CARDIAC PACING: PATIENT MANAGEMENT

PRACTICE GUIDELINE ©

DOCUMENT SUMMARY/KEY POINTS

This practice guideline relates to both temporary pacing and permanent pacemakers.

Note: All patients with external pacing should be managed within a "cardiac protected" patient treatment area, understanding this is not always possible during transit. A "cardiac protected" patient treatment area is one identified by a green sign with a white heart symbol in a white box.

Gloves must be worn when handling pacing wires, to avoid the potential for static electricity to cause a micro-electrocution.

- Cardiac pacing is a means of delivering an electrical stimulus to the heart muscle to treat low cardiac output state (LCOS) caused by an arrhythmia to optimise cardiac output.
- Patients with temporary pacing devices require continuous cardiac monitoring.
- A patient who is dependent on temporary pacing, with no underlying rhythm is unsuitable for transfer to the ward. The patient needs to have a safe underlying rhythm with adequate cardiac output prior to transfer.
- There are 4 types of temporary cardiac pacing:
  1. Epicardial pacing
  2. Transthoracic pacing
  3. Transvenous pacing
  4. Transoesophageal pacing
- A patient's coagulation profile must be checked and reviewed by the cardiac team prior to removal of pacing wires.
- General guide is an INR of <1.6 and platelets >100 000 for removal of wires. Some patients who are receiving anticoagulant therapy may have a higher INR; consult with cardiac team.

Approved by:	SCHN Policy, Procedure and Guideline Committee	
Date Effective:	1st September 2022	**Review Period:** 3 years
Team Leader:	Nurse Manager	**Area/Dept:** Cardiac Services

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CHANGE SUMMARY

- Updated to include permanent pacemakers
- Network guideline

READ ACKNOWLEDGEMENT

- All registered nurses involved in caring for patients requiring pacing must be deemed competent in the nursing management of cardiac pacing. See local NE/CNE for appropriate accreditation process.
- All clinical staff in PICU, ESW, CICU, C1S, ED, and Perioperative services must read and acknowledge the practice guideline.

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Introduction

The management of paediatric patients requiring temporary cardiac pacing is restricted to the following clinical areas:

- PICU, GCNC, ESW, CICU, C1S, ED, and Perioperative services

A patient who is dependent on temporary pacing, with no underlying rhythm is unsuitable for transfer to the ward. The patient needs to have a safe underlying rhythm with adequate cardiac output prior to transfer.

Rationale for Cardiac Pacing

- Cardiac pacing is a means of delivering an electrical stimulus to the heart muscle to treat low cardiac output state (LCOS) caused by an arrhythmia.[1] The aim of this treatment is to optimise cardiac output.

Temporary Pacing

Indications [2]

- Atrioventricular (AV) Block - second degree or third degree (complete heart block)
- As an adjunctive therapy to establish AV synchrony in postoperative arrhythmias such as junctional and Junctional Ectopic Tachycardia (JET)
- Overdrive pacing may be indicated for the termination of tachyarrhythmias, such as atrial flutter and supraventricular tachycardia (SVT)
- Any bradycardia with reduced cardiac output
- Support management of a patient prior to permanent pacemaker implantation

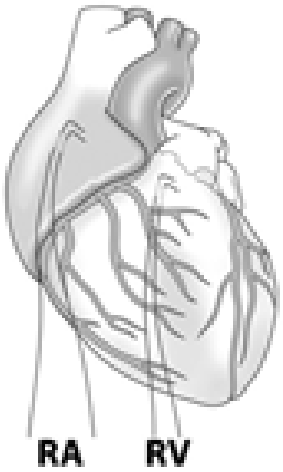
Methods or Routes Used for temporary pacing

Four types of temporary pacing:

1. Epicardial pacing

Arrhythmias are a common complication following cardiac surgery, therefore some patients may require support from a temporary pacemaker.[3,4] Epicardial wires are the preferred method if pacing is required post operatively and are routinely inserted during cardiac surgery. Epicardial pacing wires are insulated multifilament stainless steel wires that are stitched to the epicardium and brought through the chest wall before closing the sternotomy.[5,6] Usually two pairs of wires are attached, one pair attached to the right atrium (exiting the thorax on the right side of the sternum) and one pair attached to the right

ventricle (exiting on the left side of the sternum) (regardless of the underlying cardiac anatomy) unless labelled otherwise by the surgeon.[4,5,6] When there are two epicardial leads they can be used as either pole (positive or negative).



Epicardial pacing is the most common method of temporary pacing used at Sydney Children's' Hospitals Network (SCHN).

General Principles for Epicardial Pacing

Note: All patients with external pacing should be managed within a "cardiac protected" patient treatment area, understanding this is not always possible during transit. A "cardiac protected" patient treatment area is one identified by a green sign with a white heart symbol in a white box. This is to reduce the risk of micro-electrocution.[1, 7]

- The pacing device should be visible at all times and the wires secured to the patient. The device must be locked to prevent the patient accessing the pacing box and inadvertently altering the pacemaker settings.[2]
- A spare identical pacing device, including spare battery, should be readily available at the patient's bedside on the ward or on the unit in the ICU setting.[4] A spare device can be found as follows:
    - PICU store room
    - ESW arrest trolley
    - Heart Centre for Children (HCfC) Westmead
    - CICU
- When epicardial pacing wires are not in use they should have their tips insulated. This is done by curling the wire, wrapping it in gauze and adhering to the chest wall with an occlusive dressing.[5,6]
- Rubber gloves should always be used when handling epicardial pacing wires to prevent static electricity passing down the wires and causing micro-shocks.[1,7]
- Epicardial pacing wires may lose their ability to accurately sense and pace over time due to the tissue scarring that occurs at the point of the electrical impulse. This is described as increasing resistance. Pacing and sensing thresholds need to be checked daily (or

more often if the patient is “pacemaker dependant” with no underlying or intrinsic rhythm) and pacemaker settings adjusted accordingly by medical officer or accredited registered nurse in PICU/CICU.[2,7]

- Complication of epicardial wires include:
    - Infection
    - Myocardial damage
    - Arrhythmias
    - Perforation
    - Cardiac tamponade
- For a detailed table of potential complications post epicardial wire removal, see table on page 18.

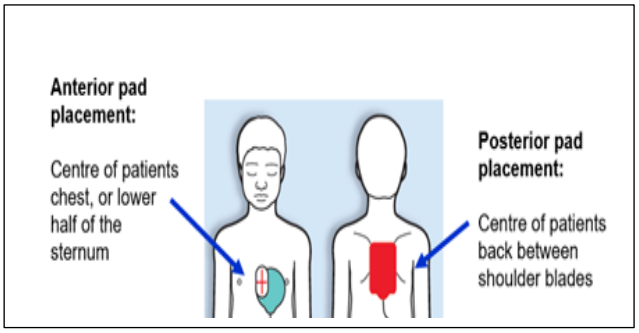
2. Transthoracic (non-invasive) pacing

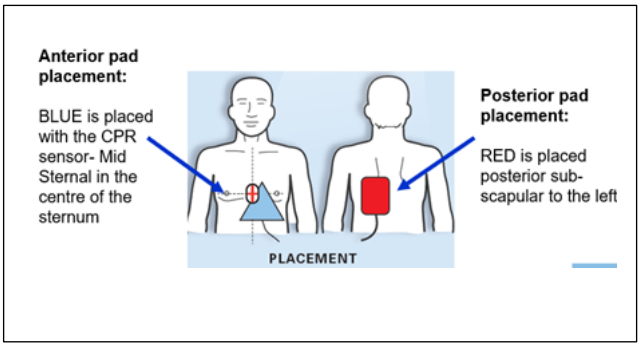
Transthoracic (non invasive) pacing is accomplished by using an external defibrillator with a pacing function.[5]

A spare defibrillator capable of delivering transthoracic pacing can be found in PICU, GCNC COU, Hunter Baillie, Camperdown, Emergency Department, CSSU, the HCfC at CHW and CICU, CIS, Recovery, ED and the HCfC at SCH.

Pad placement

The anterior pad is placed just left of the sternum, and the posterior pad is placed just left of the spine creating a ‘heart sandwich’, and a pathway for the electrical current. [1,7] For patients with dextrocardia, place the anterior pad on the right side of the sternum and the posterior pad on the right side of the spine. Do not place defibrillator pads over ECG dots, internal automated implantable cardioverter defibrillators (ICDs) or permanent pacemakers (PPM), wet skin, or bony areas such as the sternum or scapula.[7]





Pad size according to weight
<25kg- paediatric pads
>25kg – adult pads

General Principles for Non-Invasive Transthoracic Pacing

- Temporary transthoracic pacing is used primarily during emergency situations for the treatment of haemodynamically significant bradyarrhythmia or cardiac arrest that is unresponsive to resuscitative measures and pharmacology.[7]
- It is important to ensure the patient is administered analgesia and sedation.[7]
- As an effect of transthoracic pacing, the patient may experience muscular contraction of the chest and abdominal muscles.[7]

3. Transvenous pacing

Transvenous pacing - an electrode catheter is threaded through a vein (normally femoral or jugular vein) into the patient's right atrium or right ventricle.[5,7] The pacing lead is a self-contained bipolar system with two pins at the proximal end for connection to the bridging lead and pacing box.[7]

General Principles for Transvenous Pacing

- The puncture site should be covered in a transparent dressing to facilitate assessment of the site. The lead should be appropriately secured to the patient.[7]
- If the transvenous catheter is placed in the femoral vein the affected limb should be stabilised (kept as immobile and straight as comfortably possible). This is to avoid leg flexion, which may result in movement/dislodgement of the pacing lead. If there is any suspicion of lead movement, an xray must be performed.
- Circulation observations should also be performed on the affected limb. Refer to Post-Operative Management section in the 'Cardiac Catheterisation: Interventional, Non-interventional and Electrophysiological Studies' practice guideline.
- Transvenous pacing catheters positioned in the apex of the heart are prone to move or drift out of position.[5] This can result in failure to capture (see Trouble-shooting guide).
- The pacing device should be visible at all times and the wires secured to the patient with occlusive dressing. Make sure the device is locked to prevent the patient accessing the pacing box and inadvertently altering the pacemaker settings.[2]
- A spare identical pacing device should be readily available at the patient's bedside.[7]

4. Transoesophageal pacing

Transoesophageal pacing is an electrode attached to an oesophageal probe inserted to the oesophagus just behind the left atrium to permit temporary atrial pacing.[6,7] The patient is to remain sedated for the duration of this type of pacing.[7] This system may also be used in the diagnosis (electrophysiological study) and termination of arrhythmias including SVT.[4] However, as this pacing only captures the atrium, it cannot usually be used to treat AV block.

General Principles for Transoesophageal Pacing

- The bipolar lead is inserted by cardiologist via the nose or mouth, and is secured to the face with tape.
- The transoesophageal pacing lead is attached to an electrocardiographic (ECG) machine. The lead is then advanced and positioned behind the left atrium. This is indicated by the largest atrial signal as recorded on the ECG trace.
- When pacing is discontinued, the lead can be removed after consultation with cardiac team.
- Oesophageal injury and burns can be caused by long term oesophageal pacing.

Components of pacing system

A temporary pacing system consists of three main components

- Pulse generator/pacing box
- Bridging or connecting cable/s
- Pacing wires/leads/electrodes

The Medtronic 5392 (as pictured below) is commonly used at both Westmead and Randwick campus but different models may be used on occasion.

Modes of Pacing

Modern pacemakers offer several features in an effort to replicate physiologic cardiac rhythm and provide rhythm modulation as clinically indicated. To facilitate common understanding among health care providers a generic pacemaker code has been developed to describe the types and function of different devices (see table below). In practice, the temporary pacing mode is abbreviated as the 3 letter acronym.[7,8]

Pacemaker Nomenclature *NASPE/BPEG** GENERIC PACEMAKER (NBG) CODE

*North American Society of Pacing & Electrophysiology

**British Pacing & Electrophysiology Group

Temporary Pacemakers		
I	**II**	**III**
Chamber Paced	Chamber Sensed	Response to Sensing
	O = None	O = None
A = Atrium	A = Atrium	I = Inhibited
V = Ventricle	V = Ventricle	T = Triggered
D = Dual	D = Dual	D = Triggered & Inhibited

For example, AAI indicates that the atrium is paced, the atrium is sensed and the generator/pacemaker is inhibited if it senses intrinsic atrial activity. [5,7,8,9]

Nursing Management of Temporarily Paced Children

Assessing & Recording Vital Signs

All patients receiving temporary pacing therapy require continuous ECG monitoring; ensuring that the bedside monitor is set up appropriately for a paced patient. Regular assessment of hemodynamic stability is required, including the recording of **hourly** vital sign observations, or more frequently if required, including; [1]

- Heart rate
- Blood pressure
- Perfusion (skin colour, warmth, capillary refill, peripheral pulse strength)

Print a rhythm strip from bedside monitoring once per shift and place in patient notes.

How to Connect Pacing Wires

At Westmead campus It is recommended that the pacing wires should be connected by folding the wire electrode as shown (figure 1), prior to tightening the screw knobs. This will reduce the risk of the wire fracturing where the wire joins the exposed pin as shown in figure 2.

In some circumstances the fractured wire can be rendered useful again by removing a 2cm section of insulation cover from the wire and inserting it into the pacing box.

Figure 1

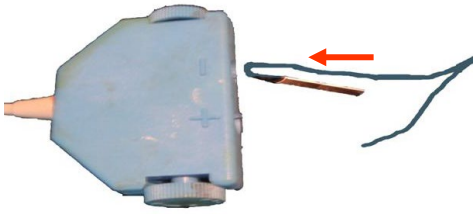
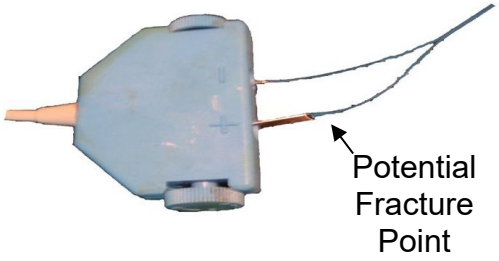


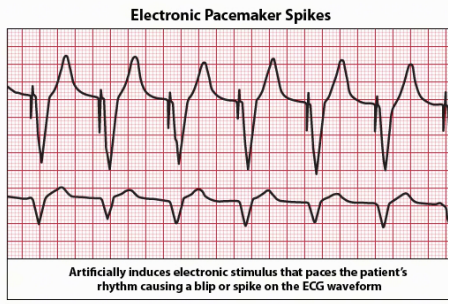
Figure 2



Assessing & Recording Pacemaker Function

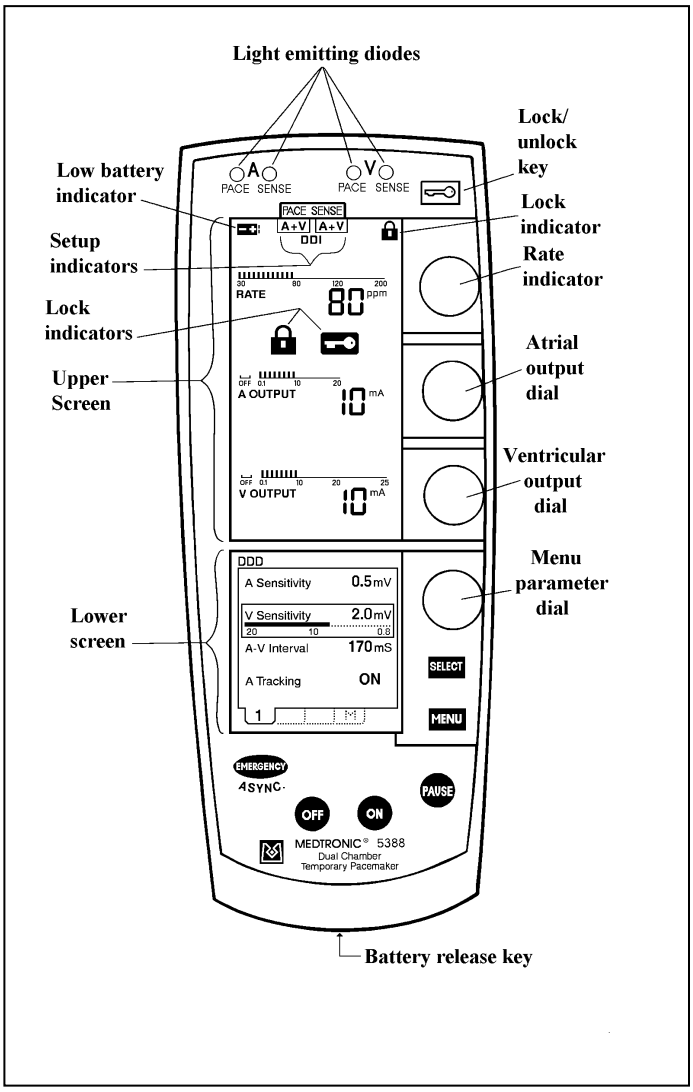
All infants and children receiving temporary pacing therapy require regular assessment and **hourly** documentation of pacemaker function, or more frequently if required, including

- Pacing mode. Ensure to check that the mode as well as the rate and output are programmed as have been prescribed. Prescription for pacing can be found in Powerchart > Interactive View and I&O > Quick View> Temporary Pacemaker-Medical. This prescription must be updated every 24hours and/or at time of pacemaker setting changes.
- Pacemaker capture - the pacing spike is followed by appropriate electrical activity, (i.e. an atrial pacing spike followed by a P-wave or a ventricular pacing spike followed by a QRS complex). Mechanical response to pacing can be supported through the palpation of the patient's pulse or correlating with the monitored pulse rate.[1]



- Pacemaker sense - the pacemaker is detecting the patient's own electrical output only (the patient's intrinsic electrical activity) and inhibits pacing appropriately in demand modes.[1]

- If the low battery indicator is displayed on the pacing device, immediate battery change is required. See 'Method for changing battery' section for further instructions.



- Check insertion sites of pacing wires into the patient's chest and ensure pacing wires are secured and no evidence of dislodgement.[1]
- Check all connections between the patient's chest and the pacing device. [1,7]
- Record observations on EMR according to local policy.

The following pacemaker checks need to be documented *every 12-24 hours*[1], or as the patient's condition warrants, and is to be performed by trained medical staff or in some circumstances by accredited RNs in the intensive care setting

- Threshold checks for capture
- Sensitivity threshold
- Determination of underlying rhythm

- Correlation between pacemaker order and pacemaker settings [1,7]
- Changes to the pacemaker order should be documented on each occasion a change occurs (the original order will be documented on the commencement of pacing)
- Additional pacemaker checking may be required if the patient has a breakthrough rhythm (an intrinsic rate that is faster than the rate set by the pacing device). Unless indicated by the patient's clinical condition, the underlying rate need not be checked more often that once per shift as this may cause a syncopal event if there is no underlying rhythm.[7]

The following section on output and sensitivity was taken from the Congenital heart disease: PICU Peri-operative management Practice Guideline – CHW. Refer to pages 31-33 of this document for further information:

Output [4,10]

The threshold is the minimum current necessary to capture & stimulate the heart. To test for this:

- Atrial and ventricular output is generated in milliamperes (mA). The typical atrial output is 5 mA and typical ventricular output is 8-10 mA. Set pacer rate 10 ppm faster than patient's heart rate
- Decrease mA until capture is lost (change in ECG)
- Increase output until capture is regained (threshold capture)
- Output setting to be 2mA above the threshold capture (example: set output at 7mA if capture was regained at 5mA)

Sensitivity [4,10]

The sensitivity is the minimum level of intrinsic electric activity generated by the heart detectable by the pacemaker. ONLY test for sensitivity if cardiovascularly stable in their intrinsic rhythm. To test for this follow:

- Atrial and ventricular sensitivity is measured in millivolts (mV). The typical atrial sensitivity is 0.5 mV and typical ventricular sensitivity is 2.0 – 5.0mV
- Set pacer rate 10 ppm slower than patient's HR
- Increase sensitivity to chamber being tested to minimum level (0.4mV)
- Decrease sensitivity of the pacer (↑mV) to the chamber being tested until pacer stops sensing patient (orange light stops flashing)
- Increase sensitivity of the pacer (↓mV) until the pacer senses the patient (orange light begins flashing). This is the threshold for sensitivity.
- Set the sensitivity at ½ the threshold value (example: set sensitivity at 1mV if the threshold was 2mV)

Method for Changing Battery

- A battery should last about 3-7 days depending on the pacemaker settings.
- Change of battery is required when the low battery indicator is shown. It is recommended to change the battery as soon as the low battery indicator is noticed.
- Battery change to be performed by Registered nurse who has completed the pacemaker accreditation.
- The pacemaker will operate for approximately 15 seconds after the battery is removed. There is a diagram inside the battery drawer to show correct orientation of battery when changing it.
- A second pacemaker should be available.
- Check settings prior to changing battery.
- Always replace with a new battery/ batteries.
- Leave pacemaker operating.
- Press battery release button, pull out drawer, insert new battery/ batteries, close drawer.
- Check that the pacing is functional after changing battery. Low battery indicator should now be inactive.
- Assess the patient, their vital signs, and assess and record the pacemaker function.

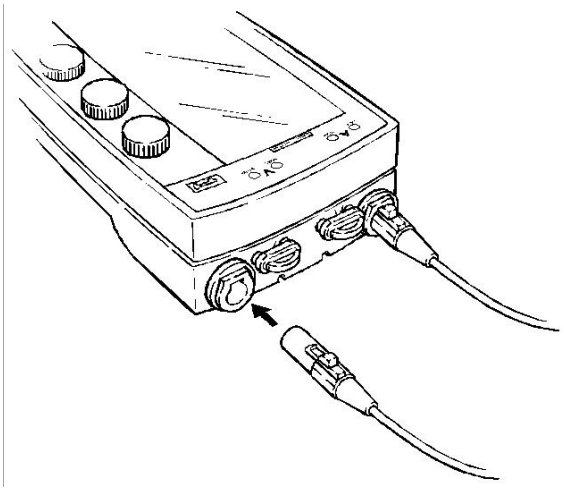
  Note: Depending on the pacemaker model, the pacemaker may require 2 AA batteries while others may require a 9volt battery. Ensure correct spare battery is ready before commencing battery change.

Method for Change of Device

If device thought to be faulty or malfunctioning (see troubleshooting table on page 15 for some common causes), notify the nurse in charge and medical team, and contact a cardiac technician if available, medical officer, or accredited Registered Nurse who is competent in changing a pacing device. At Westmead the PICU outreach service can be paged on #6664 for assistance.

If patient noted to be deteriorating due to suspected pacemaker malfunction, follow emergency protocols immediately.

- To change pacing box, preset the desired value on spare pacing device.
- Press the release button, unplug the cables from the old one and connected to the new pacing device (See diagram below).
- It is recommended for both cables to be unplugged and connected to the new device at the same time.
- The entire pacing device, including the battery, should be returned to biomedical department.



Temporary Pacing Trouble Shooting Guide[1,2,5,7]

FAILURE TO PACE: unable to pace patient despite appropriate pacemaker settings			
Signs & Symptoms	**Cause**	**Management**	**Responsibility**
No pacing activity Bradycardia Hypotension Loss of consciousness	Electrode displacement (transvenous)	Reposition patient, & reassess for pacing	Immediate RN Contact RMO
	Electrode displacement (epicardial)	CODE BLUE to be called. Emergency management for loss of cardiac output . Trained medical officer or accredited PICU RN to increase output to maximum setting on pacemaker if wire still in patient.	Emergency bell + CODE BLUE
			Page cardiac RMO
	Lead fracture	Strip insulation & reinsert wire into cable or replace wire in Op Suite	RN if able, or contact RMO
	Lead disconnection	Reconnect lead	
	Fibrotic tip or oedema/scar tissue at electrode tip	Swap polarity of electrodes	
		Increase output	
	Flat battery Pacemaker malfunction	Change pacemaker	RN/contact Cardiac Physiologist
	Electrolyte disturbance	Correct Electrolytes	RMO
FAILURE TO CAPTURE: when the pacemaker output fails to depolarise the myocardium			
Signs & Symptoms	**Cause**	**Management**	**Responsibility**
No P-wave/QRS complex after pacing spike Loss of atrial kick in atrially-paced patients Bradycardia Hypotension Syncope	Electrode displacement (transvenous)	Reposition patient & reassess for capture	Immediate RN Contact RMO
	Low output setting	Reassess threshold	RN if able, or Contact RMO
	Increase in pacing threshold due to oedema/scar tissue or fibrosis at electrode tip	Swap polarity of electrodes	
		Increase output	
	Lead fracture	Strip insulation & reinsert wire into cable	
	Lead disconnection	Reconnect lead	
	Flat battery Pacemaker malfunction	Change pacemaker	RN/contact Cardiac Physiologist
	Myocardial perforation from transvenous wire	Surgical emergency, treat haemodynamic instability	Call RMO & T/L Contact cardiac team
UNDERSENSING: when the pacemaker fails to detect intrinsic cardiac depolarisation			
Signs & Symptoms	**Cause**	**Management**	**Responsibility**
Pacing spike occurs pre-maturely or inappropriately Pacing spike may/may not produce a QRS complex depending on where it occurs in the cardiac cycle Palpitations, skipped beats Lethal arrhythmias can result from competition, or R-on-T phenomenon	Sensitivity too low (high mV number on sensitivity dial)	Increase sensitivity (reduce mV number on dial)	RN if able, or RMO
	Lead fracture	Strip insulation & reinsert wire into cable	
	Lead disconnection	Reconnect lead	RN if able
	Battery depletion Pacing box malfunction	Replace pacing box	
	Electromagnetic interference	Identify & remove cause	Cardiac Physiologist
	Fixed rate pacing	Reassess pacing modality	RMO
OVERSENSING: when the pacemaker detects non-cardiac electrical events			
Signs & Symptoms	**Cause**	**Management**	**Responsibility**
No pacing activity on ECG despite pacemaker being set at higher pulse rate than patient's intrinsic HR Sense light flashing at higher rate than patient's intrinsic pulse rate	Pacemaker sensing atrial or T wave activity in patient's intrinsic rhythm because sensitivity level is not set at appropriate level	Adjust sensitivity level	RN if able, or RMO
	Pacemaker sensing skeletal muscle contraction		
CHEST WALL OR DIAPHRAGMATIC STIMULATION:			
Signs & Symptoms	**Cause**	**Management**	**Responsibility**
Hiccups Muscle twitching Abdominal pain/discomfort	Output too high	Reassess threshold Reduce output	RN if able, or contact RMO
	Stimulation of phrenic nerve by electrode tip (transvenous lead)	Reposition patient & reassess for result	RN, contact RMO if no response to positioning

Removal of Epicardial Pacing Wires

Note: A patient's coagulation profile must be checked and reviewed by the cardiac team prior to removal of pacing wires. General guide is an INR of <1.6 and platelets >100 000 for removal of wires. Some patients who are receiving anticoagulant therapy may have a higher INR; consult with cardiac team.

Equipment:

- Dressing pack
- Gloves (non-sterile)
- Aqueous Chlorhexidine 0.5% / 0.9% Sodium chloride
- Stitch cutter
- Appropriate dressing

Timing of wire removal

- Pacing wires are only to be removed after discussion with Cardiologist and Cardiothoracic Surgeon as well as the intensivist if the patient is in the intensive care.
- The patient is to be in sinus rhythm for a minimum 24 hours prior to removal.
- It is the responsibility of the person removing the wires to ensure that the nurse in charge and a member of the cardiothoracic team are aware and available at the time of the wire removal.

Pre-procedural tests and documentation

- Most patients require a recent ECG or printed rhythm strip from bedside monitoring, and coagulation profile. INR< 1.6 and platelets >100 000.
- Consult with cardiac team for the need of establishment of IV access prior to wire removal
- It is the responsibility of the person performing the procedure to ensure all necessary tests are performed, that the results have been assessed by the medical staff and the decision to remove the wires documented.

Person performing the procedure

- The procedure will be performed by either a doctor or nurse with the relevant training and experience. Whoever undertakes the procedure must be competent or supervised in the procedure.
- Obtain assistance from another nurse or member of the medical team.

Preparation of the patient and carers

- Psychological preparation is to be given to the patient and/or parents at an appropriate level; a verbal explanation should be given of the possible complications of wires removal. The use of the child life therapist for preparation and/or distraction therapy is encouraged.

- It is not necessary to keep the patient fasted prior to pacing wire removal, but this will be determined by policy, especially where sedation is used. An assessment of the level of analgesia +/- sedation will be made on an individual patient basis

Chest Drains

- If chest drains are present they should be tapped/manipulated (in accordance with local policy for chest drain management), to ensure patency of drains thereby providing a pathway for bleeding and reducing potential for cardiac tamponade. Refer to the following SCHN chest drain practice guideline for further nursing management of patients with chest drains:

Important to remember:

- Notify the cardiothoracic registrar prior to procedure.
- The atrial pacing wire should be removed first as this allows for ventricular pacing to be undertaken should the patient's clinical status become unstable.
- Pacing wires should be removed by constant gentle traction, allowing the motion of the heart to assist dislodgment from the epicardial surface. Excessive traction should not be applied. [2,3]
- If the wires are unable to be removed due to excessive tension, stop and notify cardiothoracic nurse practitioner or fellow.

Procedure

1. Perform baseline vital signs and cardiac assessment and ensure patient is attached to a cardiac monitor
2. Print pre-wire removal rhythm strip from bedside monitoring
3. Perform hand hygiene and Don gloves
4. Remove any dressings from pacing wires
5. Clean wires and skin around puncture site with Aqueous Chlorhexidine 0.5% / 0.9% Sodium chloride
6. Cut suture holding the atrial wire
7. Place folded sterile gauze swab over atrial puncture site and wire and pull wire gently until it slides from the chest
8. Check the wire and wire tip are intact
9. Assess rhythm on cardiac monitor and assess patient
10. Assess chest tube drainage if applicable. If there is a sudden increase in drainage that does not resolve, contact cardiothoracic team before removing ventricular wire.
11. If rhythm and patient is stable, repeat previous steps to remove ventricular wire
12. Cover pacing wire sites with appropriate dressings as necessary

13. Perform vital signs and patient cardiac assessment
14. Dispose of equipment appropriately
15. Print post-wire removal rhythm strip from bedside monitoring and paste both strips on appropriate form and placed in patient notes.

Alert: Be alert for tamponade acutely or slowly evolving. Notify cardiothoracic team and cardiology fellow (who should perform immediate echocardiogram) if concerned.

Observations and Tests

- The RN should check the vital signs and perform a cardiac assessment immediately post-procedure and again every 30 minutes for 2 hours, or as the patient's condition warrants, to detect potential complications. Patient should remain on continuous cardiac monitoring until instructed to cease by team.
- Observe chest drain losses (if insitu) for signs of tamponade, eg: increased drain losses and haemoserous drainage.
- The patient should remain in the ward/unit for at least two hours post procedure. The patient (if age-appropriate) and parents should be aware of signs and symptoms of possible complications and to report any concerns to staff immediately.
- In some cases, an echocardiogram may be requested post-procedure.

Complications associated with removal of epicardial pacing wires:

Complication	Signs and Symptoms	Management
Cardiac tamponade[2]	Tachycardia, hypotension, cool peripheries with delayed capillary refill, reduced level of consciousness (LOC), arrhythmia, cardiac arrest	CODE BLUE to be called. Notify RMO/Nursing team leader (TL) & Cardiac surgeon Tap chest drains vigorously (if insitu) Assess vital signs and perform cardiac assessment Prepare Chest Opening Tray Follow emergency protocol for campus
Excessive Bleeding	Obvious bleeding from site, tachycardia, hypotension, pallor, poor peripheral perfusion, reducing LOC, shock	Notify RMO & Nursing T/L Assess vital signs and perform cardiac assessment Measure blood loss Prepare IV fluids to replace losses (blood products/4% NSA as available)
Arrhythmias[2]	Evident on cardiac monitor with or without change in hemodynamic status Irregular pulse rate	Notify RMO/Nursing T/L & Consultant Assess vital signs and perform cardiac assessment
Wires become wedged in chest	Hard to pull the wires	Do not use force to remove, Abandon the procedure and inform the cardiothoracic surgical registrar/cardiac team

Removal of Transvenous Pacing Lead

Transvenous Pacing Leads should be managed using the same principles as those for percutaneous Central Venous Access Devices (CVADs) outlined in the hospital guideline on CVADs. Once it has been deemed by the medical team that the patient's underlying rhythm is safe and reliable, the transvenous pacing lead can be removed. Ensure cuff is deflated prior to removal to avoid injury to the tricuspid valve, then remove in accordance to the removal of a non-tunnelled CVAD as per SCHN CVADs practice guideline:

Watch for arrhythmia when removing pacing lead as lead is intracardiac and can stimulate ectopic beats or arrhythmias.

Implantation of a Permanent Pacemaker (PPM)/ Automated Implantable Cardioverter Defibrillator (AICD)

The decision to insert a PPM/AICD is made by the treating cardiologist in consultation with an electrophysiology cardiologist. It is a surgical procedure requiring a general anaesthetic. The patient will present to Middleton ward (CHW) or Short Stay Surgical Unit (SCH) if an outpatient and proceed to surgery. Once recovered in the recovery unit, the patient will return to the ward. These procedures are also often performed on inpatients in the ward or Intensive Care Unit who present with primary cardiac problems or rhythm disturbances or who are post-operative following cardiac surgery.

Permanent pacemakers/AICDs can be single chamber (atrial or ventricular), dual chamber (atrial AND ventricular) or biventricular (right and left ventricle) systems depending on the mode of pacing (3,4). An AICD will **always** have a ventricular lead to elicit defibrillation shocks (3). A PPM/AICD may be a transvenous or an epicardial system (1,3) and the decision regarding which system to implant is dependent on the underlying rhythm, the size and age of the patient and goals of therapy. Single chamber systems have a single lead in either the atria or ventricle whereas dual chamber systems have two leads, one in the right atrium and one in the right ventricle. Biventricular systems have three leads, one in the right atrium and one in each of the ventricles.
AICDs often require defibrillator threshold testing (DFT) after implant, usually performed intraoperatively. If testing is not possible at the time of implant this will require subsequent general anaesthetic for this at a later date planned with the electrophysiology team.

Indications for Insertion of a Permanent Pacemaker

The following list is not exhaustive, but does include some typical indications for insertion of a permanent pacemaker. The indications for permanent pacing are relative and not absolute. Refer to 2021 PACES Expert Consensus Statement on the Indications and Management of Cardiovascular Implantable Electronic Devices in Pediatric Patients: Executive Summary for further information.

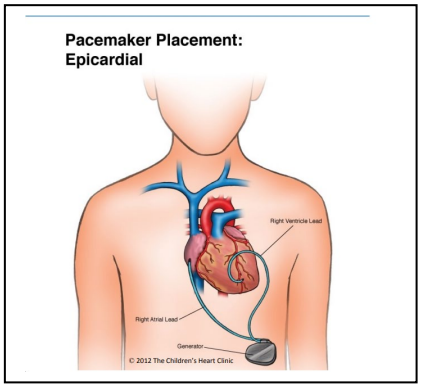
The overall clinical condition of the patient is considered rather than using this list as a definitive indication for insertion of a permanent pacemaker (for example, the rates specified for complete heart block in neonates).

- Second- or third-degree AV block with symptomatic bradycardia
- Sinus node dysfunction with symptomatic bradycardia
- An asymptomatic neonate with congenital third degree AV block and wide complex escape rhythm
- Asymptomatic patients after cardiac surgery with advanced second- or third-degree AV block where the patient's intrinsic conducted sinus rhythm did not spontaneously recover after ten days post operatively [11]

Types of Pacemakers

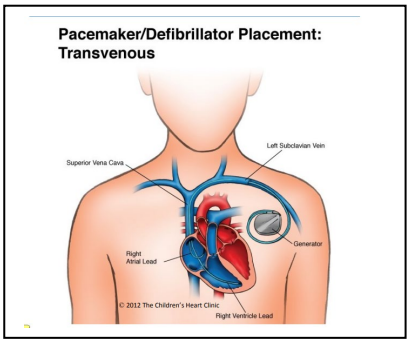
Epicardial System

Inserted into infants and young children who are smaller than 25 kg or children with congenital heart disease, particularly those with a Fontan circulation. The generator is placed in a subcutaneous or submuscular pocket in abdomen below the diaphragm (3) or in the left or right pleural cavity. The pacing leads are attached to the heart using sutures or screw-in leads and are placed via a subxiphoid approach, full or hemi-sternotomy or thoracotomy depending on location and number of leads.



Transvenous system

Inserted into older children who are ≥ 25 kg and teenagers where the central veins and heart are large enough to accept the pacemaker/AICD leads. The transvenous system is inserted through a small incision made under the collarbone (3). The generator is placed in the subcutaneous or submuscular (subpectoral) pocket just under the collarbone. The leads are threaded through the vein and placed in the endocardium of the right atrium and right ventricle



Permanent Pacemaker Nomenclature *NASPE/**BPEG GENERIC PACEMAKER (NBG) CODE

*North American Society of Pacing & Electrophysiology

**British Pacing & Electrophysiology Group [5,7,8,9]

Permanent Pacemakers				
I	II	III	IV	V
Chamber Paced	Chamber Sensed	Response to Sensing	Programmable Functions	Antiarrythmia Function
	O = None	O = None	O = None	O = None
A = Atrium	A = Atrium	I = Inhibited	P = Simple Programmable	P = Pacing
V = Ventricle	V = Ventricle	T = Triggered	M = Multi-Programmable	S = Shock
D = Dual	D = Dual	D = Triggered & Inhibited	C = Communicating	D = Dual (pace & sense)
			R = Rate Modulated	

Indications for Insertion of automated Implantable Cardioverter Defibrillator

The American Heart Association (AHA) has guidelines on the indications for an ICD.[12]

Some typical indications for insertion of an implantable defibrillator include.[12]

- Cardiac arrest due to ventricular fibrillation (VF) or ventricular tachycardia (VT) not due to a transient or reversible cause (secondary prevention)
- Syncope of undetermined origin with clinically relevant, haemodynamically significant sustained VT or VF induced at electrophysiological study when drug therapy is ineffective, not tolerated or not preferred
- Genetic channelopathies and other inherited conditions eg. long QT syndrome, Brugada syndrome, catecholaminergic VT may be an indication for primary prevention AICD insertion
- Systolic heart failure with severely impaired ventricular function in older children (>12yr) and adolescents may be an indication for primary prevention AICD insertion
- Hypertrophic cardiomyopathy may be an indication for primary prevention AICD insertion

For a full list of indications for an AICD, refer to the AHA guidelines.[12]

Alert - If patient with an AICD or PPM experiences cardiac arrest, the placement of external defibrillation pads/paddles in the anterior-posterior configuration is preferable to avoid damage to the device. Ensure pads are not placed directly over the ICD/PPM. Implantable cardioverter defibrillator shocks do not pose a danger to others during CPR; an unpleasant tingle has been described but can be prevented by wearing gloves while performing external cardiac compressions.[13]

Emergency Procedure for Malfunctioning automated implantable Defibrillation Device (ICD)/ Permanent Pacemaker (PPM)

In the circumstance of an ICD delivering a shock inappropriately, the Medtronic® Pulse Generator Magnet can be used to disable the defibrillator mode. In the event of a malfunctioning PPM, the Medtronic® Pulse Generator Magnet can be used to remove the PPM's sensing ability and places the PPM in an asynchronous pacing mode. The following information should be utilised in conjunction with the emergency protocol for each local area.

General Description

The magnet is a blue-coated, ring-shaped magnet used to verify proper operation of Medtronic® pulse generators. They are available across the hospital as follows:

- PICU (Chest opening trolley outside bed 11)
- ESW (resuscitation trolley and medication room)
- HCfC – Westmead and Randwick
- CICU (resuscitation trolley)
- C1S (resuscitation trolley)
- SCH ED (resuscitation trolley)
- OT
- ED (mobile arrest trolley)

The following information is provided by Medtronic® in the Pulse Generator Magnet product information sheet.[14]

Use of the Magnet

The patient needs to be ECG monitored when using the magnet as it will interfere with normal ICD function.

Holding the magnet against the skin directly over the implanted device will convert the device to asynchronous operation and interrupt automatic defibrillation. This means that the ICD pacing component will pace the heart at a preset heart rate as set in the pacemaker programming, regardless of the heart's own activity (intrinsic activity). Fundamentally, it will inhibit the defibrillation function but not the pacing function.

Note: the magnet needs to be left against the skin for the defibrillation function to remain deactivated.

When the magnet is used on a patient to interrupt inappropriate ICD defibrillator activity, this should be treated as a medical emergency as inappropriate ICD therapy can precipitate fatal arrhythmias. Appropriate medical staff should be contacted urgently and the Medtronic representative (or relevant industry technician) should be contacted as soon as possible to run diagnostics on the implanted device.

Care of the patient with an AICD or PPM

Patients will be admitted to inpatient ward or intensive care unit post operatively *refer to SCHN Paediatric Pacemaker Post-Operative Care*

On arrival to ward, commence continuous ECG, respiratory rate and oxygen saturation, and hourly BP monitoring and continue until advised by the Cardiac team.

Note: As the patient has a permanent pacemaker insitu, set the monitor to pacing and turn the respiratory measurement off. Keeping the respiration measurement on may affect the execution of pacing.

- Perform a head to toe cardiac assessment on arrival to the ward
- Ensure to check vital signs prior to receiving a handover on patient when transferred to the ward. Record these findings on the SPOC chart, ensuring findings are within normal parameters for age group as per the Between the Flags document: http://webapps.schn.health.nsw.gov.au/epolicy/policy/5035

Wound management

The incision site for an implantable device will be covered immediately with a dressing. This dressing can be removed on day 5 post-op. Once removed the wound should be cleaned in accordance with the Wound assessment and management Practice Guideline. Wound assessment and management practice guideline. A patient may also come back with a pleural chest drain post device insertion. Removal of chest drain should be in consultation with the cardiothoracic nurse practitioner, fellows or surgeon and is based upon the post-op chest x-ray and drainage. The removal of a chest drain should be completed as per the SCHN chest drain policy Chest drains Practice Guideline

Warnings

- Magnetic conversion of an implanted device to asynchronous operation may result in competitive pacing. This takes place when the patient's own heart rate competes with asynchronous pacing [15]
- MRI scans need to be avoided with non-conditional devices. Most new transvenous PPMs are MRI compatible. Some old transvenous systems are not MRI compatible – please contact the device company for confirmation of device compatibility.
- EPICARDIAL pacing and AICD systems are an **ABSOLUTE CONTRAINDICATION TO MRI.**
- For transvenous systems, it is important that immediately post-op, children avoid raising the arm on the side of the implant above shoulder height for the first 6 weeks post

implant. Patients should not perform load-bearing activities involving the arm on the side of the implant for 6 weeks post-operatively. Patients should not be lifted under the arms or participate in sport or physical activity involving the arms for 6 weeks post-operatively. As the leads are sutured to the pectoralis muscle, stretching and muscular activity of the arm can cause the lead to be pulled out of the heart prior to it becoming fibrosed in place by 6 weeks post-operatively.

- For epicardial systems, avoid overstretching the body for the first 6 weeks for example, avoid holding babies by the arms with their legs dangling unsupported, or for a child, avoid repositioning or physio activities that may cause the child to over reach. Most of the incisions for access to insert an epicardial system require division of skeletal muscle that is re-approximated with sutures – these incisions take 6-8 weeks to heal and in this time excess tension across the incisions should be avoided.
- Caution should be taken to prevent any direct trauma to site of implanted device to avoid device damage or lead fracture.
- See Transvenous or Epicardial cardiac device - discharge information sheets that are available in your local ward for further information.

Troubleshooting PPM *refer to SCHN Paediatric Troubleshooting PPM flowchart*

Troubleshooting a PPM in a paediatric patient is dependent upon the presenting problem. The patients should always be assessed first and haemodynamics supported. In the case of a fatal arrhythmia resulting from inappropriate pacing, the patient should be resuscitated as per hospital protocol and transferred to the PICU/CICU. Cardiopulmonary resuscitation and equipment Practice Guideline. The patient may present as stable with mild-moderate symptoms or be asymptomatic. Below are a list of problems that may present:

- Failure to capture
- Over/under sensing
- Palpitations
- Pain
- Inappropriate diaphragmatic pacing
- Symptomatic bradycardia/tachycardia outside of set pacemaker rate
- Syncope
- Abnormality detected on home monitoring

Potential causes:

- Lead fracture
- Lead dislodgment (mainly transvenous systems)
- Battery depletion of device
- Trauma to device causing damage

Troubleshooting the above can be done by:

- Observation/psuedomalfunction: review of electrolytes and patient history and assessment and optimise where able
- Device check: this can be done in business hours through the cardiac electrophysiology technicians. See appendix 1. After hours the emergency contact number for the device company should be called for urgent out-of-hours product support. A pacing technician from the device company will always be available to attend and interrogate the device. The patient/parents/carer/guardian should have a card with implant details so the device and company can be rapidly identified.
- Chest x-ray (both AP and Lateral) to observe device position and lead integrity
- 12 lead ECG: to assess rhythm
- Holter Monitor: to capture any events (asymptomatic and symptomatic)
- Reintervention: if required to replace lead/device, the patient will be presented at the JCC by the treating cardiologist or an urgent out-of-session JCC will be convened to discuss depending on clinical urgency.

Education and Follow up

Patients will require education post insertion of their device and follow up after discharge. Patients will be followed up in the pacemaker clinic 1 month after discharge and then 3 monthly (AICDs) and 6 monthly (PPMs). They will also be given a home monitor which enables their device to be checked and monitored remotely.

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Appendix 1: SCHN Paediatric Pacemaker Post-Operative Care

Handover

- Recovery RN to Inpatient Unit RN
- Inpatient Unit Medical handover to Cardiology Team

Handover documented in Patient Medical Record documented as per Clinical Standards, in addition to:

- Pacemaker details: company, model
- Pacemaker settings
- Company pacemaker representative contact details
- Commence continuous ECG, respiratory rate and oxygen saturation, and hourly BP monitoring

Day 1 Post Operative Care

- Pacemaker Check by Cardiac Physiologist or Company Representative

Pacing assessment and checks within agreed parameters?

NO → Refer to SCHN Paediatric Troubleshooting PPM flowchart

YES → Continue care provision as per nursing and medical care plan

Appendix 2: SCHN Paediatric Troubleshooting PPM

Pacemaker problem identified?

- Failure to capture
- Over/under sensing
- Palpitations
- Pain
- Inappropriate diaphragmatic pacing
- Symptomatic bradycardia/tachycardia outside of set pacemaker rate
- Syncope

↓

Assess patient
Contact on call Cardiology Fellow/Consultant
Continue care provision as per nursing and medical care plan
Perform 12 lead ECG

↓

Pacemaker check required

↓

Contact physiology department/ Company technician	
CHW	**SCH**
In hours (08:00-17:00 Mon- Fri) Contact HCfC: 52145 to speak to the cardiac physiologist	**In hours (08:00-17:00 Mon-Fri)** Contact HCfC: 98452145 to speak to the cardiac physiologist
After hours call appropriate company physiologist • Medtronic – 1800 643 193 • Abbott/St Jude – (02) 9966 7475 • Boston Scientific – 1800 245 559	**After hours** call appropriate company physiologist • Medtronic – 1800 643 193 • Abbott/ St Jude – (02) 9966 7475 • Boston Scientific – 1800 245 559