TRIED AND TRUE: NONINVASIVE TRANSTHORACIC PACING By Judy Boehm, RN, MSN

Noninvasive transthoracic pacing (NTP), an accepted emergency intervention since 1982, has been shown to be safe and effective over the ensuing years. It is considered to be a "tried and true" treatment modality so little is written about it today, even though the American Heart Association (AHA) includes it as an integral step in the ACLS bradycardia algorithm.¹ Most of the scientific basis for the practice of NTP was published in the 1980s and 1990s, with only a few advances coming to the forefront these last years. This issue of Code Communications should be especially helpful for readers new to health care who might not have been practicing when NTP was the "buzz" in emergency care innovations. For those of you in practice over many years, this article should provide a good review of NTP and confirm your expertise.

What is Noninvasive Transcutaneous Pacing?

NTP is the technique of electrically stimulating the heart by use of a set of pads placed externally on the torso. ECG electrodes are also placed on the patient to sense ventricular events (spontaneous or paced), and the pulse generator delivers a wave pulse when a predetermined escape interval has elapsed. The stimulus is intended to cause cardiac depolarization and subsequent myocardial contraction. NTP is a method to secure cardiac pacing quickly and effectively until a transvenous pacemaker can be inserted or the condition necessitating pacing resolves.

History of Noninvasive Transcutaneous Pacing

The concept of non-invasive cardiac pacing has been present for about 200 years. In 1791 Galvani reported that an electrical current applied across the heart of a dead frog resulted in myocardial contraction.² However, non-invasive pacing was not made practical until Dr. Paul Zoll's work in the early 1950s. In 1952 Zoll reported the successful delivery of current from a generator through subcutaneous needle electrodes, which resulted in fixed rate pacing of two patients with ventricular standstill.³ He later reported the development and successful use of the first true noninvasive pacemaker and monitor. This device used a pair of 3-centimeter diameter metal electrodes secured to the chest wall with a leather belt and delivered 2-20 millisecond, 120-volt, alternating current impulses. Dr. Zoll is the acknowledged father of external pacing as a result of these early achievements.



Though effective, this early technique was not widely accepted due to several factors. First, the small electrodes resulted in a high current density, which was associated with painful cutaneous nerve stimulation and superficial skin lacerations under the electrodes. Thus, pacing in this manner was restricted to unconscious patients or brief use in desperate situations. Second, the response to pacing was unrecognized because the large stimulus distorted the electrocardiogram and the muscle contractions obscured arterial pulsations. In the late 1950s when *transvenous* pacing became available, NTP fell out of favor.

Technological improvements during the early 1980s made noninvasive pacing more comfortable and less cumbersome than earlier efforts. In 1981 ZOLL Medical Corporation patented and

introduced a noninvasive external pacemaker with a longer pulse duration (40 milliseconds) and a larger electrode surface area (80 cm^2). With stimuli of 40 millisecond duration, the threshold for cardiac responses was reduced, usually to 35-70 mA. A larger electrode surface area decreased the current density. Both of these factors greatly reduced the extent and severity of muscle contractions – and thus decreased the related discomfort. With the development of high impedance electrode gel on disposable electrodes, the current density was further decreased across the skin reducing cutaneous nerve pain.

In this new generation NTP the ECG monitor presented a clearly recognizable, unique symbol of the stimulus artifact that precisely marked the time of stimulation. It was designed with a "blanking period" of 60 milliseconds right after the stimulus signal so that the high output voltages associated with the pacing stimulus were suppressed and ECG complexes were recognizable during pacing. Another advantage of the new external pacing device was its ability to operate in the demand mode (VVI), whereas older units were fixed rate (VOO).⁴



It was realized that in a crisis, placement of a temporary transvenous pacemaker can be difficult and time consuming even with skilled personnel, and the incidence of complications from the transvenous approach was up to 34%.⁵ Since this new model for NTP was simple, reliable, cost effective and could be easily and quickly applied by trained clinicians (other than physicians), there was renewed clinical interest in noninvasive pacing.

In 1982, the FDA approved the ZOLL noninvasive pacing device for use in patients with heart rates less than 40 beats per minute and asystole. With the release of the ZOLL PD 1200® in 1988, the external pacemaker was integrated with a defibrillator/monitor, and the following year multi-function electrodes with medium impedance gel were made available that could both pace and defibrillate. This is the usual design of the NTP produced by the several manufacturers today.

Physiology of Noninvasive Transcutaneous Pacing

When a strong electrical current is applied to the chest with NTP, approximately 4% will reach the heart stimulating it to depolarize and contract. With transcutaneous pacing the right and left ventricles are stimulated. Frequently the atria are activated by retrograde conduction. There is atrioventricular dissociation so the atrial kick is lost, resulting in about a 20% decrease in cardiac output. For a patient with symptomatic bradycardia, NTP results in an increased cardiac output, increased mean arterial pressure and decreased systemic vascular resistance. Studies have shown that with NTP there is no significant elevation in CKMB, so no myocardial damage occurs.⁶ Additionally, it was found that the hemodynamic response was similar for NTP and transvenous ventricular endocardial pacing.

When ECG electrodes are attached for sensing of the QRS, the pacemaker is able to operate in the demand mode. A pacemaker stimulus will occur if the intrinsic signal is slower than the pacing rate programmed by the clinician. If the device senses that the patient's heart rate is faster than the pacing rate, it inhibits the pacemaker's electrical signal.

Asynchronous (fixed rate) pacing can also be selected on the noninvasive device. In this mode the device paces at the rate set by the clinician, independent of the patient's intrinsic heart rhythm. Asynchronous pacing is used when:

- There is not time to put ECG electrodes in place
- When the pacemaker is inhibited due to sensing of signals other than the R wave (e.g., artifact from patient movement, P or T waves, and interference from another electrical device)

During asynchronous pacing there may be competition between the patient's own beats and the paced beats, unless asystole is present. There is the potential for the pacemaker stimulus to land on the T wave during the vulnerable period. Refer to the section *Safety of Noninvasive Transcutaneous Pacing* for the significance of this factor.

Indications for Use of Noninvasive Transcutaneous Pacing

Indications for NTP as outlined in the AHA's *Advanced Cardiac Life Support (ACLS) Provider Manual* follow:⁷

- Hemodynamically unstable bradycardia (e.g., blood pressure changes, acute altered mental status, ongoing severe ischemic chest pain, congestive heart failure, hypotension, syncope or other signs of shock) that persists despite adequate airway and breathing
- Unstable clinical condition that is likely due to the bradycardia
- For pacing readiness (i.e., standby mode) in the setting of acute myocardial infarction (AMI) with the following:
 - Symptomatic sinus bradycardia
 - Mobitz type II second-degree AV block
 - Third-degree AV block
 - New left, right, or alternating bundle branch block or bifascicular block
- Bradycardia with symptomatic ventricular escape rhythms
- Overdrive pacing of tachycardias refractory to drug therapy or electrical cardioversion

Transcutaneous pacing should be initiated without delay when there is impairment in the conduction system resulting in a high-degree block (e.g., Mobitz type II second-degree block or third-degree AV block). NTP is considered a Class I intervention for symptomatic bradycardias by the AHA, which means that the risk is much greater than the benefit and the "procedure/ treatment or diagnostic test/assessment should be performed/administered."¹ While waiting for the pacemaker device, atropine should be considered. In an emergency if there is no intravenous access, the atropine is not effective or the patient is severely symptomatic, NTP should be begun immediately by the trained nurse or physician.

NTP can be set up ready to use in patients who are clinically stable yet may quickly decompensate. Patients who may benefit from standby pacing include those:

- with AMI showing signs of early heart block
- awaiting cardiac surgery
- awaiting placement of a permanent pacemaker, generator change or lead wire replacement
- undergoing cardiac catheterization or angioplasty
- at risk of developing post cardioversion bradycardia⁸

Bradycardia with escape rhythms is another arrhythmia for which TCP is used. Pulseless electrical activity (PEA) from drug overdoses, toxic exposures, and electrolyte abnormalities may benefit from the support of NTP while treating the cause.

Overdrive pacing is rarely performed with the standard noninvasive transcutaneous pacemaker. The intent is to pace at a rate faster than the tachycardia in order to interrupt the reentry circuit so the SA node can regain control of the heart rhythm. The upper rate limit of most NTP devices is ≤ 180 beats/minute, so that they can only be used for slower tachycardias. Rapid ventricular pacing in patients with supraventricular tachycardias may precipitate ventricular fibrillation, and burst ventricular pacing may cause acceleration of ventricular tachycardia. So the procedure should only be performed in the electrophysiology lab by experienced providers.⁹ Often electrophysiologists are more comfortable with performing overdrive pacing using a small generator attached to either a transvenous wire, which they quickly slip in place, or transthoracic wires that were placed on the exterior surface of the heart during cardiac surgery. It is preferable to use a device that can perform programmed stimulation with synchronized extrastimuli, a technique that is least likely to cause detrimental arrhythmias.

Transcutaneous pacing may be utilized when *transvenous* pacing is contraindicated under the following circumstances:

- Difficulty placing a wire (e.g., tricuspid valve prosthesis)
- Potential for bleeding (e.g., patients who have received a thrombolytic)
- Increased potential for infection (e.g., patients with depressed immune system)

Since the bradycardia seen in children is usually secondary to hypoxic events, the treatment of choice is prompt airway support, ventilation, and oxygenation. Although less frequent in occurrence, children and infants do experience heart blocks and bradycardias where treatment with NTP is indicated and could be lifesaving. Indications for use of NTP in children include:

- bradycardias from surgically acquired AV blocks
- congenital AV blocks
- viral myocarditis
- heart block secondary to toxin or drug overdose
- permanent pacemaker generator failure



In the 2005 AHA Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, the use of pacing for patients with asystolic cardiac arrest is not recommended since randomized controlled trials have failed to show its benefit.¹ This absence of P waves and QRS complexes is seen late in arrest when ventricular fibrillation has deteriorated to asystole. Lack of response to pacing is not a failure of the technique of pacing, but rather failure of the hypoxic human heart to respond to pacing with mechanical contractions, despite electrical activity. In the hospital asystole often represents the final rhythm of a patient whose organs have failed and whose condition has deteriorated. An electrical stimulus in this circumstance usually produces no cardiac response at all, or, at the very least, brief episodes of clinically useless PEA.

There are several circumstances in the hospital when asystole appears suddenly and providers are close by to initiate lifesaving pacing:

- When the asystole is the result of a primary conduction system problem and ventricular standstill is noted quickly on the monitor in a critical care unit (P waves may still be present)
- When standstill is drug-induced (e.g., due to procainamide, quinidine, digitalis, beta blockers, verapamil)
- With unexpected circulatory arrest (i.e., due to anesthesia, surgery, angiography, and other therapeutic or diagnostic procedures)
- With reflex vagal standstill
- When asystole results following defibrillation

In this last circumstance it is quick and easy to switch modes on the bedside monitor/defibrillator/pacemaker from defibrillator to noninvasive pacemaker; see the image of the selector switch on the ZOLL R SeriesTM defibrillator.



Other contraindications to NTP include:

- Severe hypothermia since the heart is unable to respond to the electrical stimulus
- Patients who are confused since there may be difficulty keeping electrodes securely in place and the discomfort will increase the agitation
- Patients who are so diaphoretic that there is not constant electrode-to-skin interface

Noninvasive pacing is used on a temporary basis until the patient is stabilized and either an adequate intrinsic rhythm has returned or a transvenous pacemaker is inserted, whether temporary or permanent.

Procedure for Noninvasive Transcutaneous Pacing

It is extremely important to prepare the patient for what s/he will experience with NTP. Explain why use of NTP is needed and give a brief overview of the procedure – though this may need to be done quickly. Reassure the patient that this treatment is temporary and will only be performed for a limited time. Remind the patient that s/he will need to remain on bedrest during the time of pacing.

Contraction of the skeletal muscles can be frightening, so tell the patient that you will work with him/her and provide sedation and/or analgesia to improve tolerance. Lack of preparation and high anxiety can increase patient discomfort from the procedure. Patients have described the sensation of muscle contraction as a tapping, twitching or thudding. A tingling, stinging or burning sensation is the result of cutaneous nerve stimulation. A parenteral benzodiazepine may be administered for anxiety and muscle contractions, and/or a parenteral narcotic for pain. If the patient is in cardiovascular collapse or rapidly deteriorating, it may be necessary to start pacing without prior medication.

Once the defibrillator with NTP is at the bedside, apply the pacing electrodes. Pure pacing electrodes may be utilized but many institutions use multi-function electrodes that can both defibrillate and pace. The recommended position for the multi-function electrodes is anterior-posterior; see Figure 1.



Figure 1 Anterior-Posterior Electrode Placement for Noninvasive Transcutaneous Pacing

The posterior electrode is positioned to the left of the spine beneath the left scapula and should be applied first to prevent buckling of the anterior electrode when rolling the patient to the side. The anterior (negative) electrode is placed between the xiphoid process and the left nipple (V2-V3 position). In females lift up the breast and place the electrode underneath. Avoid any contact of the electrode gel with the nipple, and if possible do not place the electrode on skin folds under the breast or those visible on obese individuals. I often explain this electrode position to practitioners as "sandwiching the heart."

Another position that may be used for the multi-function electrodes is sternum-apex in which the negative electrode is placed in the left midaxillary line around the 5th intercostal space (V6 position) and the positive electrode to the right of the sternum under the clavicle. See Figure 2.





Figure 2 Sternum-Apex Electrode Placement for Noninvasive Transcutaneous Pacing

Good skin-to-electrode contact under the multi-function electrodes is of utmost importance in order to lower transthoracic impedance and improve electrical capture of the heart. To prepare the skin under the electrodes, perform the following actions:

- Remove any preparations on the skin (e.g., ointments, alcohol, Betadine).
- Remove any transdermal patch and wipe residual medication off the skin. **Note**: remember to wear gloves if removing nitroglycerin so that you don't experience vasodilation and a headache!
- Dry diaphoretic skin, which often occurs if the patient is hemodynamically unstable.
- Clip excessive hair. Note: It is better to clip the hair rather than to shave so that skin abrasions are avoided, which would cause increased discomfort.
- Avoid placing electrodes over dressings, ECG electrodes, tubes, drains, and fresh incisions.

Apply one edge of the electrode to the skin and roll it out to the other edge so that pockets of air are eliminated and the contact is secure; see Figure 3.

Figure 3 Recommended Method for Applying Pacing Electrode to the Skin



Figure 4 ZOLL pedi•padz®



When pacing children, the ECG and pacing electrode placement is the same as in the adult. But use specific pediatric pacing electrodes for those under 33 pounds. See example in Figure 4.

Next apply ECG electrodes onto the patient, choosing anatomically correct vectors but with the electrodes far away from the pacing electrodes in order to decrease artifact as much as possible. Adequate skin preparation is important with ECG

electrodes as well, in order to obtain good ECG tracing quality. Using the lead select button, choose one of the leads in which the QRS complex is quite visible and consistently detected. Each device has a way to indicate when the R wave is detected so that demand pacing can occur. With ZOLL's M Series® and R Series defibrillators, a heart (\P) flashes on the monitor screen with each R wave. If you check for R wave detection while in the monitor mode on the defibrillator, then pacing pulses won't cause confusion.

Next, choose the pacing function on the defibrillator/ pacemaker device.



Select the rate at which you desire to pace. There is usually a default pacing rate when the monitor/defibrillator is turned on (e.g., 70/minute). If you desire a rate other than this default, obtain it using the manufacturer's instructions for operating the device. Because of the loss of the atrial kick with ventricular pacing in the noninvasive method, the rate may need to be higher in order to achieve an adequate cardiac output. The *ACLS Provider Manual* instructs to set the demand rate to approximately 60/minute, and "adjust up or down



based on the patient's clinical response once pacing is established. Patients with acute ischemia should be paced at the lowest heart rate that allows clinical stability. Higher heart rates can worsen ischemia because heart rate is a major determinate of myocardial oxygen demand."⁷

When the pacing function is activated the demand mode comes up automatically, so if there is a reason to choose asynchronous it will need to be selected according to the manufacturer's instructions.

Now that the set-up is completed, it is time to begin pacing. When the pacing function is chosen on the defibrillator/pacemaker, the output (mA) will come up as zero. Note the presence of pacing stimuli occurring at the set rate, which are superimposed on the patient's ECG. With the ZOLL manual defibrillator/pacemakers, the wide pacing stimulus (one small box wide) will be negative. See Figure 5.

Figure 5 Example of Wide Pacing Stimulus with ZOLL External Pacemakers







While watching the monitor screen on the defibrillator/pacemaker, slowly turn up the output until electrical capture is seen on the ECG. Make sure to use the "Output" (mA) button in the pacing sector on the defibrillator front panel, and do not get it confused with the "Energy Select" (joules) button in the defibrillator sector. The threshold for capture with the ZOLL pacemaker is usually 40-80 mA. Electrical capture is seen as a wide QRS following each

pacing stimulus, with a wide somewhat enlarged T wave in the opposing direction. The paced configuration varies from patient to patient; see Figure 6. The patient's own beats will have disappeared since the pacemaker is suppressing the intrinsic rhythm. Do not evaluate capture on the *bedside* monitor since the ECG is distorted by the pacing stimulus. The output should be set about 10% higher than the threshold mA when capture was obtained, which ensures a safety margin even if the threshold changes.



Figure 6 Examples of Electrical Capture with ZOLL Noninvasive Transcutaneous Pacemaker

If a patient is unconscious, the output can be quickly increased to the maximum, then lowered to determine the capture threshold, – since the patient will not feel discomfort from maximal muscle contraction.

Electrical capture signifies only excitation of a cardiac depolarization. Whether a cardiac contraction follows depends on the state of electromechanical coupling in the myocardium. Thus, a pulsation occurring at the pacing rate must always be palpated. Find the pulse in the right radial or brachial artery or in the femoral arteries; avoid palpating a pulse in the carotid or left radial/brachial arteries since the muscular contractions can cause misinterpretation. Other signs of the mechanical capture resulting from an increased cardiac output include an improved level of consciousness, blood pressure, arterial oxygen saturation, and color. If the patient is in a critical care unit, invasive technology may provide other data such as improved mixed venous oxygen saturation and end tidal CO₂. Muscle twitching starts at 20-25 mA with the ZOLL NTP, so realize that skeletal muscle contraction is not an indication that capture has been achieved either electrically or mechanically.

Since emergency noninvasive pacing was probably initiated with the defibrillator on battery power, do not forget to plug the device into AC power when things quiet down. Most defibrillators will sound a warning tone when the battery power is running low, so that you can intervene before pacing stops.

Documentation of the initiation of NTP should include:

- Printed strip of rhythm for which NTP was initiated
- Patient signs and symptoms for which NTP was initiated
- Date and time pacing was initiated
- Pacemaker settings with capture (i.e., capture threshold, output setting, rate setting, demand vs fixed mode)
- Printed strip of electrical capture
- Patient response with capture (i.e., heart rate, BP, oxygen saturation, level of consciousness)
- Pain intensity rating with NTP and actions taken to minimize

If standby pacing is being instituted, follow the steps above to establish effective pacing. Leave the mA dial at 10% above capture threshold, and turn the rate down to below the patient's current pulse rate, yet at a rate that will produce an adequate cardiac output if needed. It will be uncomfortable to pace the patient while setting the pacemaker up in standby, but pacing can be performed only briefly and the necessity for doing so explained to the patient.

Evaluate the skin underneath the pacing electrodes after the first 30 minutes of pacing and periodically for signs of damage. Electrodes should be replaced after 8 hours of continuous pacing, or after 24 hours of standby use. Neonates in particular may be more susceptible to thermal injury than adults due to thinner skin, less hair, weaker intercellular attachments, fewer eccrine and sebaceous gland secretions, and an increased susceptibility to external irritants.¹⁰ It is especially important with young children to assess the skin every 30 minutes.

Later, when it is time to evaluate if pacing can be discontinued, several of the noninvasive devices have a means to lower the rate of pacing and evaluate the patient's underlying rhythm. The ZOLL pacemaker has a unique 4:1 button, which paces at ¹/₄ the pulse per minute setting when it is held down. Abrupt cessation of pacing can cause ventricular standstill, so slowly lower the heart rate prior to discontinuation.



Comfort and Effectiveness of Noninvasive Transcutaneous Pacing

Patient discomfort is predicted by the force of the skeletal muscle contraction, rather than the pacemaker's output in mA. Use sedation and analgesia to assist in patient tolerance of this discomfort. Some patients may not be able to tolerate the discomfort and the transthoracic mode of pacing cannot be continued. If the pacing electrodes have been placed in the anterior-posterior position, try moving the negative or apex electrode more laterally to evaluate if this makes it more tolerable. But don't forget when you move an electrode, pacing will be discontinued for a short time. Discomfort appears to be inversely related to age, possibly due to the older patient having less muscle mass.

Capture rates with NTP are high and vary according to the device and patient population. With ZOLL's unique pacing waveform, published capture rates are up to 96%.¹¹ It has been found that with ZOLL's 40 millisecond, constant current and duration pacing waveform, capture is achieved at a lower threshold than with waveforms used by other vendors.¹² This lower current in the ZOLL pacemaker results in less patient discomfort. One vendor has recently lengthened its waveform to 40 milliseconds, but the duration is not constant and no clinical trials of its efficacy have been published.

Based on research, the capture threshold does not appear to correlate with body size. Thresholds in children have been found to be similar to that in adults.¹³ Falk found that the threshold is similar for anterior-posterior and sternum-apex placement of the electrodes.¹⁴ Moving the posterior electrode to the right of the spine by mistake increases the capture threshold by 15%. Placement of the electrodes over large bone will increase the threshold, so be sure to place the posterior electrode *under* the scapula not over and to the *side* of the spine. Make sure that the polarity of the electrodes is correct; otherwise the capture threshold is greatly increased and the patient will not be able to tolerate the discomfort. The negative electrode must be placed in the

anterior or apex position over the heart; just follow the diagrams on the electrode package and the electrodes themselves. Transthoracic impedance and resultant capture threshold vary with skin-to-electrode contact, so it is very important to make sure that the skin is properly prepared and that the electrodes are firmly attached to the skin surface.

Higher capture thresholds have been found in NTP with the following factors:

- Hypoxia
- Acidosis
- Pulmonary emphysema
- Pericardial effusion
- Large pectoral muscles
- Certain medications (e.g., antiarrhythmics, beta blockers, calcium channel blockers)
- After open heart procedures

Troubleshooting Noninvasive Transcutaneous Pacing

It is important that clinicians know how to troubleshoot problems that may occur with NTP. The most common problems are discussed below.

Failure to Capture

When every pacing stimulus is not followed by a wide paced QRS, failure to capture is said to occur. Intervention steps to take for failure to capture are listed below.

- 1. Increase the mA.
- 2. Make sure that the pacing electrodes are well adhered to the skin. You may find the posterior electrode in the bed sheets when the patient is diaphoretic or restless. Always check after repositioning and after transferring the patient to another surface.
- 3. Check for correct placement of the electrodes.
- 4. Move pacing (negative) electrode to another place on left precordium.
- 5. Treat the acidosis and hypoxia.



R Wave Detection Problems

Another potential problem relates to R wave detection. This problem is evident when the pacing rate displayed on the monitor screen does not closely correspond to the rate set for pacing (which should be the same as the pulse rate of mechanical capture). If the rate on the screen is said to be 40 when the pacing rate is set to 70, then all R waves are not detected. On the other hand, if the rate on the screen is said to be 140 when the pacing rate is set to 70, then all R waves are being detected. Problem solving steps are listed below.

- 1. Verify whether mechanical capture is occurring at the rate to which the pacemaker is set.
- 2. Validate whether the heart-shaped detection light (\P) is blinking close to the correct rate.
- 3. Select a different ECG lead and check if the heart-shaped detection light is now occurring with each R wave. **Note**: Wait for at least 10 seconds after switching to another lead for the monitor to accurately detect the R wave.
- 4. Change the size of the ECG (i.e., increase the size if all R waves are not detected or decrease the size if other than R waves are being detected). **Note**: On some monitoring devices use of the size switch enhances the ECG display but does not assist in R wave detection.
- 5. Check that the ECG electrodes are well adhered to the skin and that the skin is in good condition.
- 6. Check the expiration date on the ECG electrodes, perform a good skin prep, and apply new ECG electrodes.
- 7. Switch to asynchronous pacing until the problem is solved.

If the rate on the display screen is higher than the rate set for pacing, the monitor may be detecting activity other than the ECG signal. When artifact is produced by patient movement, reassure the patient and provide sedation/analgesia if needed. Check for electrical signals from another source that may be detected by the pacemaker and move this instrument further away.

Noisy ECG Signal

The ECG signal may show artifact due to poor skin-electrode interface or electrical signals from another source. Steps to take to solve this problem are noted below.

- 1. Perform a good preparation of the skin and reapply ECG electrodes.
- 2. Move the ECG electrodes further away from the pacing electrodes.
- 3. Select another ECG lead.
- 4. If patient movement is involved, assess how to correct.
- 5. Evaluate for electromagnetic interference from a nearby piece of equipment.

Difficulty Interpreting Capture on the ECG

Because of the strong electrical current with the pacemaker impulse, recognition of the paced beat on a standard bedside ECG monitor is virtually impossible unless it receives an auxiliary ECG signal from the pacemaker monitor itself (the primary source of the ECG). Transcutaneous

pacemakers incorporate a special damping circuit into their oscilloscopes to permit visualization of the paced beats. Be aware that the pacing function which can be activated with some arrhythmia monitoring systems is only effective with implanted pacemaker devices and not NTP.

Despite the blanking period after the pace pulse, some of the ECG artifact may remain and a portion may be seen immediately following the pace pulse. This artifact morphology is variable and at times may resemble a QRS complex so that it can be confused with capture as in the strip below. Capture is evident only with pacing pulses 3 and 4, along with a fusion beat in pulse 10. No other pacing pulses result in electrical capture.



Delays in Initiation of Noninvasive Transcutaneous Pacing

In my role as a cardiovascular clinical nurse specialist, I have seen clinicians experience difficulty obtaining an ECG on the monitor screen of the defibrillator because they forget to attach separate ECG electrodes for sensing. During an arrest it was thought that a defibrillator was not functioning when only a dotted line appeared across the defibrillator's screen during pacing attempts. A second defibrillator/pacemaker was called for and the same error was repeated.

Delays in implementation of pacing can also occur when the multi-function cable and ECG wires are tangled. ZOLL Medical Corporation has recently introduced their new One StepTM cable, One StepTM Complete Resuscitation Electrode, and One StepTM Pacing Electrode for use with the R Series monitor/defibrillator/pacemaker. Three ECG electrodes are built right into the apex multi-function electrode, thus eliminating the need for a separate ECG cable; see Figure 7. These special leads, appearing on the monitor screen as P1, P2, and P3, are fine for sensing but should not be used for diagnostic purposes; see Figure 8.

Figure 7 ZOLL OneStep Pacing Anterior Electrode (therapy surface shown)





Figure 8 Position of Apex ZOLL

Safety of Noninvasive Transcutaneous Pacing

Zoll's original research established the safety of NTP. There was concern of a pacing stimulus landing on the T wave and causing a ventricular arrhythmia. He found that with stimuli 5-100 msec long, the threshold for ventricular tachycardia (VT) and fibrillation (VF) was 5 to 16 times the thresholds for single responses.¹⁵ Such high thresholds far exceed the maximum output of clinical noninvasive pacemakers. Thus, NTP is incapable of delivering a stimulus of sufficient amplitude to provoke VT or VF. He adds that VT/VF "were not provoked even in the presence of competition between an intrinsic rhythm and the artificial pacemaker, or during an acute myocardial infarction or other serious cardiac disease."¹⁶

Clinicians should be assured that it is safe to touch the patient while being transcutaneously paced. The only caution is not to touch the gelled surface of the pacing electrode during active pacing.

Staff should always remain close to patients who are being transcutaneously paced. Pacing thresholds may increase over time according to Dunn,¹⁷ and the patient may experience lack of capture. Careful and frequent observation of the pacing electrodes is mandatory, especially the posterior one. Alarms will sound if the pacing pads are not making good contact with the skin, if the pads are not connected to the cable, and if the cable is defective. If a condition interferes with obtaining an adequate surface ECG, the pacemaker will automatically switch to the asynchronous mode.

If the patient goes into ventricular fibrillation, pacing will be discontinued once the selector switch is turned to DEFIB. After compressions are delivered, ensure that the pacing electrodes are still in good contact with the patient's skin and resume pacing.

Education and Competency in Noninvasive Transcutaneous Pacing

It is essential that competency in NTP be established for all clinicians newly employed and whenever a new defibrillator/pacemaker is introduced. Because the frequency of using NTP in the clinical arena is low, competency should be reproduced at least every two years. See Table 1 for the NTP Competency Checklist for the ZOLL M Series defibrillator/pacemaker, and Table 2 for that with the new R Series defibrillator/pacemaker.

Conclusion

This review of NTP has included the definition, physiology, indications for use, procedure, efficacy, safety, troubleshooting, and suggested education to achieve competency. Those who perform NTP already know that this method of pacing is easy to implement and consistently achieves both electrical and mechanical capture in patients with bradycardia – so that it really is "tried and true". Patient discomfort from muscle contraction can be minimized with use of sedative or analgesia medications. It is important to understand how to troubleshoot the most common problems that can occur with NTP and realize that recognizing electrical capture is not always easy. Be comfortable with the defibrillator/external pacemaker used in your hospital so that NTP can be initiated quickly in accordance with the AHA bradycardia algorithm.



Competency Checklist: ZOLL M Series Noninvasive Transcutaneous Pacing



EQUIPMENT:

- Pacing pads appropriate to age/size of patient
- Defibrillator with monitor and noninvasive pacing capability and cable
- ECG electrodes and cable
- Patent IV or prn adapter
- Sedation/analgesia if ordered
- Emergency cart readily available

PERFORMANCE ELEMENTS	MET	NOT MET
1. *Verify the need for noninvasive pacing; evaluate the patient's cardiac rhythm		
and hemodynamic response to it. A slow heart rate does not necessarily require		
noninvasive pacing.		
2. As the situation permits, explain to the patient and family the:		
• purpose of the noninvasive pacemaker.		
 equipment used for noninvasive pacing. 		
• procedure.		
 potential sensations the patient might experience (i.e. muscle twitching, discomfort, etc.). 		
• measures that can be implemented to alleviate the pain or discomfort.		
3. Prepare the patient for noninvasive pacing:		
• Obtain a baseline 12- or 15-lead ECG if ordered; otherwise obtain a baseline		
ECG monitor strip.		
• Perform and document a baseline patient assessment.		
• Have emergency cart immediately available. Ensure that the patient has a patent IV.		
4. *Prepare the device for ECG monitoring:		
• Connect ECG cable to electrodes and plug into defibrillator with noninvasive capability.		
• Apply ECG electrodes in the conventional 3-lead system as outlined below:		
 Turn defibrillator selector switch to "MONITOR". Verify presence of rhythm for which pacing is being performed. Adjust the ECG monitor lead and size to maximize the R wave (QRS complex). Validate that the R wave is being consistently detected (Y will blink with each R wave) 		

PERFORMANCE ELEMENTS	MET	NOT MET
5. Assess surroundings for environmental electrical safety (e.g., dry floors).		
6. *Prepare the device and patient for pacing:		
• Attach the pacing pads to the cable.		
• Remove all clothing from patient's torso.		
• Do not place pads over ECG electrodes, tape, bandages, fresh incisions,		
transdermal medication patches.		
• Clip excessive hair. Avoid nicks or cuts to skin which may increase patient		
discomfort.		
• Assure that skin is clean and dry.		
7. *Apply pacing pads to the patient:		
• Apply one edge of the pad securely to the patient.		
• "Roll" the pad smoothly from that edge to the other, being careful not to trap		
any air pockets between the gel and the skin.		
A. Anterior-Posterior Placement (preferred placement):		
Pad Skin		
BACK		
APEX		
FRONT		
1) Rectangular posterior pad is placed on the left infrascapular area		
behind the heart.		
2) Round anterior pad is placed on the anterior precordial area.		
B. Sternum-Apex Placement (alternate placement):		
1 end (end (a)		
JIEKNUW AFEA		
INTEDAL		
LAILNAL		
1) Round anterior nad is placed just lateral to the left nipple in the		
midavillary line		
2) Rectangular posterior pad is placed on the right anterior upper torso		
in the subclavicular area lateral to the starnum		
in the subclaviculal alea lateral to the stellfulli.		l

PERFORMANCE ELEMENTS	MET	NOT MET
7. *Turn defibrillator with noninvasive pacing selector switch to "PACER".		
8. *Set desired pacing rate at least 10-20 ppm higher than patient's intrinsic		
rate. The default setting varies depending on the model or institutional standard.		
9. *Initiate pacing by slowly increasing the mA (milliamperes, current, or energy) until electrical pacing capture is observed. Most patients require		
40 - 80 mA to achieve capture. Then increase pacer output by 10% above		
threshold.		
12:37:59 02 12:42:00 02-JUL-07 LEAD II SIZE 1.5 HR= 82 68 MA		
many how have have by have have		
80 ZOLL Medical Corporation Recorder PNI: 8009-0200 ZOLL Medical Corporation Recorder PNI: 8009-0200 ZOLL Medical Corporation Recorder PNI: 8009-0		
10. *Verify mechanical capture by checking for a brachial or radial pulse on the right side of the body – or a femoral pulse. (Palpated carotid and left brachial/		
radial pulses may be pseudo-pulses due to muscle contraction and not indicative		
of mechanical capture).		
11. *Assess patient's response to noninvasive pacing (i.e. signs of improving		
cardiac output).		
12. Consider administration of sedation / analgesia if condition permits.		
12. Obtain a baseline 12- or 15-lead ECG of the captured rhythm if ordered;		
otherwise, obtain an ECG monitor strip.		
15. Document per policy.		

* = Critical elements

Passed \Box Needs to Repeat \Box

Participant name: _____

Validated by:

Date:





Competency Checklist: ZOLL R Series Noninvasive Transcutaneous Pacing

Participant Name: _____

Date: ____

Scenario: Your post MI patient suddenly drops his pulse to 40/minute. His blood pressure decreases to 80/40 and he becomes diaphoretic. The physician orders that 0.5 mg of atropine be given, but there is no change in heart rate. You initiate external pacing using the R Series defibrillator/pacemaker. Demonstrate your competency in this lifesaving skill.

	Steps	Evaluator Notes	Pass	Retest
1.	Verify that the R Series is ready for use.	Note that there is a green checkmark in the upper right of the device.		
2.	Verbalize how to prepare the patient's skin for the electrodes related to:			
	a. Clothing	a. Remove from torso.		
	b. Ointments	b. Wipe off.		
	c. Transdermal patch	c. Remove and wipe medication off skin.		
	d. Dressings, tubes, drains, fresh incisions	d. Move location of electrode to avoid these.		
	e. Diaphoresis	e. Wipe skin dry.		
	f. Excessive hair	f. Clip it.		
3.	Remove the OneStep Complete Electrodes from the side of the defibrillator.	Pull the electrode package by the top.		
4.	Open the electrode package.	Grasp the cable and pull back from the top.		
5.	Place the red electrode correctly onto the patient's	a. Roll patient onto side.		
	back.	b. Grasp red electrode where wire exits electrode		
		and peel it from plastic liner.		
		c. Roll electrode onto back to left of spine and		
		under scapula.		
6.	Place the blue electrode correctly onto the patient's	a. Roll patient onto back.		
	chest.	b. Grasp blue electrode where wire exits		
		electrode and peel it from liner.		
		c. Roll electrode onto left chest, with dark blue		
		triangle midway between sternum and nipple.		
7.	Verbalize how to alter location of chest electrode if	a. Place electrode under breast.		
	patient is female.	b. Avoid contact of electrode gel with nipple.		
		c. Try and avoid placing electrode on skin fold.		
8.	Turn on the device to pacing.	Set heart rate on simulator to bradycardia at		
		40/minute.		
		Turn the Mode Selector to PACER.		
9.	Cycle through the 3 P leads and determine which	The heart-shaped symbol (♥) flashes each time the		
	one is best for R wave detection.	device detects an R wave.		
10.	Set the pacing rate to 100 beats/minute.	Turn the rate knob clockwise until 100 appears on		
		the display screen.		
11.	Gradually turn the mA knob clockwise until	Turn the mA knob clockwise. Normal range for		
	electrical capture occurs.	capture is 40-80 mA.		

	Steps	Evaluator Notes	Pass	Retest
12.	Determine the capture threshold.	Turn the mA knob counterclockwise until capture is lost. Then turn the mA knob clockwise until capture is gained. This is the capture threshold.		
13.	Set the pacing output 10% above the threshold.			
14.	Print a recorder strip and verbalize how to know that electrical capture is occurring.	With electrical capture each downward pacing spike is followed immediately by a widened QRS and an extended, sometimes enlarged T wave, occurring at selected pacing rate.		
15.	Verbalize how to determine mechanical capture.	A pulse is present in the right brachial, right radial, or femoral arteries.		
16.	Utilize the 4:1 button to determine the patient's underlying rhythm.	Push and hold the 4:1 button. Three of the 4 paced impulses will be suppressed.		
17.	Show how to set the external pacemaker up in standby mode.	Set heart rate on simulator to normal sinus rhythm at 80/minute. Turn the rate below the patient's current rate now that capture has been determined.		

Scoring criteria: To pass, participant must complete all steps.

Pass _____ Retest _____

Comments:

Evaluator's Signature: _____

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