Care of the Patient with Temporary Pacemaker
In the Neonatal and Pediatric Cardiac Patient

What the Nurse Caring for a Patient with Congenital Heart Disease Needs to Know

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Introduction

A pacemaker is an electronic device which provides repetitive electrical stimuli to the right atrium (RA) or right ventricle (RV) and in dual chamber atrioventricular (AV) pacing, both. Single and dual chamber AV sequential pacing initiates and maintains the heart rate (HR) when the natural pacemaker, the sinoatrial (SA) node fails to fire is delayed or does not conduct regularly to the ventricles as in advanced AV block.

Postoperative cardiac arrhythmias are a major cause of morbidity and mortality in pediatric patients following repair of congenital heart defects (CHD). (Batra, 2008) Post-operative surgical trauma and/or surgical swelling are common and therefore some patients may require temporary pacemaker therapy support.

These guidelines review the management of patients with a temporary pacemaker. Nurses are encouraged to review their institutional policies and guidelines prior to caring for patients with pacemakers. Nurses are encouraged to review their institutional policies and guidelines prior to caring for patients with pacemakers. Please refer to the Society of Pediatric Cardiovascular Nurses (SPCN)/ Pediatric Cardiac Intensive Care Society (PCICS) guidelines on Arrhythmia Management, Postoperative Care, and guidelines on specific Congenital Heart Defects.

Critical Thinking Points

- Nurses caring for infants and children requiring permanent pacemaker therapy must be competent with pacemaker technology. Competency includes:
    - Knowledge of the types of pacemakers
    - Knowledge of programmed modes
    - Understanding of parameter settings
    - Capability to recognize and interpret normal/abnormal device function.
- Nurses must understand the patient's
    - Underlying cardiac rhythm and myocardial function
    - Degree of device dependency
    - Interpretation of intrinsic and paced electrocardiograms
    - Patient response to pacing (cardiac output)
    - Fundamental skills include:
        - Recognizing complications
            - Failure to pace
            - Failure to capture
            - Failure to sense (undersensing and oversensing)
        - Recognizing changes in patient's clinical condition when device may be a contributing factor
- Nurses should have the following basic knowledge
    - Knowledge of appropriate heart rate for age in pediatrics
    - Knowledge of pediatric cardiac arrhythmias
    - Understand pediatric congenital and acquired heart disease and associated acute and chronic electro-physiologic sequelae
    - Appreciate the surgical history, cardiac anatomy and acute and chronic electro physiologic sequelae as a result of cardiac repair

Definitions

- **Temporary Pacemaker:** Control box external to the patient and used in conjunction with temporary pacing catheter or lead(s) to help control heart rhythm.
- **Epicardial Lead(s):** lead(s) attached to the hearts epicardial surface.
- **Endocardial Lead(s):** pacing lead(s) enters into the heart chambers via a transvenous approach.
- **Inhibited:** The pacemaker does not pace when it senses an intrinsic beat.
- **Triggered:** When the pacemaker does not sense an event within a set amount of time an electrical current is delivered

Indications for Temporary Pacing

- Sinus node dysfunction with failure of the SA node to generate an appropriate heart rate response.
- Persistent bradycardia despite oxygen administration, breathing and chronotropic drug administration. (Hazinski, 2012)
- Junctional and ventricular escape rhythms
- Advanced AV block
- Congenital or acquired heart disease

- Congestive heart failure (CHF)
- Drug effects
- Hypoxic ischemic damage to the cells
- Electrolyte imbalance

Types of Temporary Pacing

- **Epicardial pacing**: leads attached to the epicardial surface of the heart via the thorax
- **Transvenous pacing:** leads inside the heart accessed through the veins
- **Transcutaneous pacing:** multifunction pads attached to the skin on the thorax, from a defibrillator with shock and pacing capabilities. This form of pacing provides ventricular demand (VVI) or fixed rate (VOO) pacing only.
- **Esophageal pacing:** an electrode passed down the esophagus and positioned directly behind the left atrium (LA). Used for emergency atrial demand pacing (AAI) for sinus bradycardia or alternatively for rapid atrial overdrive pacing of supraventricular tachycardia, (SVT) and atrial flutter. (Hazinski, 2012)

Pacing Coding System

A standardized generic coding system was established by the **North American Society of Pacing and Electrophysiology (NASPE) and the British Pacing and Electrophysiology Group (BPEG)** for anti-bradycardia pacing, adaptive rate and multisite pacing.

The Revised NASPE and BPEG Pacemaker Codes

Temporary		
I	**II**	**III**
Chamber(s) Paced	Chamber(s) Sensed	Mode(s) of Response
A=Atrium	A=Atrium	T=Triggered
V=Ventricle	V=Ventricle	I=Inhibited
D=Dual (A&V)	D=Dual (A&V)	D=Dual Triggered/Inhibited
O=None	O=None	O=None

Bernstein, et al., 2002

Position I: Refers to the specific chamber(s) being paced. The letter signifies the chamber: Atrium, Ventricular, and Dual or both.

Position II: Refers to the specific chamber(s) being sensed for intrinsic signals.

Position III: Action based on response to intrinsic signals that were sensed or not sensed (Position II)

- Inhibited mode will withhold output from the pacemaker if an appropriate timed intrinsic signal is sensed, if not it will deliver output.
- Triggered mode will provide output from the pacemaker after a programmed time interval from a sensed event. This is a very uncommon setting, mostly used during testing.
- Dual mode is dependent on what chambers are sensed (most often Dual sensed), in order to provide atrioventricular synchrony. (Miller, 2002)
- Dual mode uses both inhibited and triggered mode to function, as previously stated to provide atrioventricular synchrony.
- None mode, being zero action is taken.

Temporary Pacemaker Codes: Identified by a 3 letter coding system: (AOO, VOO, DOO, AAI, VVI, DDD, and DDI). Common temporary pacing modes are AAI, VVI, and DDD.

- **AAI** means the pacemaker paces and senses in the atrium and inhibits atrial pacing upon sensing an intrinsic atrial event.
- **VVI** means the pacemaker paces and senses in the ventricle and will inhibit ventricular pacing upon a sensed ventricular event.
- **DDD** means pacing and sensing occur in the atrium and ventricle, and the pacemaker will inhibit from atrial pacing upon a sensed P-wave. It will also track the P-wave with ventricular pacing (triggered) should a QRS not come within the specified AV interval (msec). A sensed R- wave will inhibit ventricular pacing.

Demand Pacing

- Demand pacing is the preferred form of pacing as it senses the patient's intrinsic rhythm preventing competition between intrinsic and paced beats. The sensitivity setting if set inappropriately causes inappropriate pacing.
- AAI, VVI, DDD, and DDI are examples of demand pacing which inhibit or pace in response to sensed activity.

Fixed Rate (Asynchronous) Pacing

- AOO, VOO, and DOO are modes that have no capability to sense the patient's intrinsic beats and so the pacemaker paces at a preset rate independent of the patient's rhythm. If the intrinsic heart rate rises above the paced rate, there can be competition between the pacemaker and the intrinsic rhythm. This can result in the pacemaker firing at inappropriate times and producing an "R on T" phenomenon. "R on T" is where the pacemaker fires and produces a QRS during the vulnerable T–wave, possibly precipitating ventricular tachycardia or ventricular fibrillation.
- Lack of sensed atrial beats may lead to atrial arrhythmias such as atrial fibrillation and flutter.

General Principles

- Placement of temporary pacing leads
    - Prophylactic placement of epicardial leads in the operating room (OR) (Everett, 2010)
        - Common in infants and young children
        - Patients with prosthetic valves
        - Patients with a single ventricle
    - Transvenous pacing catheters may be used for patients who need emergent pacing. Access may be via jugular or subclavian vein.

    - Transesophageal pacing is rarely used for extensive temporary pacing due to higher output requirements and patient discomfort caused by the pacing.
- Standard placement for dual chamber transthoracic (epicardial) leads
    - Atrial leads placed on the epicardial surface of the right atrium (RA)
    - Ventricular leads on the surface of the right ventricle (RV)
    - Pacing wires brought through the skin and sutured to the thorax
        - Atrial leads usually to the right side
        - Ventricular leads to the left side
        - This can be reversed in patients with dextrocardia (Reade, 2007)
- Postoperative programming
    - Takes into consideration arrhythmias that are more likely in immediate postoperative period
    - Pacemaker programming tailored to individual needs and specific congenital cardiac lesions
    - Adjustments in pacing settings made in response to observed rhythms by responsible physician
- Uses for dual chambered temporary epicardial pacing
    - Many rhythm disturbances
    - Pacing for an appropriate rate using atrial only pacing (Payne, 2011)
        - Atrial pacing
            - Requires an intact conduction system
            - Ensures the impulse conducts to ventricles.
        - Sinus node dysfunction
        - Bradycardia
    - AV block of all degrees (1^{st}, 2^{nd}, and 3^{rd} degree) with AV sequential pacing (Payne, 2011)
        - Pacing used to provide an adequate HR and AV synchrony
- First degree heart block
    - Rarely requires AV pacing
    - Unless associated with symptoms
- Atrial Pacing
    - Rapid Atrial Overdrive (RAP) pacing
        - Used to convert re-entrant tachyarrhythmias i.e. supraventricular tachycardia (SVT), atrial flutter (AFL) (Payne, 2011)
        - Procedure
            - Pacemaker set above the intrinsic atrial rate
            - Stimuli delivered until the operator lifts his/her finger off the RAP button (usually brief but may be up to 10 sec. of rapid burst atrial overdrive pacing)
    - Junctional ectopic tachycardia (JET) (Payne, 2011)
        - Establish AV synchrony
        - Procedure
            - Pacing the atrium at a rate higher than the junctional rate
            - Slowly decrease pacing rate to desired synchronous rate
            - Requires intact conduction system
- Acute monitoring and care/documentation

- Shift check between off-going and oncoming nurses ensures paced settings are in accordance to medical orders
    - Type: epicardial, transthoracic, esophageal.
    - Mode of therapy: fixed rate, demand and 3 letter code e.g. AAI, VVI, DDD or 5 letter code.
    - Programmed settings: rate (b/min); output (mA); sensitivity (mV) of atria and ventricle as applicable; AV interval (ms).
- Continuous EKG monitoring noting HR, dependence (on pacemaker) or not, presence or absence of atrial and ventricular pacing spikes vs. intrinsic beats.
- At least every 1- 4 hours depending on patient stability, phase of recovery i.e. fresh post- operative or rehabilitation, and hospital guidelines, the following checks should be performed and documented:
    - Vital signs. The pacemaker EKG does not always translate into myocardial contractions. Include patient intrinsic rhythm and rate if above paced settings.
    - Actual pacemaker activity: rate, atrial sensing, atrial pacing, ventricular sensing, ventricular pacing.
    - Complications: failure to pace, sense (under or over sensing), capture.
    - Battery check for battery icon indicator
    - Assess pacing site dressing
        - For drainage type and quality
        - Degree of swelling
        - Associated pain.
- Monitor HR from arterial line waveform or, if no arterial line exists, then from pulse oximetry using a saturation probe
- Set safe high and low alarm limits on bedside monitor
- Daily check by qualified practitioner (physician, nurse practitioner, fellow, trained RN) according to hospital policy
    - Underlying intrinsic rhythm
    - Sensing and capture thresholds
- Care of pacing wires (Reade, 2007)
    - Handled with non-conductive gloves
    - Secure safely to the patient's skin
    - Checked frequently
    - Epicardial pacing wires not attached to a pacemaker
        - Ensure they are immediately accessible and secured
        - Housed in their non-conductive caps. (Reade, 2007) If pacing wires are missing their protective caps, a plastic sleeve (e.g. Needle caps, micro lab tubes) or rubber tubing (end of Red Robinson tube) must be used to cover the terminal pins. Tape in place so wire tips remain protected. Protect patient skin from damage due to hard plastic. Temporary wires with exposed pin that cannot be covered should not be used.

- Special considerations
    - Inappropriate pacing or sensing activity (Batra, 2008)
        - Requires immediate communication with the responsible MD/Nurse Practitioner (NP)

        - Pacemaker dependent patients
            - Require a plan for accessible emergency back-up pacing equipment in case of loss of capture
            - A defibrillator with transcutaneous pacing capabilities should be readily available.
    - Electromechanical dissociation (EMD) (Reade, 2007)
        - Pacemaker output (spike) on an ECG not equate to myocardial capture and cardiac output.
        - Electrical events continue regardless of mechanical contraction
    - Deterioration of pacing threshold (Bantra, 2008)
        - Due to myocardial inflammation at the lead electrode attachment site
        - Increase in output voltage may be needed to achieve capture
    - High output pacemaker
        - Pacemaker with the capability of generating a higher energy output
        - May be needed for patients with loss of capture at the standard temporary pacemaker maximum ventricular current setting of 25 mA
        - Can deliver up to 50 mA of current

Paced Rhythm Analysis

- The ECG lead on the bedside monitor should be setup to clearly show the P-wave and QRS, the pacemaker detection mode or pacemaker tracking may be helpful. The bedside monitor alarm parameters are set to alarm for a low or high HR from the arterial pulse of an arterial line. Alternatively, if an arterial line is not present, then from the pulse wave of a saturation probe. Observing the flashing sensed and paced lights on the temporary pacemakers is useful to identify chambers paced and sensed and matching with the ECG monitor and printed ECG strip.

Atrial Pacing

- An electronic pacing spike observed before a P-wave represents an atrial paced beat.

Ventricular Pacing

- An electronic pacing spike observed before a QRS complex represents a ventricular paced beat. The QRS complex that is induced by ventricular pacing may be wide.

Varying Degrees of Paced Fusion

- **Fusion**: is present when the pacemaker's pacing impulse occurs at the same time as an intrinsic beat. The morphology is partial between the paced and the intrinsic QRS because the intrinsic beat is a combination of the pacemaker capture and intrinsic depolarization. This occurs because the timing of the pacemaker impulse was due at the same time that intrinsic beat. If there are frequent fusion beats with intrinsic rhythm, consideration may be given to reduce the low rate of the pacemaker to save battery life.

- **Pseudo fusion**: is present when there is a pacemaker spike in front of an intrinsic beat but the morphology is that of the intrinsic beat. The pacemaker spike occurred at a time when the

myocardium is already fully depolarized by the intrinsic beat. A pseudo fusion beat does not provide any indication of capture.

- **Pseudopseudo fusion:** beat is present in dual chamber pacemaker when an atrial pacing spike occurred in front of a spontaneous QRS, the pacing spike having no impact on the intrinsic QRS.

Testing & Calibration

Capture and sensing thresholds should be checked routinely and with any noted change from normal pacing function. Electrolyte imbalance, swelling, fibrosis at the wire site, class IC antiarrhythmic medications or poor myocardial function may alter the pacing or sensing thresholds. (McPherson 2004)

Threshold checks for temporary pacemakers should be done daily.

Capture Threshold

- Output is current measured in Milliamperes – mA.
- Capture threshold is the minimum pacemaker output required to stimulate the myocardium i.e. depolarization post pacing spike.
- Pacemaker settings for output should be programmed at least twice the capture threshold to provide for a margin of safety. (Hayes 2000, Reade 2007)
- Evidence of capture is a pacing spike followed by a P-wave or QRS, depending upon whether the pacing is in the atrium or ventricle or both.

Sensing Threshold

- Measured in millivolt (mV)
- Sensing threshold is the minimum amplitude of the intrinsic cardiac signal that the pacemaker is able to sense.
- If the sensitivity value is set too high [large mV number = less sensitive], the pacemaker will fail to sense intrinsic events, and may result in over pacing, competing with the intrinsic rhythm. (Reade, 2007)
- If sensitivity value is set too low [small mV number = more sensitive] the pacemaker may pick up electrical noise other than the cardiac signal and may lead to inappropriate pauses from pacing or inappropriate triggered activity, resulting in bradycardia or tachycardia respectively. (Reade, 2007)
- The sensitivity value is programmed to at least two fold more sensitive than the sensing threshold. (Hayes 2000)

Setting Original Pacemaker Parameters

- Identify underlying rhythm and decide upon the desired demand mode of pacing: AAI, VVI, DDD, or DDI (atrial tracking off).

Threshold Testing

- Set pacemaker rate dial 10 beats above intrinsic heart rate
- Turn up the output (mA) until you have capture (each spike is followed by a depolarization)

- Then test the threshold by decreasing the output (mA) while watching the monitor and looking at the pacemaker quickly when capture is lost or by counting down in your head with each click of the dial as you watch the monitor.
- Reduce the mA until 1:1 capture is lost, indicated by a pacemaker spike that does not produce a P or QRS wave depending on whether you are testing atrial or ventricular thresholds respectively.
- Set the atrial and ventricular mA's two times above their respective thresholds e.g. if captures at 3 mA, leave at 6 mA.
- Reset the lower limit (heart rate) to the desired setting.

Sensitivity settings

You may need to test the sensing threshold if you suspect that there is over-sensing (sensing of electrical activity that is not an accurate reflection of atrial or ventricular depolarization). In the event of under-sensing (pacemaker does not sense electrical activity that should be sensed), you can simply increase the sensitivity by decreasing the mV value until sensing occurs and then leave the pacemaker set at a setting between the sensing threshold and the maximum sensitivity (lowest mV value) setting on the device where over-sensing does not occur. Typically we would use 0.5mV for the atrium and 2.0mV for the ventricle.

In the event that there is under or over sensing in a dual chamber mode, you also need to consider if the problem might be an upper rate limit that is set too low or a PVARP that is too short respectively. If the sensing is appropriate at the default setting it may not be necessary or advisable to test sensitivity thresholds.

- Test the sensing thresholds and adjust the sensitivity settings of the atria and ventricles channels separately.
- Set pacemaker low rate to 10 bpm below intrinsic heart rate.
- Turn the output (mA) to the lowest non-zero setting so the pacemaker does not deliver energy inappropriately to a sensed beat in the atrium or ventricle causing atrial flutter/fibrillation or ventricular fibrillation.
- To check the amplitude of the intrinsic intracardiac signal, observe the sense indicator light while decreasing pacemaker sensitivity (increase mV value) from small to larger numbers until the sensing light stops flashing (this is the point when the pacemaker does not sense the intrinsic signal) and the pacemaker starts pacing. The sensing threshold is the minimum amplitude of the intrinsic cardiac signal that the pacemaker is able to sense.
- Set the sensitivity value to half the sensing threshold so the pacemaker will consistently sense the intrinsic intracardiac signals e.g. the pacemaker senses appropriately at 6 mV not 10mV,set the sensitivity at 3 mV.
- Reset the low rate and turn the output (mA) back to desired setting.

Checking Underlying Rhythm and Pacemaker Settings Daily

- When assessing for an underlying rhythm, slowly turn the low rate dial below the paced rate until sensing occurs. Patient hemodynamics should be monitored during this time to ensure patient stability and the pacemaker is reset back to its preset rate if the hemodynamics become compromised.

- If there are observed problems with capture or sensing, thresholds should be retested and reset accordingly.
- Document threshold and pacing settings.

Features

Upper Rate Behavior

- In dual chamber pacemakers, when the atrial rate exceeds the maximum tracking rate (MTR) of the pacemaker, the pacemaker will not be able to track the atrial rate with ventricular pacing in a 1:1 manner. It will start to show upper rate behavior (some P-waves are not tracked) depending on the pacemaker setting of the total atrial refractory period (TARP) which equals the sum of post ventricular atrial refractory period and AV delay (see below for explanation). When the atrial rate is between MTR and TARP, the ECG will show Wenckebach like group beating whereby occasional P-waves will not be tracked. When the atrial rate exceeds TARP, then only every other P-wave is tracked, ECG will show 2:1 ventricular tracking of P-waves. Thus the atrial rate will help to confirm if the pacemaker is showing upper rate behavior.

Ventricular Safety Pacing

- This feature is designed to minimize cross talk in dual chamber pacemaker. Cross talk occurs when the ventricular chamber senses the atrial pacing output and inhibits from ventricular pacing. This may be catastrophic if the patient has complete heart block and no escape rhythm. When a ventricular sensed event occurs during the noise sampling period within the AV delay after atrial pacing, the pacemaker will deliver ventricular pacing at a shortened AV interval (ventricular safety pacing interval) usually 100-120ms depending on the manufacturer.
- On the ECG this may appear to be undersensing if safety pacing is triggered by a PVC that is sensed after atrial pacing, but in fact the PVC was sensed as evident by the shortened safety pacing interval.

Additional Pacemaker Therapies

Rapid Atrial Overdrive Pacing

- Patients may have AFL or atrial tachycardia after surgery with a significant hemodynamic brady-tachycardia syndrome. This may be seen after Fontan, Mustard, Senning, and TAPVD repairs although it can occur after any cardiac operation.
- Most commonly these are reentrant arrhythmia around anatomic barriers, atriotomy, surgical scar or incision lines where areas of slow conduction or block create the substrate for the reentry circuit.
- In order to overdrive a reentrant circuit, there needs to be an excitable gap that allows the pacing stimuli to enter into the reentry circuit to reset the tachycardia (entrain) or terminate it.
- The ability of the pacing stimuli to enter into a reentry circuit depends on the proximity of the pacing site to the circuit, the size of the excitable gap. The smaller it is such as in a micro-reentrant circuit, the harder it is to enter it. It also depends upon the tachycardia rate and the pacing output. The higher the output, the more likely one can achieve capture at the faster pacing rate. (Waldo 1981) Rapid atrial pacing is used for re-entrant rhythms (SVT, AFL). Pacing for a short duration (up to approx. 10 sec) at a rate 10-20 beats higher than the

patient's intrinsic atrial rate takes over the circuit. This may terminate the dysrhythmia when pacing is discontinued and allows NSR to resume control. (Payne, 2011)

- This procedure is performed by a qualified practitioner in the hospital setting.
- Overdrive pacing using a temporary pacemaker may result in acceleration of the tachycardia or degeneration of the tachycardia to fibrillation that may require cardioversion. Thus a defibrillator should be available. It is also important to take precaution to ensure that the atrial stimuli are not capturing the ventricle before delivering rapid pacing.
- In general, short bursts of atrial pacing stimuli from 85 up to 70% of the tachycardia cycle length may be effective to terminate atrial flutter or tachycardia. (Zhu 1996)
- Consideration may be given to maintain set the low rate atrial pacing of the pacemaker slightly above the intrinsic rate to establish a regular atrial rhythm and prevent PACs from initiating atrial flutter or tachycardia. (Hayes 2000)

Cardiac Resynchronization Therapy (CRT)

- Temporary triple chamber pacemaker is available for patients who need CRT pacing in the ICU setting.
- CRT is a three wire pacemaker system (atrial lead, RV lead and LV lead) that is used to manage patients with congestive heart failure, ventricular dyssynchrony whereby the loss of coordination between right and left ventricular contraction results in inefficient pumping of blood.
- The goal of CRT pacing is to always biventricular pace in order to resynchronize the two ventricles for maximal effectiveness. When pacing occurs, two pacing spikes may be seen for ventricular capture and continuous biventricular capture should not show any changes in paced QRS morphology.
- If changes in paced QRS are noted, then it is important to investigate to see if there is loss of biventricular capture. A 12 Lead ECG may be helpful along with a full pacemaker check for stimulation thresholds.
- In rare instances, biventricular pacing may be proarrhythmic causing an electrical storm. The etiology is not clearly understood or it may be the sequelae of very sick patients. (Dubin 2005)
- There is some preliminary data showing that post-operative biventricular pacing may help to decrease ICU length of stay and shorten time to extubation. (Stephenson 2014)

Use for Diagnostic Evaluation

Temporary Pacing - Atrial Electrocardiogram

- Atrial pacemaker wires may be used to show an atrial electrogram when there is a question about the presence of P-waves during an arrhythmia. (Reade, 2007)
- When P waves are not clear or visible on the ECG, an atrial electrogram may be recorded by attaching the atrial wires to the right and left arm leads of a ECG monitor. In a three lead ECG lead II, III is a hybrid ECG and atrial electrogram. Lead I has the bipolar atrial electrogram. This recording may help to illustrate the relation of the P-wave to the QRS. (Reade, 2007)
- This type of recording can be used to differentiate JET, atrial ectopic tachycardia (AET), AFL and SVT, and may be used to differentiate the level of heart block or whenever P waves are not visible or clear. (Reade, 2007)

Complications/Trouble Shooting Pacing Failures

- Fundamental pacing problems causing failure in pacing are outlined below.

Problem/ Criteria	Cause	Treatment
Failure to Capture		
Delivered pacemaker output does not evoke myocardial depolarization, resulting in asystole or no output. Problem may be capture threshold changes or lead hardware issue.	Scar tissue Poor myocardial function Electrolyte or metabolic imbalance Class IC antiarrhythmic drugs Lead fracture or insulation damage. (McPherson 2004)	MD to check threshold and pacemaker output immediately. Increase mA to achieve capture If unable to capture adequately, a new temporary wire may need to be placed.
Failure to Sense		
Undersensing Present when pacemaker inappropriately paces after a spontaneous P - wave (atrial undersense) or R-wave (ventricular undersense). Appears as too much pacing on ECG – random pacing spikes Inappropriate pacing may induce arrhythmias and thus should be recognized and corrected quickly.	Changes in intrinsic signal amplitude (scarring). Insufficient safety margin in the programmed sensitivity Pacemaker set on Fixed Rate/Asynchronous Pacing (number value too high, sensitivity to low). Lead fracture or insulation damage or loose cable connection Poor electrode placement Battery depletion	MD to check sensing threshold and adjust sensitivity setting. Sensitivity setting should be set to half the threshold level. Decreasing the mV number increases the sensitivity. Tighten cable connection. Surgical replacement of pacing lead Reposition patient Replace battery
Oversensing Pacemaker senses false electrical signals Expected pacing beat not seen. Present when the pacemaker inappropriately inhibits pacing, resulting in pauses or inappropriate	Sensitivity may be too sensitive and the pacemaker picks up (over senses) other electrical signals such as T wave or muscle noise. Sensitivity set too high (mV number value too low)	Inappropriate sensing will require the sensing thresholds to be checked by MD and reset Increasing the mV number (decreasing the sensitivity)

tracking in DDD mode. This causes bradycardia		
Failure to Pace		
Lead Fracture	Fracture in the wires related to kinking of the atrial wire	Replace pacing lead
Lead Dislodgment	Lead no longer touching myocardium	Requires surgical replacement if required or removal if no longer needed
Battery Depletion	Dependent upon amount of usage: rate, mA, and frequency of paced beats	Replace battery when battery light indicator signals or in accordance with organizational policy

Pacemaker Mediated Tachycardia (PMT)

- This may occur in patients with a dual chamber pacemaker that is programmed in DDD and the patient has intact retrograde conduction usually through the AV node.
- PMT is seen as ventricular pacing driven at a higher rate in a repeated cycle of tracking atrial sensed retrograde P-waves. The cycle of this sustained tachycardia can be stopped when there is loss of retrograde conduction (e.g. carotid sinus massage, giving adenosine to block retrograde AV node conduction) or P-wave that is not sensed e.g. extension of the post ventricular atrial refractory period (PVARP).
- PMT may be initiated by loss of AV synchrony through PVC, loss of atrial capture, untracked PAC, and tracking of myopotential or noise.
- PMT may be prevented by programming PVARP long enough to exclude sensing of retrograde P- wave

Extracardiac Stimulation

- Usually involves inadvertent stimulation of the diaphragm, pectoral or intercostal muscles.
- Diaphragmatic stimulation may be caused by direct stimulation of the phrenic nerve; it may be caused by micro-dislodgment of the pacing lead or the proximity of the pacing electrode to the phrenic nerve or diaphragm.
- Pectoral stimulation may be due to local capture of the muscle from the pacemaker generator or current leak from a lead insulation failure or connector.
- Stimulation can be minimized or alleviated by decreasing the voltage output and/or pulse width, an adequate pacing margin of safety must be maintained, lastly the lead may need to be repositioned.

Critical Thinking Points

- In the critically ill patient, pulseless electrical activity (PEA) or electromechanical dissociation may occur despite presence of pacemaker capture of myocardium. The main causes of PEA may be severe hypovolemia, pump failure or obstruction to circulation. PEA is present when there is no corresponding arterial pulse with each paced QRS. Patient may require emergency Extracorporeal Membrane Oxygenation (ECMO). (Beun 2015; Girotra 2013)

- In epicardial pacing, atrial leads are brought through the skin on right side of sternum and ventricular leads on the left. Ensure the wires are not inadvertently crossed under dressings. Follow wires from patient to the pacemaker box. Lead wires can also be connected to the wrong pacing ports on the pacemaker itself i.e. atrial wires inserted into ventricular ports and vice versa. If the patient were to require RAP, ventricular tachycardia would be induced. (Reade, 2007)

Battery Life

- Battery should be checked with each patient pacemaker assessment
- Some institutions may keep spare batteries at the bedside, others on defibrillation carts. Spare batteries should be close at hand, regardless of specific institutional differences.
- Temporary pacemaker battery lasts approximately 1 week. Nurses must ensure that the battery status is checked by looking at the battery light indicator on the battery itself i.e. for Medtronic 5392 pacemaker there is an icon with bars. The number of bars deplete as the battery is drained. Once the battery is deplete the battery indicator illuminates up red.
- Protocols for changing battery and variations for pacer dependent patient should be established on an institutional basis since the type of temporary pacemakers used, and staffing roles may vary between institutions. For those institutions where nurses are responsible for changing the battery, nurses should practice battery change procedure to become proficient at change. Consider the need for additional medical staff to be present for battery change procedure, dependent on patient condition (i.e. pacemaker dependency).

Setting

- Recognition of normal pacemaker function e.g. upper rate behavior, cardiac resynchronization therapy, minimal ventricular pacing, anti-tachycardia pacing.
- Recognition and management of pacemaker malfunction e.g. loss of capture, oversensing, undersensing, and loss of biventricular capture.
- Programming considerations: immediate post-operative period, pacemaker dependent, arrhythmia management.

Special Considerations

Problems Specific to Pediatrics

- Temporary pacing wires may be used for up to three months in this select patient population. (Batra, 2008)

Pacing Wire Removal

- Anticoagulation levels need to be checked before epicardial wire removal. (Reade, 2007)

Magnetic Resonance Imaging (MRI) Safety

- MRI safety is not assured with temporary pacing wires and so not possible if they are dependent upon the pacemaker. (Reade, 2007)
- Temporary pacemaker units may not enter into the Magnetic Resonance Imaging area. (Reade, 2007)
- Magnetic fields and radiofrequency pulses may cause wires may migrate during the procedure. (Reade, 2007)
- Tips of wires may heat and cause damage to the myocardium. (Reade, 2007)

Complications

General

- Bleeding, infection, myocardial damage, arrhythmias, myocardial perforation, and pneumothorax. (Batra, 2008)
- Hematomas and seromas. Small hematomas can be closely monitored and managed with warm compresses to improve the absorption process. Large hematomas that compromise the suture line or skin integrity may have to be surgically evacuated. Needle aspiration increases risk of infection and is not recommended.
- Patients who are anti-coagulated are at increased risk of bleeding. In patients requiring oral anticoagulants, refer to 2014 American Heart Association /ACC Anticoagulation Guidelines.

Venous Thrombosis (Endocardial Pacing)

- There is a greater than two fold increased risk of systemic thromboemboli in patients with intracardiac shunts and transvenous pacemaker systems. Therefore transvenous leads should be avoided in the presence of an intracardiac shunt or elimination of the shunt should be pursued before transvenous lead implantation if feasible. (Khairy et al., 2006). In a situation that calls for emergency transvenous pacing this may not be possible.

Complications upon Temporary Wire Removal

- Arrhythmias, bleeding, and cardiac tamponade. (Reade, 2007)
- For patients with life threatening underlying rhythms, it is advisable to have a backup pacemaker on hand such as a transcutaneous pacemaker.

In summary, temporary pacemakers are external devices that deliver an electrical impulse when the patient's intrinsic conduction system is not functioning optimally. Depending upon the mode and programmed settings, pacemakers have the capability to sense inherent cardiac electrical activity and pace the heart. Nurses must have a solid understanding of these devices and be able to recognize normal and abnormal pacing. Pacemaker lead system malfunctions include undersensing, oversensing, loss of capture, no pacing output, battery depletion and pacemaker mediated tachycardia. Consultation with the electrophysiology team and other experts is vital to successful pacemaker therapy.

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