Mastering Temporary Invasive Cardiac Pacing

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Invasive electrical pacing is used to initiate myocardial contractions when intrinsic stimulation is insufficient, the native impulses are not being conducted, or the heart rate is too slow to maintain an adequate cardiac output.[1,2] Several pacing options are available. Selection of a particular method depends on both the patient's current condition and his or her projected future needs. Among patients with cardiac disease, noninvasive (transcutaneous), semi-invasive (esophageal), temporary invasive, and implanted (permanent) pacemakers are often indicated.[1,2] In this article, however, we focus on those invasive but temporary pacemaker systems that critical care nurses often find confusing.

Temporary invasive pacing of the myocardium is used for a variety of emergent and elective conditions[1] (Table 1). Pacing electrodes are routinely inserted during certain cardiac surgical procedures such as bypass grafting and valve repair or replacement.[2] Another common indication for insertion of a temporary pacemaker is recent myocardial infarction.[3] Although treatment with β-blocking agents is considered an important intervention after recent myocardial infarction, the agents slow the heart rate markedly.[4] In addition, serious bradydysrhythmias often occur in patients with recent myocardial infarction even without drug therapy.[5] These low heart rates interfere with successful recovery. Temporary pacing after myocardial infarction can be a lifesaving intervention, allowing patients to enjoy the benefits of β-blocker therapy while simultaneously maintaining an adequate heart rate and cardiac output.

Table 1 Indications for temporary invasive cardiac pacing

Sick sinus syndrome	Symptomatic sinus arrest Suppression of ventricular ectopy resulting from bradycardia Atrial fibrillation Bradycardia/tachycardia syndrome Symptomatic sinus bradycardia
Heart blocks	Type I (occasionally) and type II second-degree atrioventricular block Acute bifascicular or trifascicular block Complete atrioventricular block Cardiac arrest with ventricular asystole
Drug-refractory dysrhythmia	Overdrive ventricular pacing to suppress or prevent ventricular ectopic activity Overdrive atrial pacing to "break" supraventricular tachycardia or atrial flutter
Cardiovascular surgery	Prophylactic use during anesthesia and surgery in patients with a history of acute coronary syndrome or cardiac dysrhythmias Treatment for complete heart block developed during or after surgery Cardiac output augmentation postoperatively

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Although the generators used with temporary pacemakers can be intimidating, familiarity with this equipment is essential for critical care nurses.[1] In the following material, we review relevant cardiac anatomy and physiology, discuss various pacemaker components, and describe the nursing care of patients being paced with transvenous or epicardial electrodes.

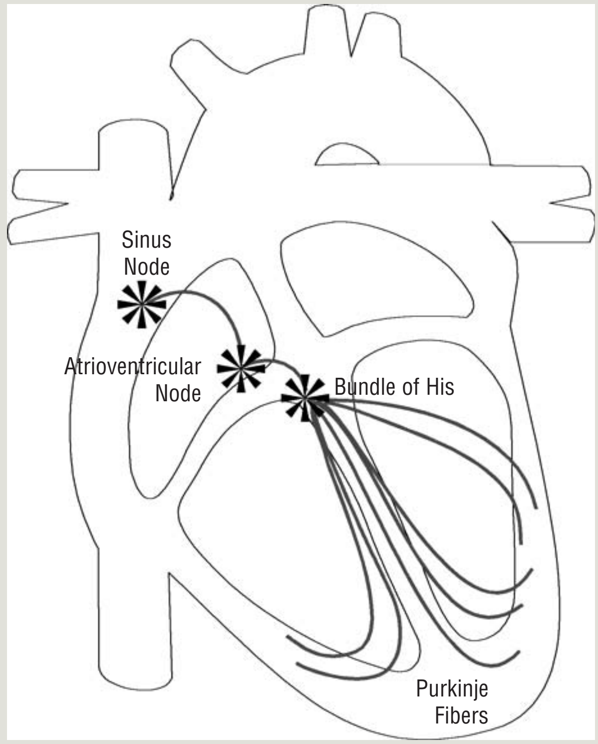

Figure 1 Cardiac conduction system.

Cardiac Anatomy and Physiology

Microscopically, myocardial tissue is differentiated by the functions of its various cell types. Working myocardial cells contract, providing pumping forces; clusters of specialized pacemaker cells initiate electrical impulses; and the Purkinje fibers provide rapid conduction of these impulses.[3] The sinoatrial node, located high in the right atrium, is the cluster of cells that initiates normal cardiac stimulation and serves as the primary pacemaker. These signals then travel across the atrium to the atrioventricular node, located close to the septal leaflet of the tricuspid valve. Conducting fibers from the atrioventricular node converge in the bundle of His, allowing rapid transmission of impulses to the Purkinje fibers of the ventricles (Figure 1). The result of this highly coordinated impulse propagation is a cardiac contraction that efficiently pumps blood throughout the entire circulatory system.[3]

Many intrinsic and extrinsic factors influence the genesis and the propagation of cardiac impulses. Dysrhythmias may arise from abnormal initiation or conduction of impulses or from both.[3] Bradydysrhythmias can result from electrolyte imbalances, the toxic effects of drugs, inherent abnormalities in the conduction system, ischemia, or myocardial damage.[2] By sustaining a rate sufficient to allow filling and emptying of the heart's chambers, artificial mechanical pacemakers can be a lifesaving adjunct for maintaining an adequate cardiac output.

Components of Pacing

The mechanics of pacing involves several fundamental components. The first of these is the battery-powered generator that initiates electrical stimulation. Three basic types of pulse generators are available:

1. single-chamber atrial pacers,
2. single-chamber ventricular pacers, and
3. atrioventricular sequential pacers, which pace both atrial and ventricular chambers.

Single-chamber atrial pacers are adequate for enhancing heart rate in patients with an intact cardiac conduction system. Ventricular pacers are designed for patients with normal contractility who require an increase in heart rate. Atrioventricular sequential pacers provide synchronization between the atria and the ventricles for optimal cardiac output.

The pacing generator is connected to 1 to 4 pacing wires and may or may not require a connecting cable between the wires and the generator. The last element of pacing is the patient's own cardiac tissue. Failure to pace may be due to a malfunction or disruption of mechanical components. Failure may also be due to poor myocardial function associated with electrolyte disturbances, myocardial scarring, or any factors that affect impulse conduction or cardiac contractility.

Pacemaker Concepts

The four basic concepts of pacemaker functioning are connection, output, capture, and sensitivity.

Connection

The connection between the pacemaker generator and the heart is made through either unipolar or bipolar electrode wires.[1] In a unipolar system, only the negative electrode is in direct contact with the heart. In a bipolar system, both negative and positive electrodes lie within the heart. Pacemakers can be either unipolar or bipolar. Distinguishing between the negative and positive electrodes is important so that the wires are connected appropriately to the pulse generator.[6]

The 2 types of invasive temporary pacing are epicardial and transvenous.[3] The transvenous category also includes devices that combine a specialized pulmonary artery catheter with a pacemaker.[1] Transvenous pacing involves a pulse generator, which is externally connected to 2 electrode wires, threaded through a large vein (generally the subclavian or internal jugular) into either the right atrium or the right ventricle.[1] These wires directly contact the endocardium within the heart (Figure 2).

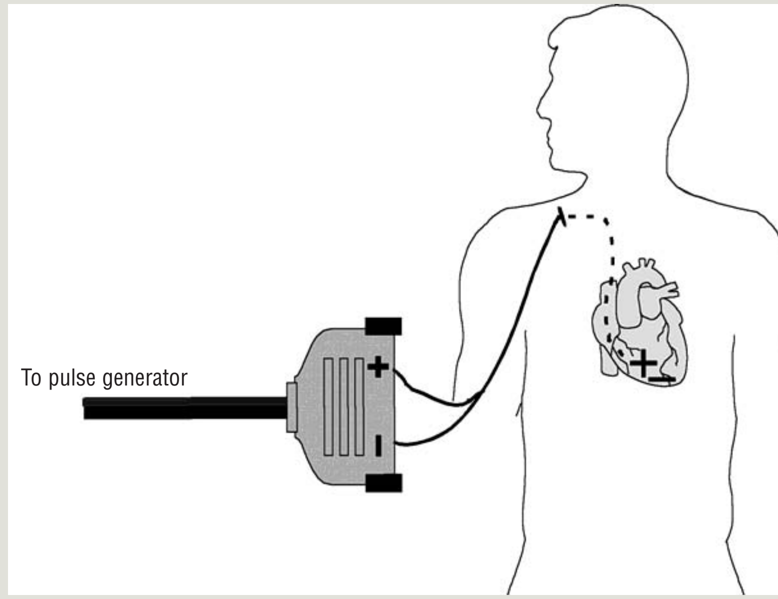

Figure 2 Temporary transvenous pacemaker.

Pulmonary artery catheters are the newest form of invasive temporary pacing. In specialized pulmonary artery catheters, dedicated atrial and ventricular ports provide sites for the introduction of electrode wires while still allowing routine thermodilution hemodynamic monitoring.[1] Unfortunately, inflating the balloon to measure pulmonary artery wedge pressure may cause the electrodes to migrate out of their pacing position. Consequently, simultaneous pacing and determinations of wedge pressures are infrequently done.

The second method of temporary invasive pacing involves directly stimulating the epicardium (Figure 3). This type of pacing is initiated after cardiac surgery.[1,2] Postoperatively, electrodes are lightly sutured to the epicardium before the thorax is closed. These pacing wires are pulled through the skin and secured to the external chest wall, ready for attachment to a temporary pacing generator as needed.[3] A patient may have a single set or a double set of electrodes, but each set of electrodes includes 2 wires that protrude from a stab incision in the chest wall. When dual-wire sets are used, one set or pair paces the

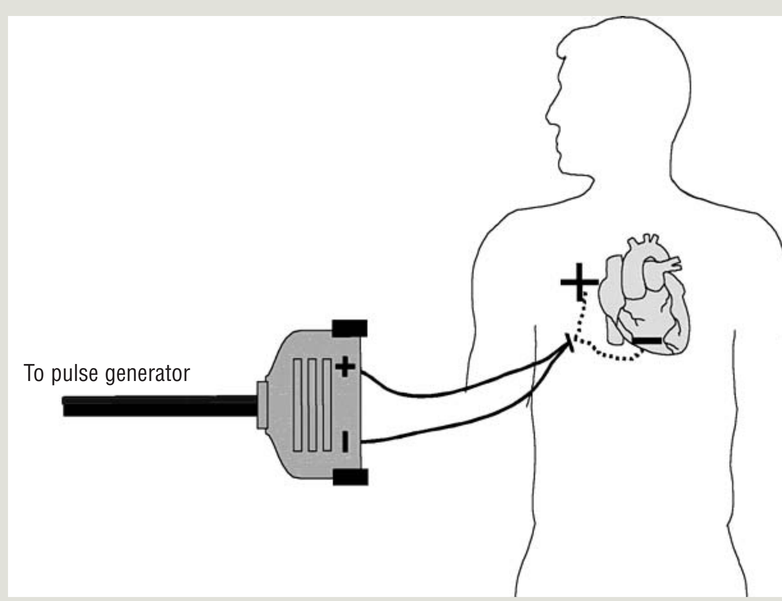

Figure 3 Temporary epicardial pacemaker.

ventricles and the other is attached to the atria.

In each pair of wires, one lead is positive and the other (commonly the shorter of the 2 wires) is negative; however, practice varies between institutions. Ventricular pacing wires exit through the left side of the sternum; atrial pairs are placed on the right side.[1] Having identifying labels on the wires is helpful. If no labels are present, ascertaining which wire is which (and marking the wires accordingly) can save precious time later in emergency situations.

Distinguishing ventricular wires from atrial wires, and positive electrodes from negative electrodes, is considerably easier in patients with transvenous or pulmonary artery catheter pacemakers. Pacing wires are threaded directly into the chambers of the right atrium and right ventricle by using the appropriate prelabeled ports.

On the top of the generator of each temporary atrioventricular sequential pacemaker are connectors labeled Atrial +/-, and Ventricular +/- (Figure 4). Single-chamber pacemakers have only 2 connector ports, positive and negative; the wires must be connected and secured to the correct port.

Output

Once the wires from the patient are connected to the generator, the amount of electrical output must be selected. The sole function of the generator is to supply sufficient energy to the heart muscle to stimulate a contraction. Setting the output has 3 components: rate, amount, and chamber. The rate determines the number of stimulations to be delivered per minute. The amount controls the level of energy provided, and the chamber defines the location in the heart to which the energy is delivered.

Figure 4 Pulse generator for a dual-chamber pacemaker.

Sometimes, the most obvious step in setting up a pacemaker is also the step most forgotten: ensuring that a fresh battery is in the generator.[1] Most institutions have a policy that requires checking a battery's energy level, or replacing the battery, before attaching the generator for each new patient. Table 2 is a quick guide to pacemaker setup.

Each patient's physician is responsible for providing initial direction regarding rate, output amount, and chambers to be paced.[1] To facilitate this step, some institutions have developed preprinted temporary pacemaker orders. Other critical care units have temporary pacing policies in place to provide nurses with guidelines for initial settings.

Rate The original rate setting depends on both the patient's condition and the reason for pacing.[1] Rates for a surgical patient can start as high as 90 to 110 beats/min. In medical patients, therapy is generally started at 70 to 90 beats/min. In patients who have had cardiac arrest, the initial rate is 80 beats/min. Pacing rates for overdrive suppression of tachydysrhythmias may greatly exceed these values.[1] The heart rate on a patient's rhythm strip should never be lower than the patient's set pacemaker rate.[3]

Amount The output amount is the level of energy delivered by the pulse generator to the heart to initiate depolarization. Output is measured in milliamperes.[1] The usual starting point is 10 mA in nonurgent situations. Output is then

Table 2 Quick guide to pacemaker setup

1. Locate the pacemaker generator.
2. Ensure that the battery is fresh.
3. Identify each wire set as atrial or ventricular.
   One or both types may be present. Epicardial ventricular wires exit from the left side of the chest; atrial wires, from the right.
4. Identify the positive and negative leads for each pair of wires.
   Negative leads are generally shorter.
5. Attach the wires to the appropriate sites.
6. Turn the pulse generator on.
7. Set the rate according to the physician's preference and the physiological needs of the patient.
   For example:
   Surgical patients: 90-110 beats/min
   Medical patients: 70-90 beats/min
   Cardiac arrest: 80 beats/min
8. Set the milliamperage. General adult guidelines:
   Nonurgent: 10 mA
   Emergent: 15-20 mA
   Increase milliamperage until capture is obtained.
9. Set the sensitivity. General adult guidelines:
   Start at 2-5 mV.
   If failure to sense occurs, turn the sensitivity DOWN.
   If the pacer is sensing beats not actually present, turn the sensitivity UP.
10. Observe the patient closely for response.
11. Secure the wires and all connections, label wires, and place the pacemaker in a safe location.

slowly increased until capture is obtained and the "pacing threshold" is defined.[1] This level is not constant; it fluctuates over time as an endothelial sheath forms around the tips of the electrodes. Therefore, to prevent loss of capture, the output is set 1½ to 3 times higher than the identified pacing threshold.[1] In emergent circumstances, starting with a high output (15-20 mA) is recommended. Threshold testing is performed to fine-tune the settings.

Chamber The atrial chamber, the ventricular chamber, or both chambers of the heart can be paced. Pulse generators for dual-chamber pacemakers have separate atrial and ventricular output controls.[1] If both the atrium and the ventricle are paced, a separate output setting is required for each chamber. The settings for the 2 chambers may be different or identical. The chamber to be paced is selected by programming the generator.[1]

Capture

Electrical capture, the ability of the electrical impulse to initiate a cardiac response, is detected by examining an electrocardiogram. Capture is both an electrical and a mechanical event. Electrical capture is indicated by a pacer spike followed by a corresponding P wave or QRS complex, depending on which chamber is being paced (Figures 5 and 6). If the atrium is paced, the spike appears before the P wave.[7] If the ventricle is paced, the spike occurs before the QRS complex.[1]

Because the pacemaker causes the heart to depolarize in an artificial fashion, the path of depolarization is abnormal, resulting in widened P waves and QRS complexes.[3] A pacer spike without a corresponding P wave or QRS complex indicates failure to capture[1] (Figure 7). For a list of potential causes of loss of capture, see Table 3.

If loss of capture occurs, the patient is assessed first and then connections and settings are checked to

Figure 5 Normal electrical capture, ventricular pacer. Normal ventricular electrical capture is demonstrated by a pacer spike (Vp) followed by a corresponding, widened QRS complex.

Abbreviations: Vp, ventricular pacing; Vs, ventricular stimulation (intrinsic).

Rhythm strip courtesy of Medtronic, Inc, Minneapolis, Minn.

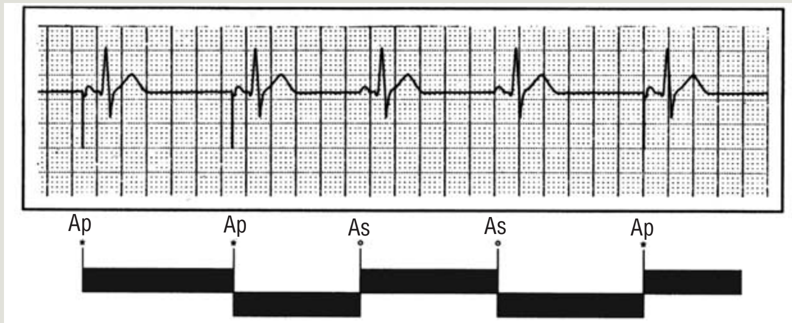

Figure 6 Normal electrical capture, atrial pacer. Normal atrial electrical capture is demonstrated by a pacer spike (Ap) followed by a corresponding P wave.

Abbreviations: Ap, atrial pacing; As, atrial stimulation (intrinsic).

Rhythm strip courtesy of Medtronic, Inc, Minneapolis, Minn.

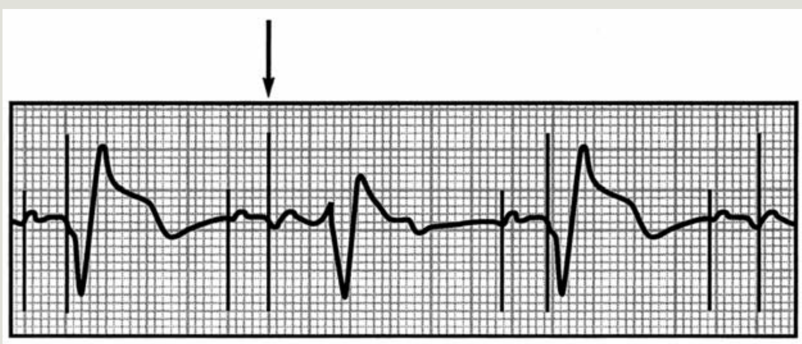

Figure 7 Failure to capture, dual-chamber pacemaker. Failure to capture occurs when a pacer spike is present but is not followed by a corresponding waveform (P wave or QRS complex). Arrow indicates electrical stimulus without ventricular capture.

Rhythm strip courtesy of Medtronic, Inc, Minneapolis, Minn.

detect disconnections, broken wires, or other mechanical issues. If the patient's condition is stable, threshold testing is done. If hemodynamic compromise exists, the milliamperage is quickly increased until capture occurs. Turning the patient onto his or her left side may also improve capture by increasing contact between the electrode and myocardial tissue.[6]

Electrical capture alone is inadequate. Adequacy of mechanical capture is assessed by feeling for a pulse or checking blood pressure.[7] Mechanical capture exists when the pacer spike and its corresponding QRS complex are followed by a cardiac contraction.[2]

Sensitivity

Sensitivity is the component of pacing that often confounds even experienced clinicians. Nonetheless, sensing merely refers to the ability of the generator to detect and recognize the impulses the myocardial tissue is generating on its own.[1] Intrinsic cardiac activity is usually more organized and global than are paced beats. Intrinsic activity stimulates better contractions, and more effective forward flow of blood, from the chambers of the heart, especially when the atria and ventricles are intrinsically beating synchronously. When atrial beats are unsynchronized or absent, as in atrial fibrillation, atrioventricular block, or sinus arrest, cardiac output decreases because less blood than usual is ejected from the atria during ventricular diastole. This concept is important because almost 30% of normal cardiac output is due to the atrial "kick," or atrial systole, that occurs during ventricular filling when the 2 chambers perform in sync.[3]

These physiological principles can be directly applied to the use of mechanical pacemakers. Whenever possible, intrinsic beats should be allowed to occur naturally, providing a more global and organized contraction. However, intrinsic

Table 3 Factors that influence capture and sensing*

	Capture	Sensing
Fluid status changes	X	X
Pericardial effusion	X	X
Electrolyte or metabolic abnormalities	X	
Medications	X	
Tissue inflammation, fibrosis, or necrosis	X	X
Generator battery failure	X	X
Low pulse generator voltage	X	
High pulse generator amperage		X
Development of endothelial sheaths	X	X
Disconnection, dislodgment, or fracture of leads	X	X

*X denotes an influence; no entry indicates no influence.

beats must be supplemented when the rate is insufficient or conduction of the beats does not generate ventricular contractions. For maximum effectiveness, paced beats and intrinsic beats must be synchronized. To synchronize the beats, the generator first analyzes the intrinsic rhythm and then stimulates the heart only as needed.

Adjusting the sensing level sets the pacer to "look" for intrinsic beats. Pacemaker generators can be programed to deliver an impulse to the ventricle each time an atrial beat is sensed, or they can be set to stimulate only when no intrinsic beat has been detected during a predetermined interval. For example, in a patient with an intrinsic rate of 30 beats/min, the generator may be set to pace both chambers at 80 beats/min. The pacemaker will have no way of determining what the intrinsic rhythm is, or when to stimulate in synchrony, unless the sensitivity is adequately adjusted to provide pacing only on demand.

The sensitivity setting is measured in millivolts[3] and is initially set at about 2 to 5 mV. Failure to sense occurs when the generator does not recognize the heart's intrinsic impulses[1] (Figure 8). The most common cause of failure to sense is displacement of the electrode[2] (Table 3). Repositioning the patient on his or her left side may improve contact between the electrode and the myocardium. If the response is still inadequate, then the sensitivity must be increased.[3] This increase is accomplished by turning down the millivoltage, allowing the generator to detect beats that occur at lower millivolt levels. Conversely, if the pacemaker is detecting beats that are not actually occurring (inappropriate sensing), then the sensitivity threshold must be increased to block out artifact. This increase is accomplished by turning up the millivoltage.[1]

Care of Patients With Pacemakers

Once the wires are inserted into the pacemaker box, the generator is turned on, settings are adjusted, and pacing should begin. However, if the device is set to pace only when a patient's heart rate is lower than a certain value, no pacing will occur until the designated limit is reached.

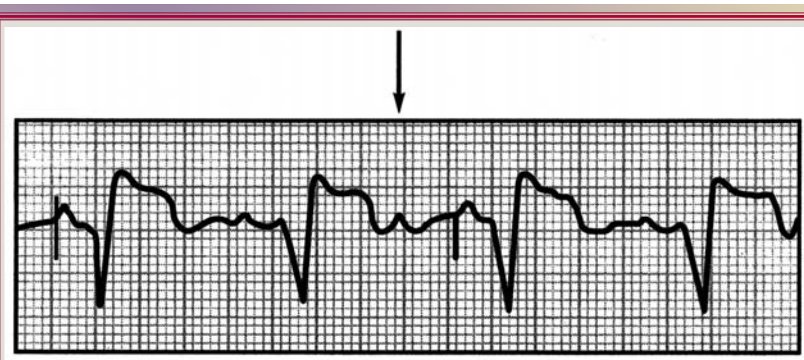

Figure 8 Failure to sense, single-chamber atrial pacemaker. Failure to sense occurs when the generator does not detect intrinsic beats and initiates an inappropriate impulse that may or may not capture. Arrow indicates an atrial beat not sensed by the pulse generator, which is followed by a pacer spike.

Rhythm strip courtesy of Medtronic, Inc, Minneapolis, Minn.

Electrical safety practices are especially important in caring for patients with pacemakers. To prevent microshocks, nurses should always wear gloves when handling electrodes and should cover unused transthoracic wires with the fingertip of a disposable glove.[1] Microshocks are associated with ventricular dysrhythmias. The pulse generator must be placed in a location where it will not be dropped on the floor. Lengthy cables attached to the pacemaker need careful attention so that wires are not inadvertently dislodged.

Routine nursing care of patients with temporary pacemakers consists of regular cardiovascular assessment to evaluate pulses, level of consciousness, heart rhythm, pacer activity, and hemodynamic response. Daily management also includes an assessment of the insertion site. Depending on the type of connection, the site will be either a transthoracic or a central venous catheter insertion site. The wires must be secure and not at risk for dislodgement.[2] Nurses should check to see if the wires are intact and should note the number and location. Care for a transvenous wire site is the same as care for a central vascular access site; dressing are changed as prescribed by institutional protocol.[7] Usually, the site is cleaned with povidone-iodine or another antimicrobial agent, and a sterile occlusive dressing is applied, with changes every 48 to 72 hours.[7]

In the first 48 hours after cardiac surgery, epicardial wires usually are under the initial dressing of the chest tube or midsternal incision. Once these bulky dressings are removed, care of the epicardial site should be performed daily whether the site is left open to air or covered with a light dressing.[7] The area is cleaned with isotonic sodium chloride solution and assessed for redness or drainage. The wires must be taped securely to the skin to prevent accidental dislodgement.

Capture and sensitivity threshold testing should be performed every 12 to 24 hours to determine the best settings for the generator (Table 4). As time passes, both transvenous and epicardial wires acquire endothelial sheaths around their tips and thus require more milliamperes to capture and fewer millivolts to sense.[7] The ability to capture and sense is also influenced by patients' fluid volume status and changes in cardiac tissue. Therefore, thresholds must be tested regularly to ensure proper pacing and prevent loss of capture or inappropriate stimulation. Chambers are tested one at a time; atrial and ventricular chambers should not be tested simultaneously.[7] Threshold testing is generally contraindicated when patients are being paced more than 90% of the time because of the risk of losing capture while the patients are dependent on generator-initiated beats.[7]

Table 4 Threshold testing procedure[6]

Test atrial and ventricular chambers separately.

Capture

Do not test capture if the patient is being paced 90% or more of the time.

1. Turn the pacemaker rate up 10 beats/min higher the patient's intrinsic rate.
2. Decrease the milliamperage until loss of capture occurs, and then slowly increase it until depolarization occurs after every pacer spike. The milliamperage setting at which depolarization occurs with every spike is the threshold for capture.
3. Set the milliamperage to 1½ to 3 times the determined threshold.
4. Reset the pacer to the prescribed rate.

Sensitivity

Do not test sensitivity if the patient is being paced 90% or more of the time.

1. Set the heart rate at 10 beats/min lower than the patient's intrinsic rate.
2. Reduce the output to 0.1 mA to prevent competitive pacing.
3. Increase the millivoltage until the sense indicator stops flashing and the pace indicator starts flashing.
4. Slowly decrease the millivoltage until the sense indicator flashes continuously. This value is the sensing threshold.
5. Set the millivoltage at half the sensitivity threshold value.
6. Reset pacer to prescribed rate.

Summary

Competent management of patients with an invasive temporary pacemaker is an important skill for nurses who provide care for critically ill patients with cardiac disease. Such management requires familiarity with normal cardiovascular anatomy and physiology, conduction system defects, and rhythm interpretation. With an understanding of the basic concepts of rate, output, chambers, sensitivity, and capture, pacing can be done with ease. Care of patients with a temporary invasive pacemaker requires monitoring cardiac tissue and hemodynamic status, observing for changes that would indicate the need for modifications in the pacemaker settings. Nursing interventions include physical assessment, care of the insertion site, routine threshold testing, and management of the pulse generator.

References

1. Dirks J. Cardiovascular therapeutic management. In: Urden L, Stacy K, eds. *Priorities in Critical Care Nursing.* St Louis, Mo: Mosby; 2000:183-209.
2. Wood M, Belz M, Ellenbogen K. Cardiac pacemakers and implantable defibrillators in the intensive care unit setting. In: Grenvi A, Ayres S, Holbrook P, Shoemaker W, eds. *Textbook of Critical Care.* 4th ed. Philadelphia, Pa: WB Saunders Co; 2000:1061-1078.
3. Woods S, Sole M. Dysrhythmia interpretation. In: Sole M, Lamborn M, Hartshorn J, eds. *Introduction to Critical Care Nursing.* Philadelphia, Pa: WB Saunders Co; 2001:41-81.
4. Killip T. Treatment of myocardial infarction. In: Grenvi A, Ayres S, Holbrook P, Shoemaker W, eds. *Textbook of Critical Care.* 4th ed. Philadelphia, Pa: WB Saunders Co; 2000:1018-1029.
5. O'Donnell M, Dirks J. Cardiovascular disorders. In: Urden L, Stacy K, eds. *Priorities in Critical Care Nursing.* St Louis, Mo: Mosby; 2000:146-182.
6. Thelan L, Urden L, Lough M, Stacy K. *Critical Care Nursing Diagnosis and Management.* St Louis, Mo: Mosby; 1998:529-584.
7. Paschall FE, McErlean ES. Temporary transvenous and epicardial pacing. In: Lynn-McHale DJ, Carlson KK, eds. *AACN Procedure Manual for Critical Care.* 4th ed. Philadelphia, Pa: WB Saunders Co; 2001:285-297.

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