



TRANSCUTANEOUS AND TEMPORARY TRANSVENOUS PACING CRITICAL CARE AIR TRANSPORT CLINICAL PRACTICE GUIDELINE

First Publication Date: 12 Dec 2013

Publication Date: 30 Jan 2020

Supersedes: 12 Dec 2013

Contributors

Col Richard Strilka, USAF, MC	Maj Andrew Clark, USAF, MC
Maj Jonathan Henderson, USAF, MC	Maj Nathan Anderson, USAF, MC
Lt. Col Brian J Gavitt, USAF, MC	Maj Jay Nasir, MC, USAF
Lt. Col Joe Aguirre, USAF, MC	Maj Jennifer Childress, USAF, NC
Lt Col Amy Schimke, USAF, MC	SSgt Joshua Taylor, USAF, RRT
SSgt Samantha Roberts, USAF, RT	

Table of Contents

Major updates.....	3
Goal.....	3
Background.....	3
Physiology of Noninvasive Transcutaneous Pacing.....	4
Physiology of Transvenous Pacing.....	4
Important Contraindications Specific to Transvenous Pacemakers.....	5
Complications of Temporary Transvenous Pacing.....	5
Temporary Pacing & Prophylactic Transvenous Pacemaker Placement.....	5
Indications for Temporary Cardiac Pacing ⁶	5
Indications for Prophylactic Transvenous Pacemaker Placement ⁶	6
Pacing Equipment Available to ERCC.....	6
Pre-flight Checklist & Considerations for ERCC Movement.....	7
Plan for Loss of Capture with Transcutaneous Pacing In-flight.....	8
Plan for Loss of Capture with Transvenous Pacing In-flight.....	8
Placement of Transvenous Pacing System.....	9
Transvenous Pacemaker Modes.....	10
Transvenous Pacing Scenarios with Associated ECG Tracings.....	11
(1) Electromagnetic Interference.....	11
(2) Failure to sense.....	12
(3) Loss of capture.....	12
References.....	13
Appendix A: Overview of the Medtronic 5388 Dual Chamber Pacemaker.....	14

Legend of Figures and Tables

Figure 1. An example of R-on-T from a pacemaker.....	5
Figure 4. Ventricular pacing with capture.....	11
Table 1. Transvenous Pacemaker.....	11
Figure 5. An example of EMI that causes pacemaker inhibition.....	12
Figure 6. An example of failure to sense (or undersensing).....	12
Figure 7. An example of loss of atrial capture.....	12
Table A1. The power up values for the 5388 dual Medtronic pacemaker.....	14
Table A2. Emergency Values.....	15
Table A3. Current Settings.....	15

Major updates

1. A discussion of transcutaneous pacing and indications for the prophylactic placement of a transvenous pacemaker has been included.
2. An overview of physiology of transcutaneous and transvenous pacemakers has been added.
3. Algorithms for loss of capture for transcutaneous and transvenous pacemakers have been developed.
4. An appendix detailing how to program the Medtronic 5388 transvenous pacer has been developed to review the most commonly used dials to make appropriate setting adjustments.

Goal

The goal of this clinical practice guideline (CPG) is to optimize care of patients with hemodynamically significant bradycardia in the aeromedical environment. This guideline reviews the physiology, indications, and algorithms for troubleshooting transcutaneous and transvenous cardiac pacing systems. A pre-flight checklist has been developed for patients that are to be evacuated. The algorithms to troubleshoot pacemaker malfunction also include the special conditions encountered by en route care personnel. [Appendix A](#) includes a basic transvenous pacemaker programming instruction set. However, it is not intended to replace the device manual. The series is developed by the Center for Sustainment of Trauma and Readiness Skills and derived from the Tactical Critical Care Evacuation Course.

Background

Myocardial infarction (MI) occurs relatively frequently in the deployed setting, therefore, En Route Critical Care (ERCC) personnel must be familiar with the treatment of its complications. Unstable bradycardia is one such complication, making temporary cardiac pacing a required skill for all deploying providers. Team members need be familiar with the indications for intravenous and transcutaneous cardiac pacing. They must also be to troubleshoot pacemakers in the austere locations within which they operate. For example, electromagnetic radiation from aircraft electronics and RADAR can interfere with transvenous pacemakers and place patients at risk during transport; ERCC personnel must also understand the transvenous pacemaker modes that mitigate the effects of aircraft electromagnetic interference (EMI).¹

The pacemaker technologies available downrange include temporary transcutaneous and temporary transvenous pacing systems. Portable transcutaneous pacemakers are found at Role 1, 2, and 3 facilities, as well as on various Aeromedical Evacuation (AE) platforms. Some Role 3 facilities have the additional capability of placing a temporary transvenous pacemaker before patient evacuation. En route care personnel must be familiar with both types of temporary pacing technologies: transcutaneous and transvenous.

Temporary cardiac pacemakers are only bridges to definitive care. Patients with hemodynamic unstable bradycardia often require cardiac catheterization, advanced cardiac electrophysiologic studies, and potentially permanent pacemaker placement. None of these medical capabilities are available downrange. Therefore, patients who require temporary pacing should be categorized as “urgent” for evacuation purposes, as mortality and morbidity are increased if definitive care is delayed.²

If the ERCC provider is not experienced with managing or troubleshooting a transvenous pacemaker, the theatre cardiologist may be brought on the flight as mission-essential-personnel (MEP) to augment the ERCC team. If a theater cardiologist is not available, the global cardiologist consult service (cards.consult.army@mail.mil) can be utilized to help formulate the best care plan given that equipment and resources available.

The physiology, indications, and complications associated with temporary cardiac pacing will be discussed below. There will also be a focus on special considerations associated with AE.

Physiology of Noninvasive Transcutaneous Pacing

Both the right and left ventricles are stimulated with transcutaneous pacing. The atria are frequently stimulated in a retrograde fashion; this produces atrioventricular dyssynchrony which decreases cardiac output by about 20% from the loss of an atrial kick. Although a patient with symptomatic bradycardia will experience an increase in cardiac output and mean arterial pressure because of pacing, the cardiac output will not usually return to pre-bradycardia levels. This 20% cardiac output decrease, however, will usually be well tolerated unless left ventricular function is severely diminished.³

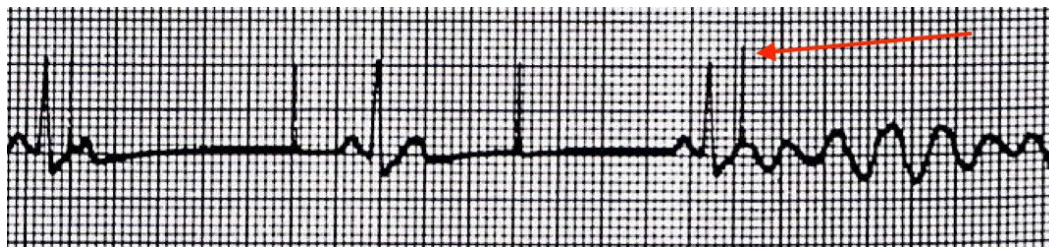
Studies have demonstrated that transcutaneous pacing does not injure the myocardium and from this perspective there is no time limit associated with transcutaneous pacing. Capture rates with the Zoll MD monitor (used by ERCC) are high and vary according to the device and patient population; some published capture rates are up to 96%, although this may be best case scenario.⁴ Limitations of transcutaneous pacing include skin damage and patient discomfort.

Physiology of Transvenous Pacing

Transvenous pacemakers can do two things: (1) pace the heart and (2) sense the intrinsic cardiac rhythm. Unlike transcutaneous pacing, a transvenous pacemaker can pace the atrium, ventricle, or both; the term dual chamber pacemaker is used when both the atrium and ventricle can be stimulated. Depending on the clinical circumstance and the pacemaker settings, a dual chamber pacemaker can maintain atrioventricular synchrony and therefore cardiac output.⁵

The transvenous pacemaker can pace the heart at a fixed rate regardless of the underlying heart rhythm; this is termed asynchronous. It can also sense the heart's electrical activity to determine if it is necessary to stimulate a cardiac contraction to maintain a predetermined heart rate; this is termed synchronous. Therefore, in the synchronous mode the pacemaker does not fire if the intrinsic heart rate is above a predetermined value. In the asynchronous mode, the pacer fires at a fixed rate regardless of the underlying rhythm.

The entire point of pacemaker sensing is to avoid the R-on-T phenomenon (the superimposition of an ectopic beat on the T wave of a preceding beat) that can degenerate into ventricular tachycardia/ventricular fibrillation (VT)/(VF) (see red arrow in Figure 1 below). This is because a "sensing" pacemaker will not produce an electrical impulse that is "too close" to an intrinsic cardiac contraction. Therefore, any environment that interferes with a pacemaker's ability to sense properly will place the patient at risk for VT/VF. Two clinical settings found downrange that can disrupt pacemaker sensing are (1) the operating room and (2) the AE environment; in both situations EMI is the culprit.

Figure 1. An example of R-on-T from a pacemaker

The asynchronous mode protects the patient from R-on-T when the pacemaker is not sensing correctly, the pacemaker rate is set **higher** than the patient's intrinsic heart rate. In this mode, the provider becomes the sensor.

To avoid VT/VF, it is imperative that the pacemaker rate be set to a value greater than the patient's intrinsic heart rate; this also applies to transcutaneous pacing.

Important Contraindications Specific to Transvenous Pacemakers:¹

- Asynchronous pacing is contraindicated in the presence of intrinsic cardiac rhythms, unless there is EMI that renders the pacemaker's ability to sense the heart's intrinsic electrical activity ineffective.
- Atrial pacing is ineffective in the presence of atrial fibrillation or flutter.
- Single chamber atrial pacing is contraindicated in the presence of AV conduction disorders.
- Pacing modes that allow sensing in the atrium to trigger a ventricular response are contraindicated in the presence of rapid atrial arrhythmias such as atrial fibrillation or atrial flutter.

Complications of Temporary Transvenous Pacing

Conventional temporary transvenous pacing is associated with substantial complications, including local infection, thrombosis, and a lead dislodgement rate ranging from 10 to 37%.⁵

Lead dislodgment highlights the importance of having a transcutaneous pacing system in place at all times, particularly in-flight where patient transfers and movement may increase the dislodgement rate.

Temporary Pacing & Prophylactic Transvenous Pacemaker Placement

Indications for Temporary Cardiac Pacing⁶

Indications for pacing a patient with bradycardia are hemodynamic instability (hypotension), acute altered mental status, ongoing severe ischemic chest pain, congestive heart failure, syncope, 3rd degree heart block, bradycardia unresponsive to drug therapy, or other signs of shock.

Boluses or infusions of chronotropic medications, such as atropine, epinephrine, dopamine, or isoproterenol may be considered before initiating pacing. Note that atropine, however, is typically not effective for Mobitz type II and complete heart blocks. Do not delay initiating pacing with signs of shock if bolus medications are not immediately available.

Sinus bradycardia is common shortly after ST elevation MI (STEMI), particularly after inferior wall infarcts; if symptomatic, atropine may be used followed by temporary transcutaneous pacing if necessary.

Indications for Prophylactic Transvenous Pacemaker Placement⁶

The incidence of complete heart block is nearly 4% with inferior/posterior MI. In certain cases, a transvenous pacer may need to be placed before flight after discussion with the theatre cardiologist.

Prophylactic placement of a temporary transvenous pacing system is recommended for high-grade AV block and/or new bundle-branch (particularly with LBBBs) or bifascicular block in patients with anterior/lateral MI.

High-grade AV block with inferior/posterior STEMI usually is transient and associated with a narrow complex/junctional escape rhythm that can be managed conservatively. Application of transcutaneous pacing pads for potential use is reasonable in the hospital setting; a discussion with cardiology as to whether a transvenous pacing system should be placed prophylactically before evacuation should occur.

Bradycardias are common with right heart MI's. An adequate heart rate is essential to maintain cardiac output with right ventricular dysfunction. Transvenous pacer placement before flight should be considered if bradycardias are present. However, it may prove problematic with an ischemic right ventricle: be prepared to pace transcutaneously.

Another indication for transvenous pacing is if the patient is too diaphoretic to allow good electrode-to-skin adhesion for transcutaneous pacing. Large pectoral muscles also increase capture thresholds; therefore fit muscular patients may be better served with a prophylactic transvenous pacemaker in certain cases. Cardiology should be included in the decision when planning these for contingencies.

As a general rule, transcutaneous pacing should not be maintained for longer than 24 hours without converting to a transvenous pacemaker.

Pacing Equipment Available to ERCC

ERCC personnel must be familiar with the operation of the Zoll MD Monitor. Transcutaneous pacing is performed with the monitor and dermal electrodes during patient movement by ERCC.

The portable transvenous pacemaker generator currently stocked downrange is the Medtronic 5388 dual chamber pacemaker unit. ERCC members should also become familiar with this unit prior to transporting a patient. [Appendix A](#) will highlight some important programming aspects of the Medtronic 5388, to include safe modes to mitigate EMI's negative effects. The appendix is not meant to replace the device's user manual. All ERCC personnel should review the manual before deploying; the link to an electronic copy on the Medtronic website is:

http://manuals.medtronic.com/wcm/groups/mdtcom_sg/@emanuals/@era/@crdm/documents/documents/198092001_cont_20071214.pdf

Pre-flight Checklist & Considerations for ERCC Movement

1. A chest x-ray should be done to verify correct transvenous pacer placement and to exclude pneumothorax from pacer placement.
2. A 12-lead ECG and pulse exam should be performed to confirm consistent mechanical capture.
3. Consider pre-flight intubation if transporting a patient requiring transcutaneous pacing. Transcutaneous pacing is painful and will require analgesia and sedation; this is more easily accomplished in the intubated patient. Note that the force of the skeletal muscle contraction, rather than the pacemaker's output in mA, predicts patient discomfort. Discomfort appears to be inversely related to age, possibly due to the older patient having less muscle mass. Therefore, young muscular males may be the most susceptible to transcutaneous pacer intolerance.
4. ERCC personnel should not perform transvenous dressing changes in-flight. If appropriate, have the Role III nurse change the dressing prior to departure.
5. Secure the TVP unit directly to the patient, ensuring it does not fall during patient movement, which could potentially cause lead displacement and loss of capture.
6. A central line and arterial line should be placed prior to flight. If the symptomatic bradycardia is secondary to an acute MI, ensure central and arterial lines are placed at compressible locations if full anticoagulation and/or fibrinolytics may be used.
7. Correct all electrolytes pre-flight to include potassium, magnesium, calcium and phosphorous. Potassium and phosphate replacements are not in the ERCC allowance standard and must be obtained from the Role III prior to departure.
8. Review all cardiac studies to include ECGs, echocardiogram results, and troponin levels.
9. Plan for pacing system malfunction by obtaining (or preparing) infusions of chronotropic medications: epinephrine, dopamine, or isoproterenol. Isoproterenol must be obtained from the Role III as it is not included in the ERCC allowance standard.
10. A request for the Role 3 cardiologist to accompany the AE as mission-essential-personnel (MEP) is possible if the ERCC physician has limited experience with transvenous pacing.
11. After the patient has been transferred to the aircraft, reassess all leads and connections to ensure electrical capture and check a pulse to verify that mechanical capture has not been lost during patient movement on the ground.
12. Patients being paced require continuous and close observation because pacing thresholds can increase over time; patients should be monitored to ensure continuous mechanical capture during flight.
13. An extra battery for the transvenous pacing unit should be taped to the back of the unit or kept immediately available. Confirm that the battery is fully charged prior to departure.

Plan for Loss of Capture with Transcutaneous Pacing In-flight

- Good skin-to-electrode contact lowers transthoracic impedance and improves electrical capture of the heart. All chest hair under the electrode should be clipped or removed.
- Replace pacer pads every 24 hours, regardless of if they are being used. The accumulation of sweat under the pads can result in loss of capture if pacing is initiated.
- Moving the posterior electrode to the right of the spine increases the capture threshold by 15%, as compared to placement over the spine. Therefore, to maximize capture the posterior pad should be under the right scapula.
- Higher capture thresholds for transcutaneous pacing have been found in patients with the following factors: hypoxia, acidosis, pulmonary emphysema, pericardial effusion, large pectoral muscles, and certain medications (e.g., antiarrhythmics, beta blockers, calcium channel blockers).

Steps to take for failure to capture in-flight are:

1. Increase the mA until electrical and mechanical capture are confirmed.
2. Make sure the pacing electrodes are well adhered to the skin.
3. Check for correct placement of the electrodes (posterior electrode under the right scapula). You may find the posterior electrode in the litter when the patient is diaphoretic or restless.
4. Move the pacing (negative) electrode to another place on left precordium.
5. Treat any acidemia and/or hypoxemia present.
6. Consider an infusion of a chronotropic agent if the above steps fail to achieve capture; also consider flight diversion. An in-flight cardiology consult would be appropriate.
7. ***Intermittent loss of capture must be addressed urgently, as sudden and complete loss of capture will likely result in asystole.***

Plan for Loss of Capture with Transvenous Pacing In-flight

An example of loss of capture with ventricular pacing is shown in Figure 2. **Note:** only the first QRS complex is associated with a pacing spike, the red arrows mark “pacing spikes” that do not capture.

Figure 2. Ventricular loss of capture



All patients requiring temporary transvenous pacing should be transported with transcutaneous pads in place and connected to a monitor that has external pacing capability. The monitor should be preprogrammed so immediate transcutaneous pacing can be initiated. If the temporary pacemaker is discontinued abruptly, asystole may result.

Steps to take for failure to capture in-flight are:

1. Check the battery and replace as needed. Transcutaneous pacing may be required until completed. The battery should be checked twice daily.
2. Increase the mA, then decrease the sensitivity to zero.
3. If the catheter has a balloon, it should be inflated (with saline) and the catheter advanced to regain capture; once capture is obtained the balloon should be deflated. Sometimes, however, the catheter requires withdrawal (with the balloon down) to regain capture. For these maneuvers, the pacer catheter should have been placed through a sterile sleeve so that in-flight adjustments can be easily done. The provider must understand the risks associated with catheter advancement and withdrawal (i.e. cardiac perforation). The back-up plan to catheter adjustment is transcutaneous pacing, which may be the safest option depending on the clinical scenario and experience of the provider.
4. Consider an infusion of a chronotropic agent if the above steps fail to achieve capture; also consider flight diversion. An in-flight cardiology consult would be appropriate.
5. Treat any acidemia and/or hypoxemia present.

Intermittent loss of capture must be addressed urgently, as sudden and complete loss of capture will likely result in asystole.

Placement of Transvenous Pacing System

- Placement of a temporary transvenous pacemaker requires central venous access with a 6.0 French (Fr) percutaneous introducer catheter. If an 8.5Fr introducer is used (typically used in trauma resuscitations), it may leak blood from around the pacing catheter.
- Catheter placement in the right internal jugular vein is preferred. Placement in the left subclavian is also acceptable, but this location should be avoided in patients who are being anticoagulated or who may need fibrinolytics. Fluoroscopic guidance is not absolutely necessary at these pacer insertion locations, but a chest x-ray should be obtained to rule out hemothorax, pneumothorax, and to confirm appropriate position of the pacer wire.
- Standardization of pacemaker catheters across military treatment facilities has not been achieved; review the manufacturer's instructions set prior to using.
- If the pacer catheter has a balloon, it should be inflated (with saline) while the catheter is advanced and capture is obtained. Once capture is obtained, the balloon should be deflated and left deflated. The pacemaker catheter should be placed through a sterile sleeve so that in-flight adjustments can be done easily.

Transvenous Pacemaker Modes

The different modes for transvenous pacing are defined with a three-letter code:

1. First letter defines the area of the heart paced: atrium (A), ventricle (V), or both atrium and ventricle (D).
2. Second letter defines the area of the heart sensed: atrium (A), ventricle (V), or both atrium and ventricle (D).
3. Third letter defines what the pacemaker does with the sensing information. Sensing can result in:
 - Pacemaker being inhibited from firing (letter I used to denote “inhibited”).
 - No effect on how the pacemaker fires (letter O used to refer to “none”).
 - Both the atria and ventricle are paced (letter D used to refer to atrium and ventricle, or A+V).
 - Only the atrium is paced (letter A used to refer to atrium).
 - Only the ventricle is paced (letter V used to refer to ventricle).

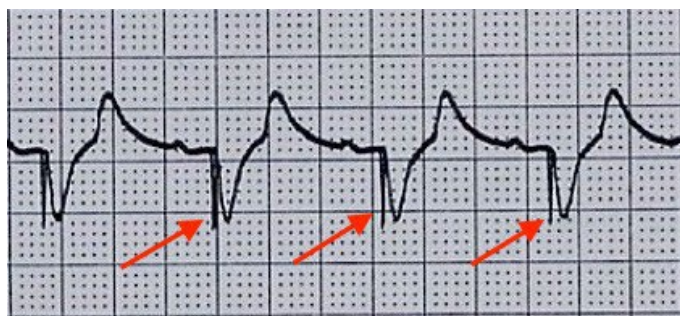
The most commonly used pacing mode for the treatment of bradyarrhythmias is ventricular demand pacing. When it is important to maintain cardiac synchrony (treating a critically ill patient with impaired ventricular function) a dual chamber pacemaker is preferred as it can improve cardiac output by up to 20%. Ventricular demand pacing, however, will be satisfactory for most patients.

Ventricular demand pacing is the mode of choice during patient evacuations because attaining the correct electrode position when “floating” the transvenous pacemaker is relatively simple. It will be well tolerated provided that the left ventricular function is not severely depressed. It is also the least sensitive to small changes in catheter positions.

Settings for temporary ventricular pacing are VVI and VOO.

- In mode VVI (synchronous mode), the ventricle is paced, as well as sensed. If the pacemaker’s pulse generator senses an impulse created by the heart, the pacemaker’s impulse is not sent, thus the pulse generator is inhibited. This mode is used to prevent R-on-T complications when there is an underlying ventricular rhythm. This is the preferred mode, unless EMI is present.
- In mode VOO (asynchronous mode), the ventricle is paced at a fixed rate and there is no sensing; electrical impulses are delivered regardless of the underlying ventricular rhythm. This mode is best used if electrocautery is being used (during surgery), and during periods of excessive electrical stimulation from EMI due to aircraft electronics. The rate with VOO must be greater than the patient’s intrinsic heart rate to avoid R-on-T which can result in VT/VF.

An example of ventricular pacing is shown in Figure 4. Notice the wide QRS complexes; they are normal with ventricular pacing and each “pacing spike” (marked by red arrows) is associated with such a complex.

Figure 4. Ventricular pacing with capture

Transvenous pacemaker modes to use for particular conduction pathologies are summarized in Table 1.

Table 1. Transvenous Pacemaker

Code	Definition	Indication
AOO	Atrial paced, no sensing, no inhibition	Sick sinus syndrome with intact conduction system, use for in-flight EMI
AAI	Atrial paced, atrial sensed, inhibited by atrium	Sick sinus syndrome with intact conduction system
VOO	Ventricular paced, no sensing, no inhibition	Third degree heart block with atrial fibrillation, use for in-flight EMI
VVI	Ventricle paced, ventricle sensed, inhibited by ventricle	Third degree heart block with atrial fibrillation
DOO	Dual paced, no sensing, no inhibition	Third degree heart block without atrial fibrillation, use for in-flight EMI
DVI	Dual paced, ventricle sensed, inhibited by ventricle	Third degree heart block with supraventricular tachycardia
DDD	Dual pace, dual sensed, dual inhibited	Third degree heart block

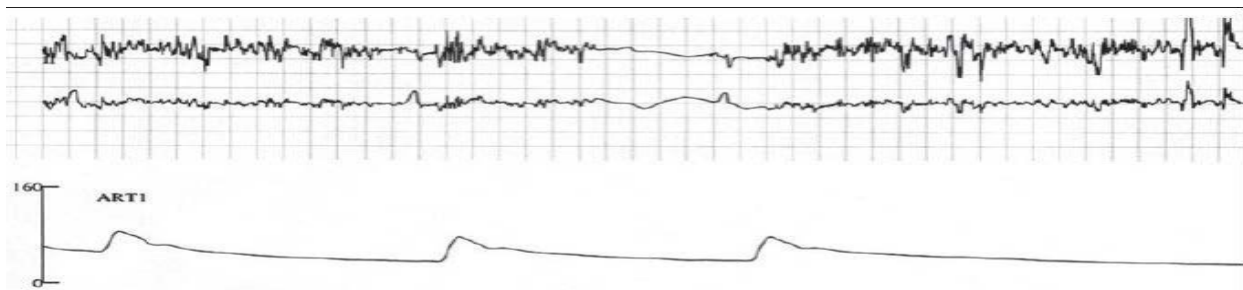
Transvenous Pacing Scenarios with Associated ECG Tracings

(1) Electromagnetic Interference

- If electromagnetic interference is present and inhibiting the pacemaker from firing, then the pacemaker should be switched to an asynchronous mode such as dual-chamber asynchronous pacing DOO or VOO.
- Use DOO for third degree heart block without atrial fibrillation.
- Use VOO for third degree heart block with atrial fibrillation.
- Remember that the rate with VOO and DOO must be greater than the patient's intrinsic heart to avoid R-on-T which can result in VT/VF.

A typical ECG with EMI will look similar to the tracing in Figure 5 below.

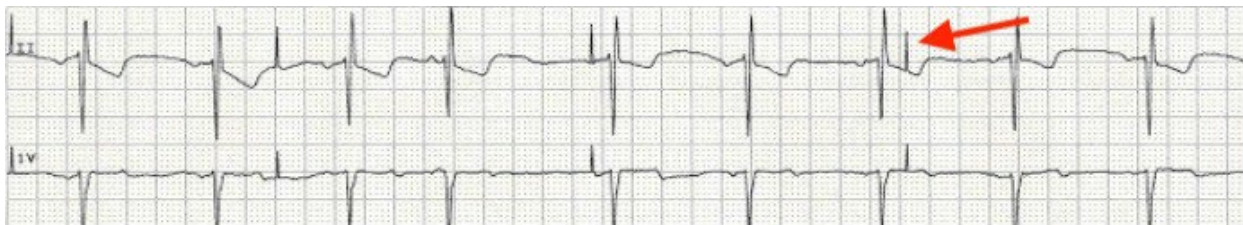
Figure 5. An example of EMI that causes pacemaker inhibition



(2) Failure to sense

Failure to sense (or undersensing) is shown in the Fig. 6. It occurs when the pacemaker fails to recognize spontaneous myocardial depolarization. This is identified by the generation of an unnecessary pacing spike (one that follows too closely behind the patient's QRS complexes). To correct this, consider increasing the sensing threshold, see [Appendix A](#).

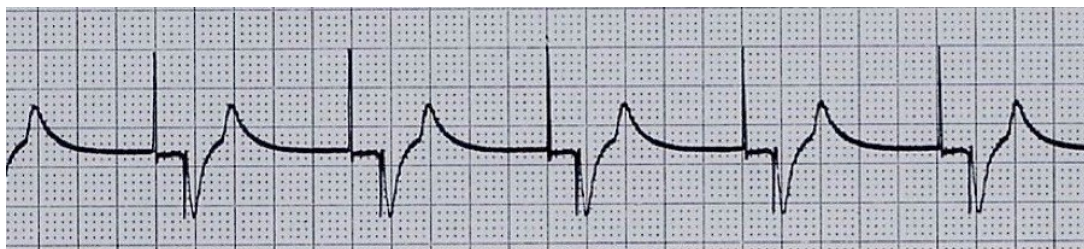
Figure 6. An example of failure to sense (or undersensing)



(3) Loss of capture

An example of loss of atrial capture is shown in Figure 7 below. Note there are no p waves that follow the “upward” atrial “pacing spikes.” Refer to [Appendix A](#) for how to increase the atrial Ma.

Figure 7. An example of loss of atrial capture



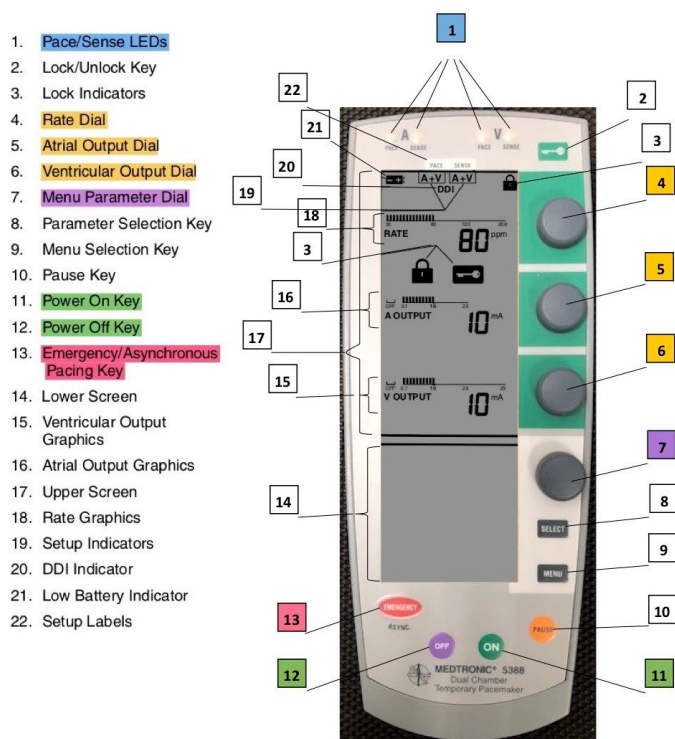
REFERENCES

1. Medtronic 5388 Dual Chamber Pacemaker, Technical Manual, 2009, Medtronic, Inc., Minneapolis, MN 55432.
2. Risgaard B, Elming H, et al. Waiting for a pacemaker: is it dangerous? *Europace* 2012;14 975-980
3. Gammage MD. Temporary cardiac pacing. *Heart*, 2000 Jun 1;83(6):715-20.
4. Madsen JK, Meibom J, Videbak R, Pedersen F, Grande P. Transcutaneous pacing: experience with the Zoll noninvasive temporary pacemaker. *American Heart Journal*, 1988 Jul 1;116(1):7-10.
5. Lepillier A, Otmani A, Waintraub X, Ollitrault J, Le Heuzey J, Lavergne T. Temporary transvenous VDD pacing as a bridge to permanent pacemaker implantation in patients with sepsis and haemodynamically significant atrioventricular block. *Europace*, 2 Jan 2012;14(7):981-5.
6. T O'Gara P, Kushner FG, Ascheim DD, Casey DE, Chung MK, De Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, Granger CB. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction. *Journal of the American College of Cardiology*, 29 Jan 2013;61(4):e78

Appendix A: Overview of the Medtronic 5388 Dual Chamber Pacemaker

A schematic of the Medtronic 5388 is shown below (Figure A1); a few selected dials and buttons will be explained within this appendix. The Medtronic manual should be used for a comprehensive review of the device; the manual was used to construct this brief review in the event that the Medtronic manual would be unavailable in the deployed setting.

Figure A1. Schematic of the Medtronic 5388



POWER ON/OFF: The ON button is marked in green (number 11, Figure A1) and the OFF button is number 12 above. Press the ON key once. The upper screen lights up and the pacers initiates a self-test. Once a successful self-test is completed the following occurs: A sufficiently charged battery will allow the device to begin sensing and pacing in both the atrium and ventricle at the following nominal parameter values. Press the “OFF” button twice within 5 seconds. After the first press, a message appears in the lower screen telling the user to press OFF a second time to turn the device off.

Table A1. The power up values for the 5388 dual Medtronic pacemaker

Base Rate	80 per min
A output and V output	10 mA and 10 mA
A sensitivity	0.5 mV
V sensitivity	2.0 mV
A Tracking	ON

EMERGENCY/ASYNCHRONOUS BUTTON: Press this key (number 13, Fig A1) once to select high-output, dual-chamber asynchronous (DOO) pacing at any time, whether the device is off or locked. Use caution to avoid accidentally activating the Emergency key. This button should be used if electromagnetic interference causes over sensing inhibiting the pacemaker from firing causing hemodynamic instability. The device will pace at the following values:

Table A2. Emergency Values

Base Rate	80 per min
A output and	20 mA
V output	25 mA
A sensitivity	ASYN (no sensing)
V sensitivity	ASYN (no sensing)

Adjusting the rate, A output, and V output in emergency mode: These parameters can be adjusted using the three upper dials (numbers 4, 5, and 6) on the right side of device marked in yellow in Figure A1; these dials will be detailed below. To return the device to demand or synchronous pacing:

- Press the ON key once if the asynchronous pacing message is displayed in the lower screen.
- Press the ON key twice if the asynchronous pacing message is not displayed in the lower screen. The first press of the ON key causes the asynchronous message to appear.
- The number 14 in Figure A1 identifies the lower screen.

The device will begin synchronous pacing with the following values:

Table A3. Current Settings

Base Rate	Current settings
A output and	Current settings
V output	Current settings
A sensitivity	0.5 mV (nominal)
V sensitivity	2.0 mV (nominal)

ADJUSTING RATE, A OUTPUT, AND V OUTPUT: the parameter settings are displayed numerically and graphically. The dials for adjustment are the numbers 4, 5, and 6 respectively (marked in yellow, Figure A1). The line next to each dial shows the range available for each parameter. The liner graph appears above the corresponding numerical value.

Rate dial (number 4 in Figure A1): The optimal RATE setting once the device turns on is 80 BPM. The pacing rate ranges from 30 to 200 beats per minute (BPM). Turning the RATE knob clockwise increases the rate, and counter-clockwise decreases the rate.

A (Atrial) OUTPUT dial (number 5 in Figure A1): The atrial output ranges from 0.1 to 20 mA. Turn the dial clockwise to increase A OUTPUT. Turn the dial counterclockwise to decrease or turn A OUTPUT OFF. When A OUTPUT is set to OFF, both the atrial output and the atrial sensitivity are turned off (i.e., there is no atrial pacing or sensing).

V (Ventricle) OUTPUT dial (number 6 in Figure A1): The ventricular output ranges from 0.1 to 25 mA. Turn the dial clockwise to increase V OUTPUT. Turn the dial counterclockwise to decrease or turn V OUTPUT to OFF. When V OUTPUT is set to OFF, both the ventricular output and the ventricular sensitivity are turned off (i.e. there is no ventricular pacing or sensing).

PACE LEDs

- Two green LEDs at the top of the device, marked PACE, number 1 in Figure A1, indicate delivery of a pacing pulse but do not necessarily indicate the pacing pulse has initiated cardiac stimulation.
- The green LED next to the A flashes each time the device delivers a pacing pulse on the atrial channel.
- The green LED next to the V flashes each time the device delivers a pacing pulse on the ventricular channel.

Adjusting Atrial and Ventricular Sensitivities

- The lower screen (number 14, Figure a1) allows adjustment of the atrial and ventricle sensitivities.
- Menu 1 provides access to the:
 - Atrial sensitivity (A SENSITIVITY),
 - Ventricular sensitivity (V SENSITIVITY),
 - A-V Interval (A-V INTERVAL), and
 - Atrial tracking option (A TRACKING).
- Depressing the Menu button (number 9, Figure A1) and then using the Select button (number 8, Figure A1) to choose Menu 1 allows access to change the sensing values for the atrium and ventricle.
- Unless manually adjusted, the atrial sensitivity (A SENSITIVITY) is set to the nominal value of 0.5 mV.
- When selected, the A SENSITIVITY may be adjusted between 0.4 and 10 mV by turning the Menu Parameter dial.
- Unless manually adjusted, ventricular sensitivity (V SENSITIVITY) is set to the nominal value of 2.0 mV.
- When selected, the sensitivity may be adjusted between 0.8 and 20 mV by turning the Menu Parameter dial.