CRITICAL CARE AIR TRANSPORT CLINICAL PRACTICE GUIDELINE (CCATT CPG)

Transcutaneous and Temporary Transvenous Pacing

This CPG provides guidance for the management of cardiac pacing in the aeromedical environment.

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First Publication Date:	Revision Date:	Supersedes:
12 Dec 2013	26 Jan 2025	12 Dec 2013

Acknowledgment: This CPG is based on the hard work, authorship, and previous revisions, by Col Richard Strilka, USAF, MC, et al.

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MAJOR UPDATES

1. Provided a broader overview of the objective and background of this CPG
2. Simplified the flow

OBJECTIVE

The goal of this clinical practice guideline (CPG) is to provide patient care guidance and optimization of patients with hemodynamically significant dysrhythmias, such as symptomatic bradycardia, bundle branch blocks, and 2nd and 3rd degree (complete) heart block, in the aeromedical environment. This guideline reviews the physiology, indications, and algorithms for initiating and troubleshooting transcutaneous and transvenous cardiac pacing systems. A pre-flight checklist has been developed for patients that are to be transported. 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 as reference; however, it is not intended to replace the device manual.

PATHOPHYSIOLOGY

Temporary cardiac pacing, whether transcutaneous, transvenous, or epicardial, is a potentially lifesaving technique for patients with arrythmias which cause hemodynamic instability.

Etiology of malignant rhythms may be due to structural heart disease, most often and commonly associated with ischemia or infarction, but can also include adult congenital heart disease, infiltrative cardiomyopathies (amyloidosis, lymphoma), infection or inflammation (viral myocarditis, infectious endocarditis, Lyme disease, Chagas disease, diphtheria, toxoplasmosis, sarcoidosis, malaria, Dengue fever, viral hemorrhagic fevers, etc.), post-surgical (post coronary artery bypass grafting, valvular surgeries) or thoracic blunt force trauma. Nonstructural or extrinsic causes of arrythmias may include electrolyte and endocrine abnormalities, hypothermia, whether accidental or purposeful (targeted temperature management), drug or toxin effects (organophosphates, medication overdoses), and neurogenic shock.

When the cardiac conduction system suffers an insult, such as described above, the loci of cardiac impulse generation, in the sinoatrial (SA) node, and the pathway of electrical impulses downward through the intraatrial conduction pathways, atrioventricular (AV) node, bundle of His, bundle branches, and terminating with the Purkinje fibers, are all potential locations of dysfunction, resulting in a variety of dysrhythmias.

Of the resulting arrythmias and the associated hemodynamic compromise and end organ dysfunction that may present with those arrhythmias, those that benefit from cardiac pacing are bradycardia, symptomatic 2nd degree, type I (Wenckebach's) block, 2nd degree, type II (Mobitz type II) block, 3rd degree (complete) block, sick sinus syndrome, and junctional (escape) rhythms. In some cases, tachyarrhythmias (such as Torsades de pointes and ventricular tachycardias) benefit from providing external electrical stimulus to overcome the native dysfunction (i.e. overdrive pacing). Most patients that require cardiac pacing suffer from symptomatic bradycardia or either 2nd - or 3rd -degree heart block.

INDICATIONS AND INTERVENTIONS

Patients who present with the above arrythmias accompanied by hypotension and or signs of poor perfusion including syncope, altered mental status, signs of end organ ischemia such as angina warrant immediate intervention. If time and resources permit, a trial of pharmacological intervention is reasonable with a low threshold to progress to or add cardiac pacing. Drug therapies may include anticholinergic drugs such as atropine, or inotropes and chronotropes such as epinephrine or dobutamine, however do not delay initiation of cardiac pacing if medication is not readily available, or there is a lack of response to medication.

Cardiac pacing can be performed transcutaneous, through externally applied pacing pads, transvenous, via a central venous catheter serving as an introducer for a pacing wire that is floated through the venous system into the heart, or via epicardial leads that are placed surgically. Each application will be discussed below. Cardiac pacing is a temporary measure, designed to buy time for treatment and intervention, such as cardiac catheterization or electrophysiology studies, resolution of the underlying cause, or until definitive intervention, such as placement of a permanent pacemaker.

Pacing capabilities are depending on the echelon of care the patient is being retrieved from and can also be influenced by resource and conflict scale variables as well. CCATT and Aeromedical Evacuation (AE) teams do not have the capability to place transvenous pacers, however they should certainly be familiar with patient management, troubleshooting, and contingency plans, like transcutaneous pacing via appropriate flight approved equipment. Patients requiring cardiac pacing should be triaged as at urgent for patient movement as definitive care is usually not available until Role 3 facilities or higher. Besides familiarization with this CPG, augmenting the patient care team with a member who is familiar and comfortable with cardiac pacing and troubleshooting is advised if possible. If not, it is reasonable to call the ADVISOR hotline at 1-833-ADVSRLN (1-833-238-7756 or DSN 312-429-9089) to speak with a cardiologist for further guidance and support.

TRANSCUTANEOUS PACING AND CONSIDERATIONS

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]

STEPS FOR TRANSCUTANEOUS PACING

1. IF time and patient condition permits, provide IV analgesia (e.g. fentanyl) and/or IV anxiolysis (e.g. midazolam).

2. Apply pads in either anterior-lateral (AL) configuration (to the patients right upper chest wall and left lower chest wall, mid axillary line) or in an anterior-posterior (AP) fashion (anterior lower left chest wall and posteriorly under the left scapula).

    a. The AL configuration is often used in emergent situation as you do not have to roll the patient,

however the AP fashion supports a more appropriate vector for electrical conduction through the heart should defibrillation or cardioversion be required and has been found to produce mechanical capture (described below) at a lower energy output.[4]

b. Good skin-to-electrode lowers transthoracic impedance and improves electrical capture of the heart. Hair should be clipped or removed prior to pad placement and skin should be dry.

3. Turn device to "pacing mode" and notify the Aeromedical Evacuation (AE) MCD and/or other appropriate teams (e.g. Boom Operator, Load Master, Front End crew)

4. Apply ECG electrodes, if necessary, to evaluate underlying rhythm.

5. Appropriately set the desired heart rate, usually at least 30 beats above native rhythm, and typically between 60-80 bpm.

6. Starting at 70 milliamperes (mA) slowly increase the device's current output in 10 mA increments until you see electrical capture, reflected on the devices ECG rhythm.

   a. Some devices will recognize pacing spikes if toggled on.

7. Confirm mechanical capture by palpating a pulse.

8. Once pacing is captured and confirmed, set output to 5-10 mA over the capture threshold.

9. Re-evaluate patient's circulation and overall condition

10. If analgesia and anxiolysis has not already been provided, administer if appropriate as transcutaneous pacing is considerably uncomfortable and usually not well tolerated in the awake patient.

TRANSCUTANEOUS PACING POINTS TO CONSIDER

- Pacer pads should be replaced every 24 hours due to accumulation of moisture and sweat which impedes capture

- Higher thresholds are sometimes noted in patients with concomitant hypoxemia, acidosis, pulmonary emphysema, pericardial effusions, significant musculature, obesity, or medications (e.g. antiarrhythmics, beta-blockers, calcium channel blockers)

- Consider prophylactic intubation prior to flight if the patient is already being transcutaneously paced, to facilitate patient tolerance

TROUBLE SHOOTING TRANSCUTANEOUS PACING FAILURE

1. *Intermittent loss of capture must be addressed urgently, as sudden and complete loss of capture will likely result in hemodynamic instability or collapse. Consider in-flight diversion if possible or a communication patch to a Cardiologist*

2. Increase the mA until electrical (i.e. ECG tracing) and mechanical capture (i.e. pulse) are confirmed.

3. Make sure the pacing electrodes are well adhered to the skin and correctly placed (i.e. not dislodged)

4. Move the anterior pacing electrode to another location 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

TRANSVENEOUS AND EPICARDIAL PACING AND CONSIDERATIONS

Transvenous pacing utilizes a central venous catheter (CVC), usually placed into the right internal jugular or left subclavian vein, which serves as an introducer to "float" a pacing wire through the venous system utilizing a small balloon, terminating into the apex of right ventricle. Transvenous pacers (TVPs) typically have both atrial and ventricular electrodes which permit pacing in a physiological, dual chamber manner to promote AV synchrony, optimizing cardiac output. Transvenous pacing is very well tolerated and comfortable for the patient and does not require sedation, if secured well is less likely to fail or lose capture compared to transcutaneous pacing and has the added benefit of utilizing a pacer box to control pacing output.

TVP placement complications is not without risk. Complications may be related to venous access (e.g. arterial puncture, pneumothorax, etc.), right heart catheterization (e.g. dysrhythmias, atrial or ventricular perforation, misplacement of the wire into the coronary sinus, valvular damage, etc.), the pacing wire itself (e.g. wire fracture, displacement, fibrosis, infection), and the external generator.

INDICATIONS FOR PROPHYLACTIC TVP PLACEMENT

If a patient has required transcutaneous pacing and time and resources permit, a TVP should be placed urgently, ideally in the first 24 hours. Certain pathology also predisposes patients to arrythmias, and often a TVP should be place prophylactically prior to transport. Myocardial infarctions (MIs) affecting the inferior or posterior aspects of the myocardium can result in complete (3rd degree) heart block in up to 5% of patients. These patients may also have a high degree AV block (P wave to QRS complex ratio of ≥ 3:1), which is usually transient and less likely to be symptomatic. Right sided MIs often affect the SA node and conduction system, resulting in symptomatic bradycardia requiring pacing. An anterior-lateral MI may also result in high grade AV blocks, new bundle branch block, particularly the left bundle branch, or bi-fascicular blocks. Prior to transport a Cardiology consultation may be helpful to guide prophylactic TVP placement.

EPICARDIAL PACING

Epicardial wires are placed during cardiothoracic surgery and sutured directly into the epicardium and exit through the skin and are covered by a dressing. By surgical convention, atrial (A) wires emerge on the patient's right, and ventricular (V) wire emerge on the patient's left. These wires will connect to the pacemaker box using a special cable with a screw in connector that will accept the wires placed by the surgeon. Patients will always have V wires but will not uncommonly have A wires as well; a patient will never have only A wires. Pacer box usage is the same for both epicardial or transvenous pacing, with the exception being if the patient does not have atrial epicardial wires.

TRANSVENOUS PACER BOX NOMENCLATURE AND MODES

1. A generator box is used for both transvenous and epicardial pacing. The first letter defines the area of the heart paced: atrium (A), ventricle (V), or both atrium and ventricle (D).

2. The second letter defines the area of the heart sensed: atrium (A), ventricle (V), both atrium and ventricle (D), or neither (O).

3. The third letter defines what the pacemaker does with the sensing information. Sensing can result in:
   - I (Inhibited): The pacemaker being inhibited from firing
   - O (None): No effect on how the pacemaker fires
   - D (Dual): Both the atria and ventricle are paced
   - A (Atrium): Only the atrium is paced
   - V (Ventricle): Only the ventricle is paced

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. Although the loss of AV synchrony can result in about a 20% decrease in cardiac output, it is generally tolerated by most patients, apart from those with significant myocardial depression. It is also the least sensitive to small changes in catheter positions.

- 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 electromagnetic interference (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 ventricular tachycardia (VT) or ventricular fibrillation (VF).

Transvenous pacemaker modes to use for conduction pathologies are summarized in Table 1 below:

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

TROUBLESHOOTING TRANSVENOUS PACING

1. *Intermittent loss of capture must be addressed urgently, as sudden and complete loss of capture will likely result in hemodynamic instability or collapse*. *Consider in-flight diversion if possible or a communication patch to a Cardiologist.*

2. Immediately prepare to transcutaneous pace while troubleshooting.

3. Check to ensure electrodes are properly inserted and attached to pacer box.

4. Ensure the pacer box has battery power.

5. Assess the patient for landmarks on the TVP catheter wire.

    a. May also utilize point of care ultrasound to evaluate wire position.

6. Consider switching to asynchronous mode (e.g. DOO, VOO).

7. Evaluate systematically:

    a. EMI from aircraft (pacemaker will be inhibited from firing and ECG will look like electrocautery or perhaps even VF)
        i. Switch to asynchronous mode, but ensure rate is greater than the patient's intrinsic rate to avoid R on T phenomenon.
            1. DOO for 3rd degree heart block without atrial fibrillation
            2. VOO for 3rd degree heart block with atrial fibrillation

    b. Failure to pace due to output failure (pacing spikes absent or heart rate not reaching set value)
        i. Increase mA (20mA atria and 25mA ventricle) and decrease sensitivity (if in VVI) while observing cardiac monitor to ensure there is electrical capture
        ii. Switch to an asynchronous mode to prevent oversensing (DOO, VOO)

    c. Failure to capture (visible pacing spikes on ECG but lack of mechanical capture – pulse, arterial line wave form pulsation)
        i. Increase output
        ii. Check connections, rule out mechanical issue
        iii. May also be due to drug interaction (anti-arrhythmics) or post cardiac defibrillation

d. Failure to sense (producing pacing spikes inappropriately)
   i. Decrease absolute value of sensing (therefore making it easier to inhibit)

e. Oversensing (inhibited pacing)
   i. Large P or T waves may be sensed as intrinsic atrial activity
   ii. Increase sensitivity (therefore making it hard to inhibit) or switch to asynchronous mode (DOO, VOO)

f. AV dyssynchrony – loss of atrial kick causing hypotension (SBP usually falls at least 20 points)
   i. Ensure both leads are properly capturing and pacer is in dual chamber mode

TRANSVENOUS PACING: OTHER POINTS TO CONSIDER

- CXR should be performed after TVP placement and before flight to rule out pneumothorax and confirm wire placement
  - If x-ray is not available, point of care ultrasound can be utilized to verify lung sliding and examine the RV for wire and balloon location

- If possible, 12-lead ECG should be performed to confirm capture

- Document TVP placement depth in case of dislodgement or failure to capture in route.

- All patients with TVPs should have external (transcutaneous) pads applied and an appropriate pacing device available

- All patients with TVPs should ideally have an additional pacer box if possible, and at the least, additional batteries

- Ensure the TVP is secure appropriately and the dressing changed prior to transport; do not change en route

- After all patient movement, reassess all lead connections, TVP depth and ensure there is both electrical and mechanical capture

- Prepare for electromagnetic interference (EMI) from aircraft electronics

OTHER EN ROUTE CARE CONSIDERATIONS

- Correct all electrolytes pre-flight to include potassium, magnesium, calcium and phosphorous.

- Patient should have arterial lines for beat-to-beat pressure monitoring and frequent blood draws for evaluation of acid-base status and electrolytes

- Additional central venous access should be obtained if possible

- Obtain and prepare infusions of chronotropic medications as pharmacologic backup

- If unfamiliar or uncomfortable for cardiac pacing, consider augmenting your team with a member who is, and/or calling the ADVISOR hotline

REFERENCES

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3. Gammage MD. Temporary cardiac pacing. Heart, 2000 Jun 1;83(6):715-20.

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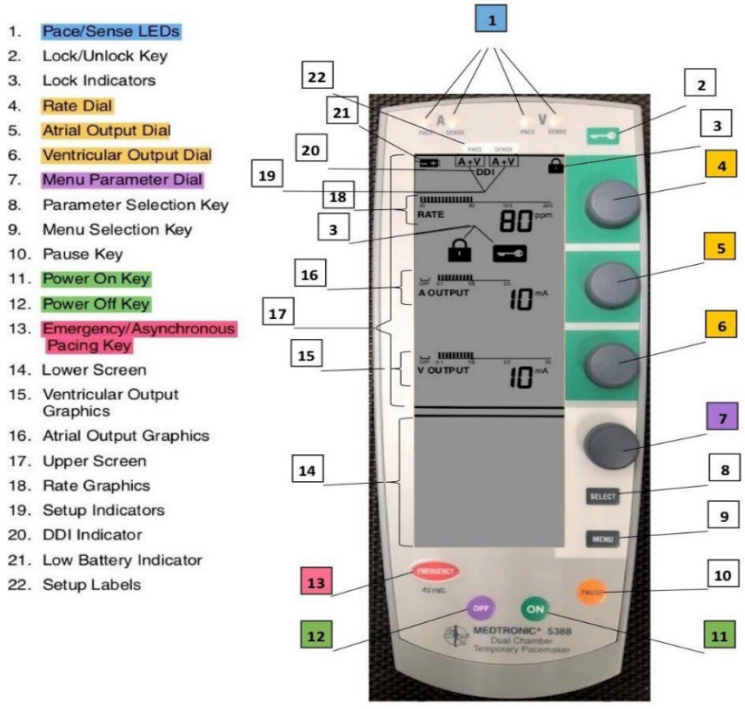
APPENDIX A: OVERVIEW OF THE MEDTRONIC 5388 DUAL CHAMBER PACEMAKER

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 counterclockwise 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.
- The blue LEDs next to both flash when the device senses a native impulse and thus inhibits a pacing pulse in synchronous mode.

Adjusting Atrial and Ventricular Sensitivities

- The lower screen (number 14, Figure a1) allows adjustment of the atrial and ventricle sensitivities.

- 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.
  - Atrial sensitivity (A SENSITIVITY),
  - Ventricular sensitivity (V SENSITIVITY),
  - A-V Interval (A-V INTERVAL),
  - and Atrial tracking option (A TRACKING).

- 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.