Guideline Title: Epicardial Pacing

Summary: Patients admitted to the ICU who require temporary epicardial pacing will be managed and monitored appropriately. Temporary pacing can be in the form of transvenous, epicardial or transcutaneous. This guideline will concentrate on epicardial pacing and management of a pacemaker box

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Replaces Existing Guideline: Epicardial Pacing 2013

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1. Background Information: Temporary pacing is used when a patient’s heart rate is not fast enough to maintain cardiac output. Temporary epicardial pacing consists of pacing wires sutured to the epicardium of the heart, on the atrium and on the ventricle. The ventricular wires commonly exit the skin on the left side of the sternum, while the atrial wires exit the right side of the sternum which are then attached to pacing leads and connected to a pacing box or pulse generator.

   The pacemaker essentially does two things:
   1. It senses the patient’s own rhythm using a “sensing circuit”;
   2. It sends out electrical signals using an “output circuit”.

   If the patient’s intrinsic rhythm becomes too slow, the electronic pacemaker senses that, and starts sending out signals along the wires leading from the control box to the heart muscle.

   The signals, if they’re “capturing” properly, provide a regular electrical stimulus, making the heart contract at a rate fast enough to maintain the patient’s blood pressure. The electrical signals are represented on the ECG monitor as “spikes.”
2. Introduction:
The risk addressed by this policy:

Patient Safety

The Aims / Expected Outcome of this policy:
Staff caring for a patient with epicardial pacing wires will have the skills and knowledge to provide safe and effective management of the patient and the temporary pacemaker

Related Standards or Legislation

| NSQHS Standard 1 Governance |

Related Policies
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<td>LH_PD_ICU_2015 Transcutaneous Pacing</td>
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<tr>
<td>LH_PD_ICU_2015 Transvenous Pacing</td>
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<tr>
<td>LH_PD_ICU_2013 Care post cardiac surgery</td>
</tr>
<tr>
<td>LH_PD_ICU_2015 Epicardial pacing wire removal</td>
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3. Policy Statement:
- All care provided within Liverpool Hospital will be in accordance with infection prevention/control, manual handling and minimisation and management of aggression guidelines.
- Pacing wires must always be handled while wearing gloves
- Batteries must be checked before commencing pacing and second hourly once attached
- Wires must always be secured to chest
- DOO mode must not be used in ICU as this is an asynchronous mode of pacing (exception: may be used when diathermy used which may inhibit pacing)
- Daily thresholds and underlying rhythm must be checked and documented on pacing chart
- Sensitivity thresholds are only to be performed if accredited by a CNE
- All patients post valve surgery must be attached to a pacing box, with settings ready to go in case the patient becomes bradycardic
- Patients returning from OT to ICU with Biotronic (white) pacemaker attached must be swapped to the Medtronic (blue) pacemaker
- Patients who require pacing when transferred to ward must be swapped to the Biotronic (white) pacemaker

4. Principles / Guidelines

a. Indications
   - Sinus bradycardia
   - AV blocks
   - Complete heart block
   - Overriding tachy atrial and/or ventricular arrhythmia (AF, A Flutter & SVT) Re-entrant tachycardia's
   - Prior to the implant of a permanent pacemaker
   - Acute myocardial infarction complicated by heart block
   - Temporary support of a patient after heart surgery

b. Precautions
   - Do not attempt to change battery while pacing a dependent patient. It is always safer to use another operating pacemaker whilst batteries are being changed, rather than attempting to change batteries while the device is in use.
If batteries need to be replaced in an emergency, pacing will be maintained for 30 seconds if the settings are at nominal levels.

Asynchronous operation (DOO) has the potential to induce life threatening arrhythmias, and in general is not used in ICU. Ensure a defibrillator is at hand, and return to synchronous operation as soon as possible. Asynchronous operation particularly in patients who have some intrinsic rhythm may potentially induce Ventricular fibrillation, and should always be used with caution, whilst the patient is being monitored.

Microshocks:
- While epicardial pacing wires are meant to provide a safeguard against dysrhythmias, they have the potential to cause a lethal rhythm. Because the unattached wires provide a direct route for electrical current to flow to the heart, any stray current poses a threat to the patient, with as little as 0.1mA causing Ventricular Fibrillation.
- To avoid Microshocks, when handling pacing wires gloves should always be worn.
- It is also necessary to keep the wires insulated by covering each one with gauze.

**c. Equipment**

- Pacing Box / Generator with new batteries
Pacing leads

- Gloves
- Gauze, tape

d. Procedure

Pacing wires are fixed directly to the myocardium and are exposed through the skin on the chest wall. Ventricular wires exit skin on left side of chest and atrial wires exit skin on right side of chest.

Placement of epicardial pacing wires: www.legalmedicalexhibits.com

Atrial pacing wire placement

Ventricular pacing wire placement
- Attach atrial wires to atrial pacing lead, tighten screws and then attach lead to atrial side of pacing box.
- Attach ventricular wires to ventricular pacing lead, tighten screws and then attach lead to ventricular side of pacing box.
- Set rate at 70-90bpm
- Set AV delay at 150 ms
- Set Atrial sensitivity at 0.2mv
- Set atrial output at 10 V
- Set ventricular sensitivity at 2.0mv
- Set ventricular output at 10 V
- Turn pacemaker on to DDD mode
- If the pacing box is capturing, on the monitor you will see spike before every “p” wave (if atrial pacing) and before every “QRS” complex (if ventricular pacing).
- If the monitor is sensing you will see a sensing dot on the monitor before every p wave and another sensing dot before every QRS complex. If the pacing box is sensing the light will flash next to the chamber being sensed.

- Assess patient's hemodynamic status to ensure pacing is improving cardiac output.
- If patient is stable Thresholds need to be performed
- Secure wires and lead blocks to patients chest by placing blocks on gauze and taping to chest
- **Common settings:**
  - **Atrial**
    - DDD
    - Rate 80- 100
    - Sensitivity 0.4mv
    - Output 5.0V/10V
    - AV delay 150 ms
  - **Ventricular**
    - DDD
    - Rate 80- 100
    - Sensitivity 0.8mv
    - Output 5.0/10V
    - AV delay 150 ms

- **Thresholds**
  
  - **Output:**
  
  Once the pacemaker has been programmed, it must now be adjusted to deliver the minimal amount of energy to provide a pacing stimulus. Many variables can affect the amount of energy necessary to pace the heart such as the type of electrodes, scar tissue and electrolyte disturbances. We need to determine the amount of energy that assures the pacemaker stimulates the heart to depolarise.

  - **Output thresholds:**
    - **To find output /stimulation threshold (for atrial and ventricular pacing)**
      - If the patient is not being paced, then increase the pacemaker rate to 10 above the patient’s rate. This is because the patient must be in a paced rhythm to check output threshold.
      - As a safety feature it is necessary to ensure that the patient has a reasonable underlying intrinsic rate prior to performing threshold checks. If the patient is already in a paced rhythm, turn the pacemaker rate down and observe the ECG monitor for the patients intrinsic heart rhythm. If the patient is still pacing at a rate of 60, abort the checking of the output threshold.
Explain to the patient that they may briefly become ‘light-headed’ during the checking procedure.

Obtain an ECG.

Decrease the output setting until loss of capture occurs.

Increase the output setting until you just see that capturing is occurring. Indicated by a pacing spike followed by a “p” wave or “QRS” complex. This is called the stimulation threshold.

You then set the output at double the threshold and add one as a safety margin.

E.g. Threshold is 3 V

- 3 x 2 = 6
- Add one (for safety margin)
- 6 + 1 = 7
- Therefore you set the output at 7 V.

Document the output threshold on the pacing chart. It is important to check the threshold at least once a day.

Check settings and document output settings every 2 hours.

**Sensitivity** is the pacemaker’s ability to sense a patient’s intrinsic rhythm or when natural depolarisation is occurring.

- The sensitivity number represents the minimum size, in millivolts, of an electrical signal that will be detected by the pacemaker
- The higher the sensitivity (number) the less likely the pacemaker will see the patient’s rhythm

**Sensitivity threshold:** The sensitivity threshold is the maximum sensitivity at which the pacemaker can sense intrinsic events.

It is the minimum atrial or ventricular intra cardiac signal amplitude required to inhibit or trigger a demand pacemaker, expressed in millivolts.

- **To find sensitivity threshold**
  
  *(Only to be performed if accredited by a CNE: otherwise leave sensitivity on lowest setting: ventricular 0.8mv, Atrial 0.4mv)*

**NB** if patient has no intrinsic rate with an adequate output this test cannot be performed.

- Reduce the pacemaker rate to just below the patient’s intrinsic rate.
- Obtain an ECG if not previously done
- Decrease the output setting to the lowest number possible, thereby avoiding potentially dangerous competition between the pacemaker and the patient’s intrinsic heart rate.
- Decrease the pacemaker’s sensitivity (i.e. ↑ number)
- Observe the pacemaker for the sensing light to stop flashing. You then ↓ the number on the pacemaker box until the sensing light just start to flash. This is called the sensitivity threshold.
- You then set the sensitivity on the pacemaker at half the sensitivity threshold and minus one, as a safety margin.

- E.g. Sensitivity 6mV
  - 6 ÷ 2 = 3
  - Minus one (for safety margin)
  - 3 – 1 = 2

- Document the sensitivity threshold on pacing chart.
- Check and document sensitivity settings daily
- Correct setting of sensitivity ensures that the pacemaker will be inhibited if the patient’s intrinsic rate exceeds the pacemaker rate.
f. Troubleshooting 

Non-capture: An electrical stimulus delivered by the pacemaker does not initiate depolarisation of the atria or ventricle

- Pacemakers malfunction with inconsistent capturing (atrium or ventricle). Can be diagnosed from the electrocardiogram when there are pacemaker spikes that are not followed immediately by either a P wave or QRS complex.

Non-capture may be intermittent so that only occasional non-captured pacemaker stimuli are seen; in persistent cases the electrocardiogram shows the patient’s underlying rhythm which is slower than the pacemakers demand rate. In the latter cases the pacemaker stimuli are dissociated from the intrinsic P waves or QRS complexes.

Causes
- Inappropriate output setting
- Increased resistance to conduction
- QRS complex not visible
- Faulty cable connection
- Dislodged/fractured lead
- Generator malfunction
- Battery depletion
- Oedema or scar tissue at electrode tip

Management
- Increase output setting
- Replace lead / wire
- Replace battery
- Check generator
- Check and tighten all connections of leads and pacing box

Under / Non-sensing: Failure of the pacemaker to sense intrinsic R-waves or intrinsic P waves.

- The pacemaker will fire and stimulate the atria or ventricles at its own predetermined rate, independently of the intrinsic rhythm, seemingly haphazardly. The intervals between the intrinsic and paced complexes are variable

Causes
- Inappropriate sensitivity setting
- Battery depletion
- Decreased QRS voltage
- Fusion beat
- Dislodged/fractured lead
Management
- Adjust sensitivity settings
- A fusion beat can usually be overcome by changing the pacing rate slightly, if it is occurring regularly
- Change leads
- Changes in QRS voltage, which can occur due to changes in chemistry, and with the administration of some drugs, it can also occur as a result of tissue damage or infarct. This can be picked up early by performing regular sensing threshold tests.

Over sensing: Inhibition of the pacemaker by events the pacemaker should ignore, e.g. EMI, T-waves, and myopotential

Causes
- Inappropriate sensitivity setting
- Myopotential inhibition
- EMI
- T-waves outside of refractory period
- Dislodged/fractured lead

Management
- Check sensitivity levels
- Sensing of T-waves in the atrial channel may cause inhibition of the atrial pace, and pacemaker mediated tachycardia, this can be overcome by extending the refractory period.

Myopotentials are the electrical signals given out by muscles other than the heart, which can be sensed by the pacemaker, particularly if set up in a unipolar configuration. These can sometimes be overcome by repositioning the lead. It may also be possible to eliminate myopotential sensing by making the pacemaker less sensitive, if this can be done without compromising appropriate sensing. Electromagnetic interference can potentially come from any poorly insulated electrical equipment operating near the temporary pacemaker, and transmitters such as mobile phones etc. Keep pacing leads well insulated, and protected. Move sources of interference away from the patient.

No Capture: Pacemaker fails to emit stimuli at the programmed intervals

Causes
- Battery depletion/pacemaker off
- Over sensing
- Faulty cable connection
- Dislodged/fractured lead
Management

- Check all connections, and ensure the correct pins are inserted in the pacemaker, that they are connected to the right chamber. Ensure that good contact is being made by all the connections.
- A dislodged lead can only be overcome by repositioning.
- No output can potentially be caused by a regular source of interference inhibiting the pacemaker.
- Check the pace/sense indicators on the pacemaker to see if it is sensing anything, or if it says that it is pacing.
- It sounds obvious, but it is worth checking to make sure the pacemaker is turned on, and that the low battery indicator is not showing.

Complications

Serious complications of internal pacing are rare, but are important to recognize, and include:

- Lead dislodgement and disconnection
- Bleeding
- Pericardial tamponade
- Thrombophlebitis
- Pulmonary embolism
- Catheter knotting
- Air embolism
- Various arrhythmias including ventricular tachycardia and ventricular fibrillation
- Electrical hazards, such an inadvertent induction of ventricular fibrillation
- Pneumothorax
- Subdiaphragmatic stimulation
- Infection
- Perforation
- Asystole

Clinical Issues

Underlying rhythm

- The need for ongoing pacing should be regularly reassessed. This is best done by turning down the pacing rate and allowing the intrinsic rhythm to appear.
- This is a better strategy than turning down the pacing energy output until capture is lost, as there may be no underlying rhythm at all.
- The patient's underlying rhythm should be documented on the pacing chart. If the patient is haemodynamically stable when the pacing rate is decreased a daily ECG should be done.

Care of pacing wires

- The pacing wire sites can be covered with a sterile dressing
- Always wear gloves when handling pacing wires
- Once attached to the pacing box the wires should be placed on top of gauze and taped to patients chest
- If wires are not being used they should be wrapped in gauze and taped to patients chest
- The sites must be checked daily for signs of infection, such as redness or purulent discharge and a swab sent for culture and sensitivity with any change reported to the Cardiothoracic team immediately.
- The wires must not be bent or pulled during the daily dressing.
- If the pacing wires are attached to the Pulse generator (Pacing Box) this should be securely hung on an Intravenous stand to prevent it from accidentally dropping to the floor, pulling on the cables or pulling out the wires.
- All pacing observations must be documented on the pacing checklist every 2 hours.
Battery 2:

- It is essential to have a spare battery particularly if the patient has NO underlying rhythm. Spare batteries and pacing boxes are located on the emergency trolley.
- If battery needs to be replaced on dependant patient a new box with new battery should be set up with same settings.
- The ventricular lead swapped first, then the atrial lead swapped from the previous box.
- The battery drawer, on the bottom of the temporary pacemaker, accepts two AA-sized alkaline batteries.
- Battery life is 7 days minimum with continuous operation for an alkaline battery when the RATE is set at 80 min and all other parameters are at nominal values =). Note: After 6 days or when the battery status displays 1 bar, the low battery status indicator flashes. When the low battery indicator flashes, the temporary pacemaker has 24 hours of battery life remaining.
- Battery drawer latch release button – The battery drawer latch release button at the bottom of the temporary pacemaker opens the battery drawer when it is pressed.

5. Performance Measures

All incidents are documented using the hospital electronic reporting system: IIMS and managed appropriately by the NUM and staff as directed.

6. Definitions

- Ampere (AMP, A)
  A measure of electrical current flowing past a point in a conductor when one volt of potential is applied across one ohm of resistance. In pacing, these currents are so small that they are expressed in thousandths of amperes (milliamperes, mA) or in millionths of amperes (microamperes, μA).

- Amplitude
  The maximum absolute value attained by an electrical waveform, voltage or current. The amplitudes of pacemaker output pulses are expressed in volts (the difference in electrical potential), or in milliamperes (the measure of the electrical current flow).

- AV Interval / Atrioventricular Interval, AV Delay
  In a dual chamber pacemaker mode the AV Interval is the period of time between an atrial event (sensed or paced) and a scheduled paced ventricular event. It is typically measured in milliseconds. The AV Interval can also be thought of as the pacemaker equivalent to the PR interval in normal conduction.

- Asynchronous pacemakers
  (a = not; syn = together; chrono = time) are those that are not together in time with the heart because they do not know what the heart is doing. Pacemakers such as AOO and VOO are asynchronous as they stimulate the heart at a fixed, preset rate independent of the electrical and/or mechanical activity of the heart.
- **Capture**
  Initiation of depolarisation of the atria and/or ventricles by an electrical stimulus delivered by an artificial pacemaker. Capture can be visualized on the monitor by a spike before every p wave (for atrial pacing) and a spike before every QRS (for ventricular pacing).

- **Dual-Chamber Pacemaker**
  A pacemaker with two leads (one in the atrium and one in the ventricle) to allow pacing and/or sensing in both chambers of the heart to artificially restore the natural contraction sequence of the heart.

- **Electromagnetic Interference (EMI)**
  Radiated or conducted energy – either electrical or magnetic – which can interfere with the function of the pacemaker.

- **Fusion Beat**
  Spontaneous cardiac depolarisation which occurs coincidentally with a paced depolarisation. The paced and natural depolarization waveforms collide or fuse, causing distortion of the surface ECG complex.

- **Intrinsic**
  Inherent; belonging to or originating from the heart itself, (e.g., an intrinsic beat refers to a naturally occurring heart beat).

- **Inhibited**
  Any pacemaker which, after sensing a spontaneous depolarisation, withholds its pacing stimulus. Examples are AAI, VVI

- **Millivolt**
  One one-thousandth of one volt. A unit of measure for low levels of voltage. Spontaneous, intrinsic P-waves and R-waves are measured in millivolts.

- **Milliseconds**
  One one-thousandth of one second. Most pacemaker timing functions, e.g., pulse width and pacing intervals, are expressed in milliseconds.

- **No Output**
  The absence of energy delivery to the heart.

- **Output**
  The electrical stimulus or energy generated by a pulse generator and intended to trigger a depolarisation in the chamber of the heart being paced.
- Pacing Modes

<table>
<thead>
<tr>
<th>CODE</th>
<th>Chamber Paced (1st Letter)</th>
<th>Chamber Sensed (2nd Letter)</th>
<th>Response to sensing Trigger or Inhibited (3rd Letter)</th>
<th>MEANING</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOO</td>
<td>Atrial pacing</td>
<td>None</td>
<td>None</td>
<td>Asynchronous atrial pacing occurs at a set rate, regardless of intrinsic atrial activity.</td>
</tr>
<tr>
<td>VOO</td>
<td>Ventricular Pacing</td>
<td>None</td>
<td>None</td>
<td>Asynchronous ventricular pacing occurs at a set rate, regardless of intrinsic Ventricular activity.</td>
</tr>
<tr>
<td>DOO</td>
<td>Ventricular &amp; atrial pacing</td>
<td>None</td>
<td>None</td>
<td>Asynchronous atrial &amp; ventricular pacing at a set rate regardless of intrinsic atrial &amp; ventricular activity</td>
</tr>
<tr>
<td>AAI</td>
<td>Atrial pacing</td>
<td>Atrial sensing</td>
<td>Inhibits pacing</td>
<td>A sensed P wave will cause the pacemaker to withhold atrial pacing. Absence of intrinsic p wave will lead to atrial pacing</td>
</tr>
<tr>
<td>VVI</td>
<td>Ventricular pacing</td>
<td>Ventricular sensing</td>
<td>Inhibits pacing</td>
<td>A sensed R wave will cause the pacemaker to withhold ventricular pacing. Absence of intrinsic R wave will lead to ventricular pacing</td>
</tr>
<tr>
<td>DDD</td>
<td>Atrial &amp; ventricular pacing</td>
<td>Atrial &amp; ventricular sensing</td>
<td>Inhibition of pacing &amp; trigger of pacing impulses</td>
<td>Intrinsic P &amp; R waves will cause the pacemaker to withhold pacing. Pacing impulses will be triggered when programmed intervals are exceeded</td>
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- Sensitivity
  Is the pacemaker’s ability to sense a patient’s intrinsic rhythm or when natural depolarisation is occurring.
  - The sensitivity number represents the minimum size, in millivolts, of an electrical signal that will be detected by the pacemaker
  - The higher the sensitivity (number) the less likely the pacemaker will see the patients rhythm
Sensing Threshold
The minimum atrial or ventricular intracardiac signal amplitude required to inhibit or trigger a demand pacemaker, expressed in millivolts.

Stimulation or output Threshold
The minimum electrical stimulus needed to consistently elicit a cardiac depolarisation. It can be expressed in terms of amplitude (volts, milliamps) and pulse width (milliseconds), or energy (microjoules).

Triggered
In pacemaker terms, a Triggered pacing mode is the opposite of inhibited. Upon detecting a spontaneous depolarisation or other signal, a triggered mode will deliver an electrical stimulus to the heart.

7. References / Links
1. Cardiac Pacemakers – Biological Aspects, Clinical Applications and Possible Complications. pg 135 -160, Chapter 7.
5. Pacemaker Following Adult Cardiac Surgery. Silvero Miriam, Browne Leonardo and Solari Gabriel Hospital San Juan de Dios de La Plata Argentina. www.intechopen.com
8. Temporary cardiac pacing for Critical Care Nurses resource folder. Prince of Wales Hospital. Amanda Joens, NE, POWP ICU July 2010
9. Medtronic pacing glossary. 2005
10. Systematic Assessment of Basic Pacemaker Function Kimberly Scheibly, RN, MS, CNS AACN. Advanced Critical Care Volume 21, Number 3, pp.322–328. 2010

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