ppm.
    ii. OFF. No device response to magnet placement. Magnet placement will not result in asynchronous pacing. This is an uncommon programming.
    iii. Store EMG. In this mode the device will store an EMG when a magnet is placed on the device for at least 3 seconds. Once the device stores an EMG or after 60 days in this mode, whichever comes first, the magnet response will revert to asynchronous pacing provided the magnet was placed for at least 3 seconds, removed for 3 seconds and placed again. Use of this programming is uncommon in the modern era.
    iv. Note: When device programmed in "MRI Protection Mode" asynchronous pacing is enabled and the device magnet response is disabled.
    v. Note: "Electrocautery Protection Mode" can be enabled with asynchronous pacing at the device's lower rate limit as an alternative to a magnet placement for electrocautery protection. While in "Electrocautery Protection Mode" magnet response is disabled.

b. ICD
    i. Suspend tachytherapies (nominal setting) with magnet placement.
    ii. OFF. No device response to magnet placement. Magnet placement will not suspend tachytherapies. This is a highly uncommon programming.
    iii. Store EMG. In this mode, an EMG is stored when a magnet is placed over the device for at least 3 seconds. After one EMG is stored or 60 days in this programming, whichever comes first, the magnet response will revert to suspend tachytherapies provided the magnet was placed on the device for 3 seconds, removed for 3 seconds, and placed again on the device. Utilization of this programming is uncommon in the modern era.
    iv. Note: In "MRI protection mode" there is no device magnet response.
    v. Note: "Electrocautery Protection Mode" can be enabled. While in Electrocautery Protection Mode tachytherapies are disabled and device response to a magnet is disabled.

5. Microport/LivaNova/Sorin

a. All devices are labeled/branded either MicroPort or Sorin. No devices were ever manufactured using the LivaNova brand. LivaNova was formed out of the merger between Cyberonics and Sorin. In 2018, LivaNova divested the CRM business unit and it was acquired by MicroPort Scientific Corporation.

b. PM
    i. Asynchronous pacing is the only magnet response option with a rate 96ppm gradually declining to 80ppm at ERI.

c. ICD
    i. Magnet placement will suspend tachytherapies.
    ii. In legacy MicroPort/Sorin ICDs (*Paradym, Ovatio, Alto, Defender*), magnet placement will result in suspension of tachytherapies as well as synchronous pacing at a rate of 96ppm (bradycardic response) gradually declining to 80ppm at ERI.

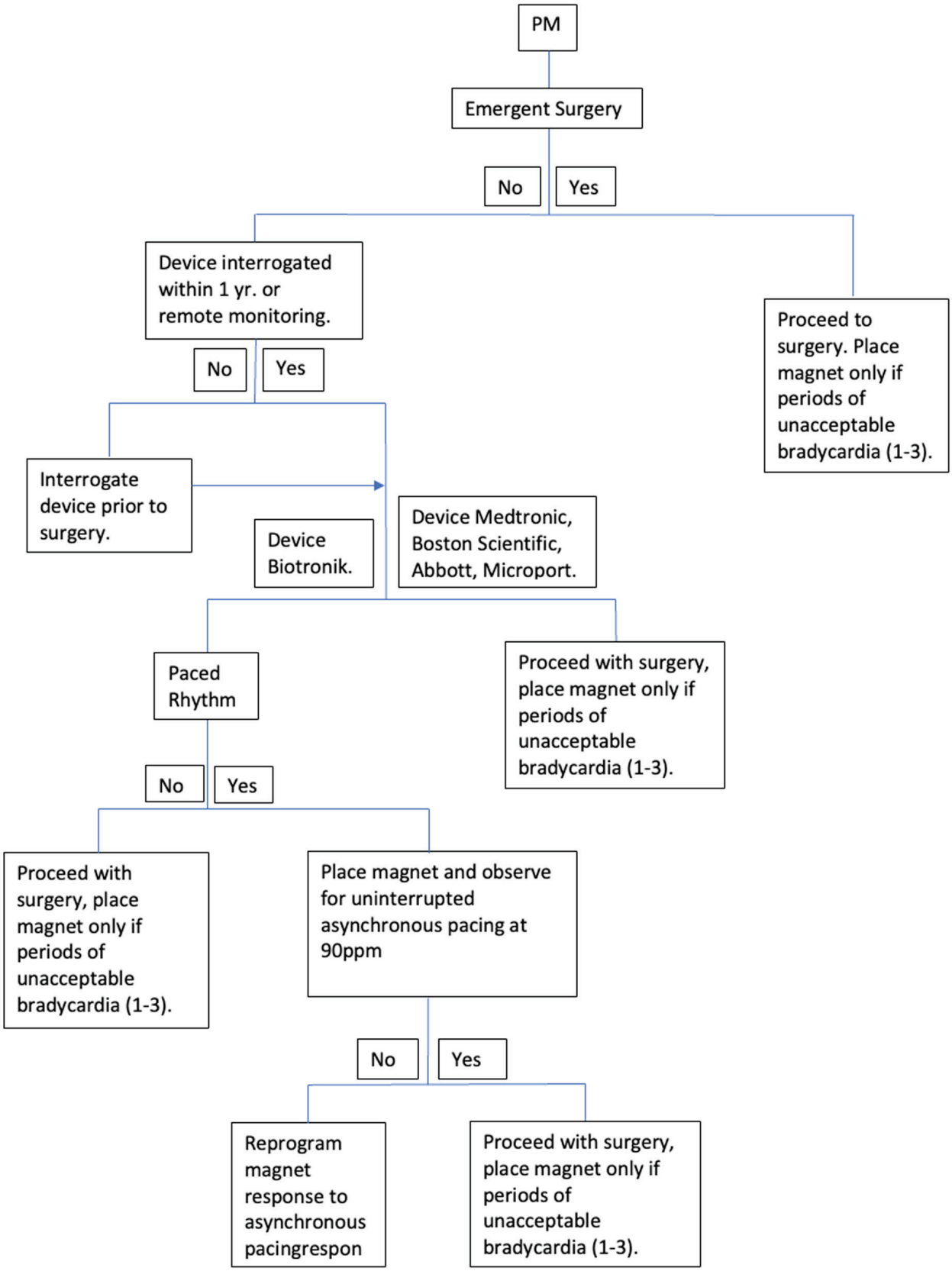
6. **Leadless PM**
   a. Medtronic *Micra*
      i. There is no magnet response. The device will not pace asynchronously with magnet placement. The device must be reprogrammed to achieve asynchronous pacing.
   b. Medtronic *Micra AV*
      i. There is no magnet response. The device will not pace asynchronously with magnet placement. The device must be reprogrammed to achieve asynchronous pacing.
      ii. Note: Device tracks atrial contraction via accelerometry to accomplish concordant AV pacing.
   c. St. Jude *Nanostim*
      i. Asynchronously pacing is the only magnet option with a rate of 90ppm gradually decreasing to 65ppm at ERI.
      ii. Device did not receive FDA approval and trial use was discontinued in 2016.
      iii. Many were explanted but some implanted devices remain in use.
   d. Abbott *Aveir VR*
      i. Leadless PM implanted in the right ventricle.
      ii. Magnet response is programable.
         1. Asynchronous pacing (nominal setting) with magnet application at a rate 100 ppm and progressively decreases to 85ppm at ERI.
         2. OFF. There is no magnet response. The device will not pace asynchronously with magnet placement. This is an uncommon device programming.
         3. Correct magnet placement/capture must be assured by noting a change in pacing from synchronous at the device programmed rate to asynchronous at the device magnet rate on ECG.
   e. Abbott *Aveir DR*
      i. Approved in 2023, incorporates separate atrial and ventricular leadless PM devices.
      ii. Atrial and ventricular devices communicate and pace atria and ventricle.
      iii. Magnet response is the same as *Aveir VR*.

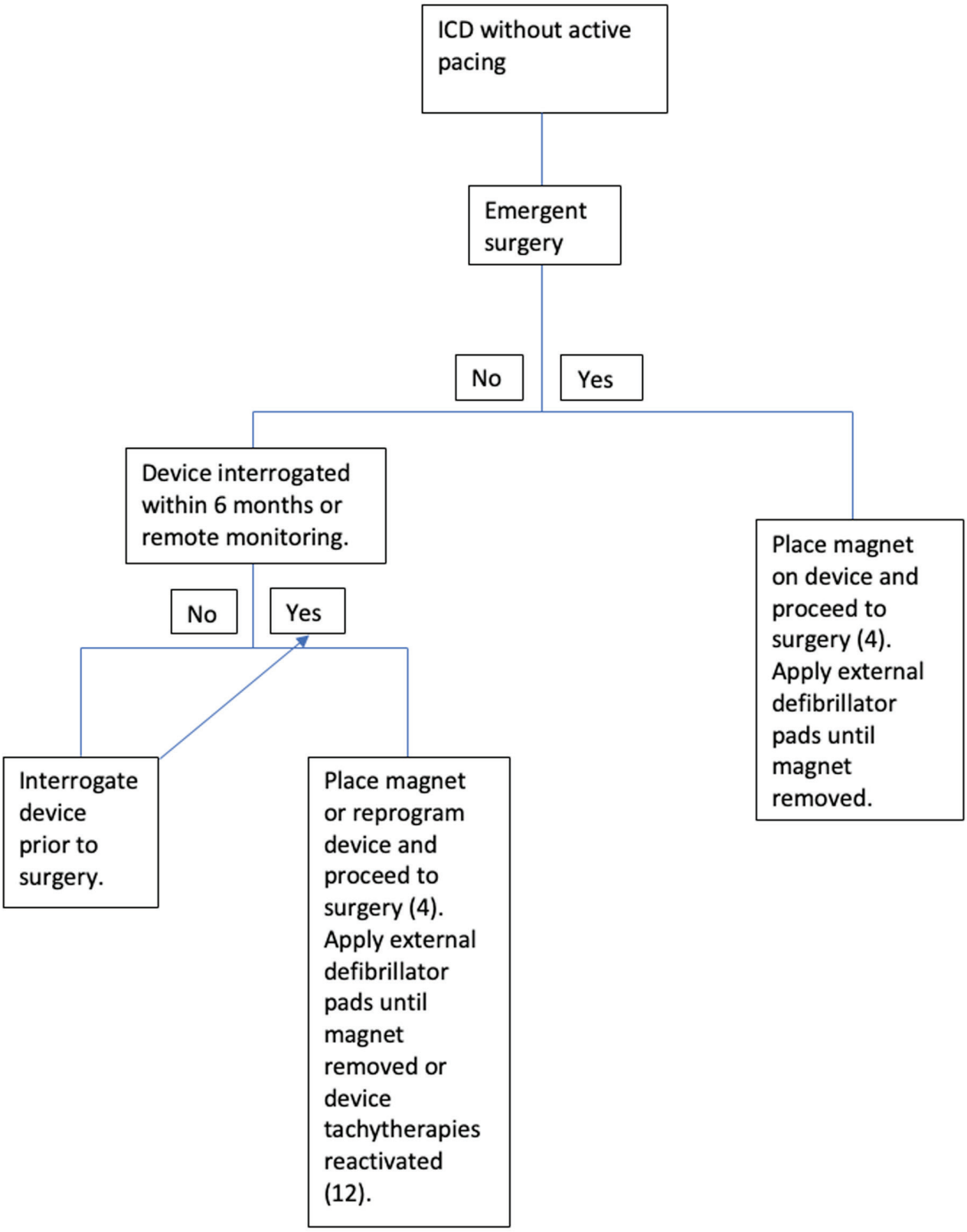
7. **Subcutaneous ICD (SICD)**
   a. Manufactured by Boston Scientific.
   b. Magnet placement will suspend tachytherapies.
   c. When device is In “MRI protection mode”, the device magnet response is disabled.

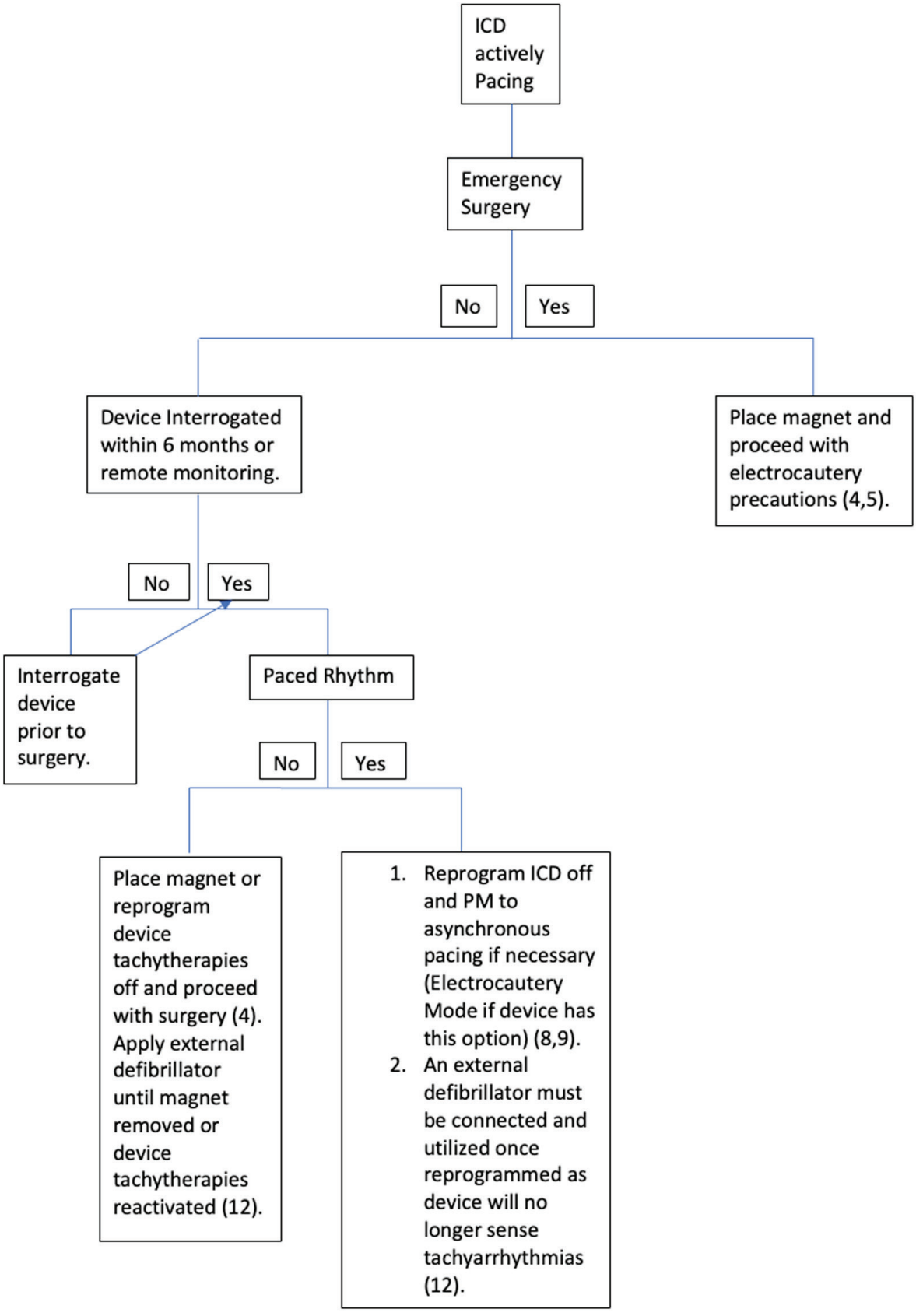
Reference

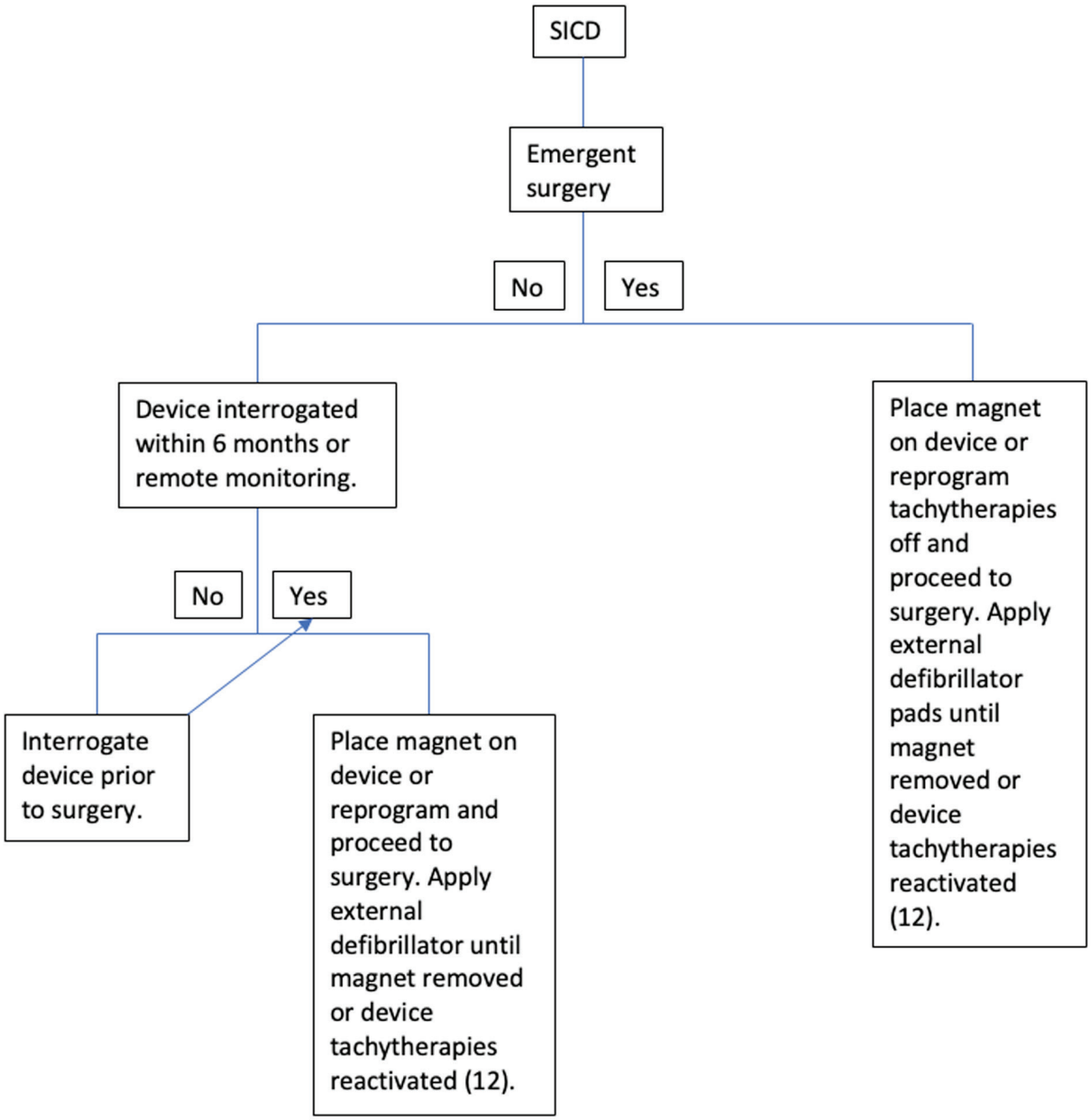
1. Streckenbach S, Dalia A. Perioperative Management of Cardiac Implantable Electronic Devices: A Single-Center Report of 469 Interrogations. *J Cardiothorac Vasc Anesth*. 2021; 35:318.

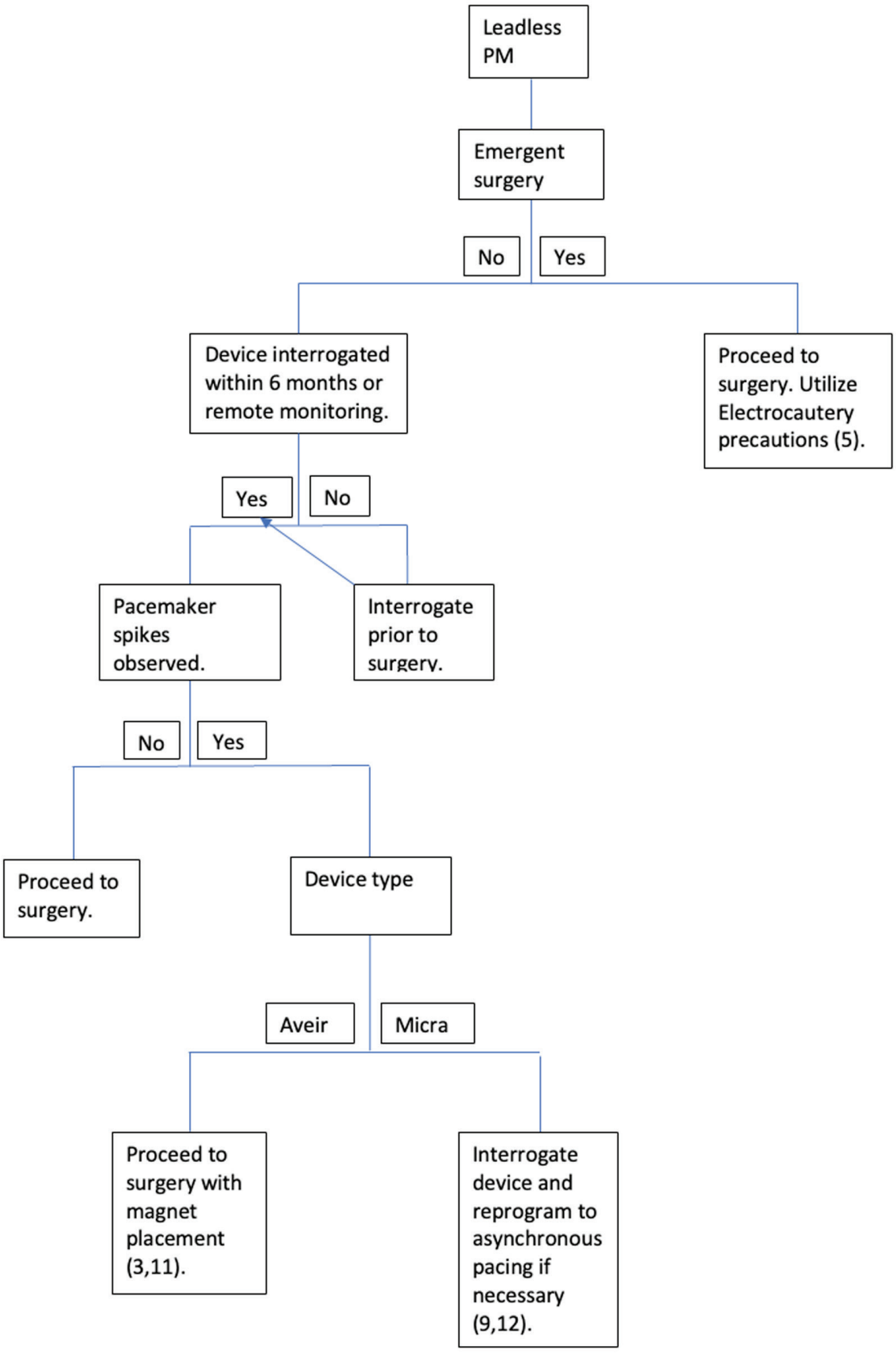
The following diagrams are flowchart CIED management algorithms by device type with footnotes.

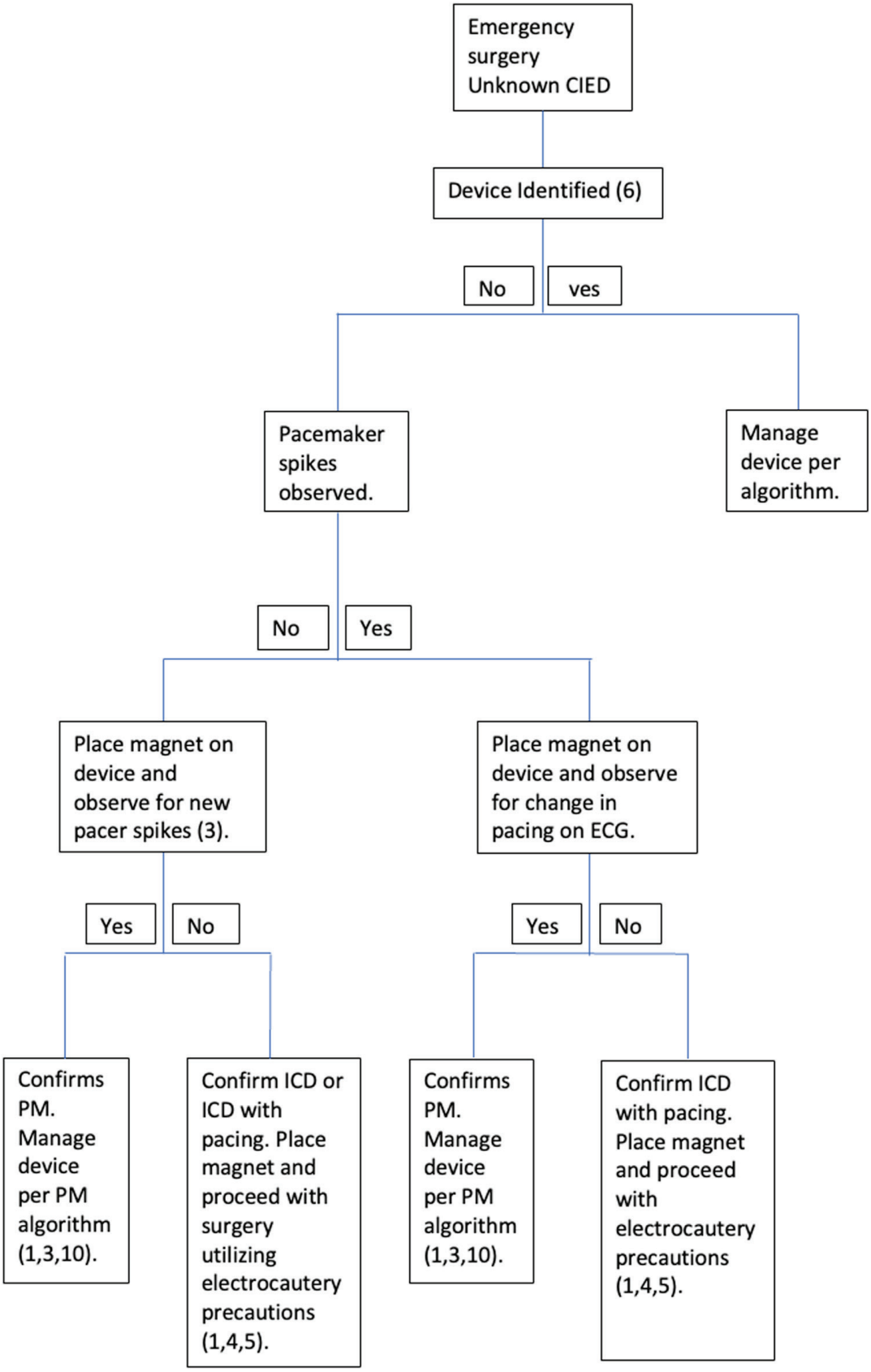


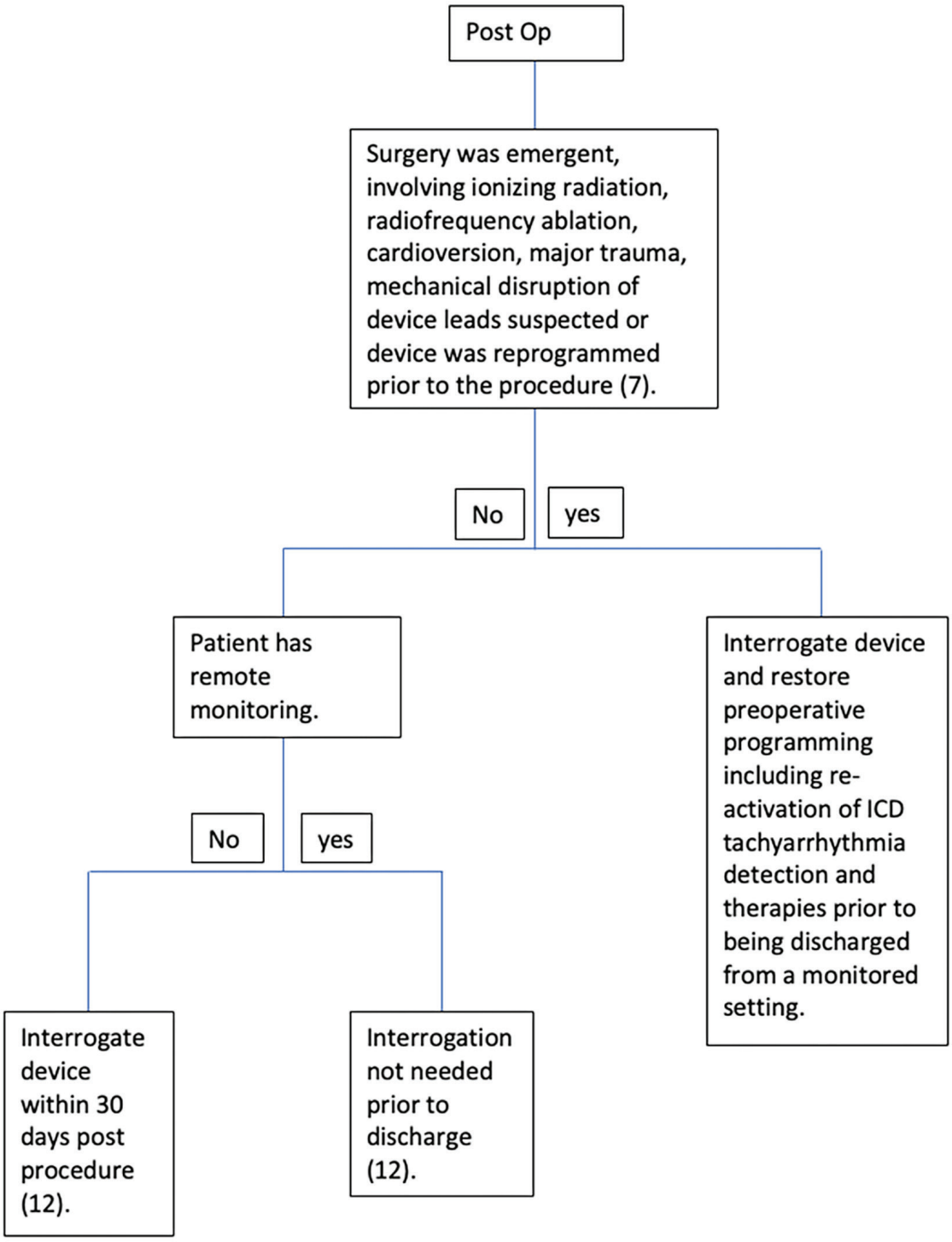

ICD without active pacing
Emergent surgery
No
Yes
Device interrogated within 6 months or remote monitoring.
Place magnet on device and proceed to surgery (4). Apply external defibrillator pads until magnet removed.
No
Yes
Interrogate device prior to surgery.
Place magnet or reprogram device and proceed to surgery (4). Apply external defibrillator pads until magnet removed or device tachytherapies reactivated (12).


ICD actively Pacing
Emergency Surgery
No
Yes
Device Interrogated within 6 months or remote monitoring.
Place magnet and proceed with electrocautery precautions (4,5).
No
Yes
Interrogate device prior to surgery.
Paced Rhythm
No
Yes
Place magnet or reprogram device tachytherapies off and proceed with surgery (4). Apply external defibrillator until magnet removed or device tachytherapies reactivated (12).
1. Reprogram ICD off and PM to asynchronous pacing if necessary (Electrocautery Mode if device has this option) (8,9).
2. An external defibrillator must be connected and utilized once reprogrammed as device will no longer sense tachyarrhythmias (12).


SICD
Emergent surgery
No
Yes
Device interrogated within 6 months or remote monitoring.
No
Yes
Interrogate device prior to surgery.
Place magnet on device or reprogram and proceed to surgery. Apply external defibrillator until magnet removed or device tachytherapies reactivated (12).
Place magnet on device or reprogram tachytherapies off and proceed to surgery. Apply external defibrillator pads until magnet removed or device tachytherapies reactivated (12).


Leadless PM
Emergent surgery
No
Yes
Device interrogated within 6 months or remote monitoring.
Proceed to surgery. Utilize Electrocautery precautions (5).
Yes
No
Pacemaker spikes observed.
Interrogate prior to surgery.
No
Yes
Proceed to surgery.
Device type
Aveir
Micra
Proceed to surgery with magnet placement (3,11).
Interrogate device and reprogram to asynchronous pacing if necessary (9,12).


Emergency surgery Unknown CIED
Device Identified (6)
No
ves
Pacemaker spikes observed.
Manage device per algorithm.
No
Yes
Place magnet on device and observe for new pacer spikes (3).
Place magnet on device and observe for change in pacing on ECG.
Yes
No
Yes
No
Confirms PM. Manage device per PM algorithm (1,3,10).
Confirm ICD or ICD with pacing. Place magnet and proceed with surgery utilizing electrocautery precautions (1,4,5).
Confirms PM. Manage device per PM algorithm (1,3,10).
Confirm ICD with pacing. Place magnet and proceed with electrocautery precautions (1,4,5).


Post Op
Surgery was emergent, involving ionizing radiation, radiofrequency ablation, cardioversion, major trauma, mechanical disruption of device leads suspected or device was reprogrammed prior to the procedure (7).
No
yes
Patient has remote monitoring.
Interrogate device and restore preoperative programming including re-activation of ICD tachyarrhythmia detection and therapies prior to being discharged from a monitored setting.
No
yes
Interrogate device within 30 days post procedure (12).
Interrogation not needed prior to discharge (12).

Flowchart Footnotes

1. PM exceptions
    a. Although rare, some pacemakers produced by Biotronik, St. Jude and Boston Scientific can be programmed to ignore magnet application and will not convert to asynchronous pacing with magnet placement. This is an uncommonly utilized programming option.
    b. Medtronic's *Adapta* and *Sensa* require 1 hour time interval between reprogramming and magnet activation of asynchronous pacing. If asynchronous pacing is desired within 1 hour of reprogramming, reprogramming must include immediate reactivation of magnet response.

2. Magnet activation of asynchronous pacing is recognized differently depending on the underlying rhythm.
    a. **For paced patients**: Magnet application results in an increased HR. Each manufacturer has a prespecified HR with magnet application ranging from 80-100ppm. Magnet application in this scenario will result in a change in HR to the manufacturer prespecified magnet rate. In cases of pathological or secondary atrial tachycardia (atrial fibrillation, fever, exercising, etc.) with atrial tracking and ventricular pacing, magnet application will result in regular pacing at the manufacturer's prespecified rate resulting in disorganized and competing heart ECG tracings. In the case of competing heart rhythms, magnet removal is indicated.
    b. **Patients not paced with intrinsic HR below magnet response rate**: Magnet application will result in asynchronous pacing at an increased HR corresponding to the manufacture's set magnet rate.
    c. **Patients not paced with intrinsic HR above magnet response rat**e: Magnet application will result in regular pacing at the manufacturer's prespecified rate resulting in disorganized and competing heart ECG tracings. Magnet removal is indicated in this situation.

3. Intrinsic heart rates can vary depending on vagotonic, vagolytic, and stress responses during surgery. After magnet placement, the ECG must be monitored to detect an increase in intrinsic HR above the asynchronous device magnet rate. This will cause a competing rhythm. In this situation magnet removal is indicated to allow for native rhythm to predominate.

4. ICD magnet response exceptions:
    a. ICD devices produced by Boston Scientific and Abbott/St. Jude have programming options which include "ignore magnet" or OFF. Use of this programming option is highly uncommon and there have been no reports of device's programmed in this manner or devices programmed in this manner delivering unintended shocks. However, it remains a theoretical possibility that an ICD could be programmed to "ignore magnet" or OFF.
    b. Some Biotronik ICDs revert to preprocedural settings with >8 hours continuous magnet placement. In this instance, to continue suspension of tachytherapies, the magnet must be removed for 10 seconds and reapplied again.

5. Electrocautery precautions: Some PM can be programmed to ignore magnet application and all ICDs with active pacing have no **pacing** magnet response. In these situations, utilizing short (<5 seconds) electrocautery bursts can prevent significant bradycardia in PM-dependent patients.

6. CIEDs can be identified by:
    a. Patient's CIED wallet card.
    b. Querying device manufacturers.
        i. Contacting the specific device manufacturer.
        ii. Querying all manufacturers: Medtronic, St. Jude/Abbott, Boston Scientific, Biotronik, and MicroPort if the device manufacturer is unknown.
    c. Reviewing implanting hospital records.
    d. Reviewing implanting physician records.
    e. CXR
        i. The device manufacturer/type can be determined by a CXR with adequate resolution.
        ii. Noting presence of shocking coils indicates that the device is an ICD or ICD with pacing.
        iii. Noting absence of shocking coils indicates that the device is a PM.
    f. Many ICDs emit a tone with magnet application indicating tachyarrhythmia detection/treatment is disabled.
        i. Medtronic ICDs. Devices emit a tone with magnet deactivation of tachytherapies.
        ii. Abbott/St. Jude ICDs. Devices after 2019 emit a tone with magnet deactivation of tachytherapies.
        iii. Boston Scientific ICDs. Devices emit a tone with magnet deactivation of tachytherapies and beeping for 60 seconds with SICD deactivation.
        iv. Biotronik ICDs. There is no tone emitted with magnet deactivation of tachytherapies.
        v. MicroPort ICDs. There is no tone emitted with magnet deactivation of tachytherapies.
7. Surgeries associated with mechanical disruption of pacing/ICD leads include major thoracic surgery, trauma surgery, cardiac surgery, penetrating and blunt chest trauma, and procedures involving chest compressions.
8. An external defibrillator must be applied to all patients with ICDs reprogrammed to suspend tachytherapies and must remain intact until device tachytherapies are reactivated with reprogramming.
9. Reprogramming a PM or ICD with pacing for surgeries utilizing monopolar electrocautery <15cm from the device includes interrogating the pacing function to determine whether the patient's intrinsic HR is adequate to maintain hemodynamic stability during periods of electrocautery use and oversensing. Periprocedural hemodynamic instability is unlikely in patients with intrinsic HR >45ppm. If intrinsic HR<45ppm, the PM should be reprogrammed to pace asynchronously at a desired HR.
10. In legacy MicroPort/Sorin ICDs (*Paradym*, *Ovatio*, *Alto*, *Defender*), magnet placement will result in suspension of tachytherapies as well as institution of synchronous pacing at a rate of 96ppm (bradycardic response) gradually declining to 80ppm at ERI.
11. Correct magnet placement on *Aveir* leadless PM for asynchronous pacing can be verified by noting a change in pacing from synchronous at the device programmed rate to asynchronous at the device magnet rate of 85-100ppm on ECG.
12. If ICD or PM has been reprogrammed for surgery, it must be interrogated prior to discharge from a monitored setting and preoperative programming restored and ICD detection and therapies re-activated.

General Concepts for Perioperative CIED Management

1. Some Biotronik, Boston Scientific, and Abbott/St. Jude CIEDs have a “Store EMG” magnet functionality which is rarely utilized.

2. Appropriate magnet placement on a CIED requires the magnet to be placed directly over the device generator. If the magnet is dislodged, the magnet response will be terminated, and the device will return to its preoperative programming. In some instances, magnet approximation to the device may not be reliable due to body habitus, surgical positioning, or a combination. In such instances, the device must be reprogrammed for the desired response.

3. Intraoperative ECG monitors must be appropriately configured to detect PM spikes. Many ECG monitors have advanced filters which can obscure pacing spikes and require deactivation for PM spikes to be displayed.

4. The term “Magnet” in this document refers to a 7.5cm ring magnet producing 90 gauss at 4cm.

Standard 90-gauss ferrite ring magnet

5. For surgical procedures with only magnet placement and removal and no electrocautery use during the procedure, all CIEDs will revert to their pre-programmed parameters with magnet removal. Postoperative device interrogation is not indicated unless cardioversion, ionizing radiation or mechanical disruption of leads has occurred or is suspected.

6. Patients with remote monitoring can be discharged to an unmonitored environment, including home, provided surgery was not associated with cardioversion, ionizing radiation, or mechanical disruption of device leads. Otherwise, device interrogation is indicated at the conclusion of the procedure.

7. For patients without remote device monitoring, device interrogation is recommended within 30 days after the procedure.

8. There are certain uncommon algorithms for PM which can complicate ECG interpretation.
   a. *Sleep mode/night mode* is a PM algorithm which allows for pacing at a rate lower than the usual device lower rate. This can occur when the patient is stationary for a period and can be inactivated with patient movement or magnet placement over the device.
   b. *Hysteresis:* PM programming that allow for intrinsic conduction at a HR lower than the lower device rate limit. This can be desirable when native conduction is present and can be defeated with magnet placement on the device.
   c. *Rate responsiveness:* Nearly all modern PM have a function to increase HR with perceived activity based on either bioimpedance (respiratory rate) or accelerometry (movement). In devices utilizing bioimpedance such as Boston Scientific and Microport, tachypnea may result in an increased device pacing rate. Reducing the respiratory rate to <14 breaths/minute or placing a magnet on the device can prevent this response.
   d. *Atrial fibrillation with or without RVR:* PM Mode Switching can occur with loss of atrial tracking. This will result in ventricular pacing at preprogrammed device baseline rate. If an increased HR is desired, magnet application will result in manufacturer magnet rate (85-100ppm).

9. Monopolar grounding pads should be placed away from CIED, generally on the thigh or buttock.

10. Magnet placement is not required for patients with precordial placed CIEDs having surgical procedures below the umbilicus, provided the ground pad is placed below the umbilicus as well. The ECG should be monitored, and magnet availability assured throughout the procedure.

11. Underbody dispersion pads should be avoided as they can decrease the distance between the CIED and electrocautery current path, increasing likelihood of device oversensing.

12. Removing the magnet from an ICD will result in reinstation of programmed tachytherapies and can be utilized to shock VT/VF if hemodynamically stable. Fifteen-thirty seconds is required for shock delivery after magnet removal. Hemodynamically unstable tachycardias should be managed with external shocks while leaving the magnet on the device.

13. Electrocautery Protection Mode refers to reprogramming of a CIED to ignore electrocautery. For ICDs, this entails disabling the tachytherapies. For PM, this entails enabling asynchronous pacing. For ICDs with pacing, this entails enabling asynchronous pacing and suspension of tachytherapies.

14. CEID manufacturers contact numbers
   a. Biotronik 1-800-547-0394
   b. Medtronic 1-800-633-8766 (1-800-MEDTRON)
   c. Boston Scientific 1-800-227-3422 (1-800-CARDIAC)
   d. Abbott/St. Jude 1-800-722-3423 (1-800-PACEICD)
   e. MicroPort 1-312-635-6602