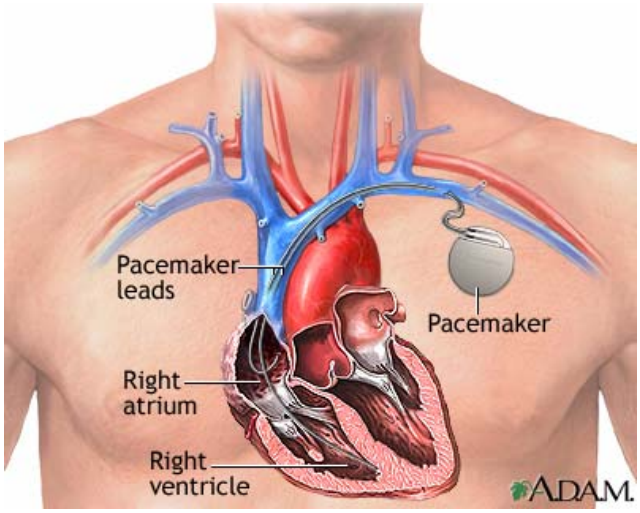
TEMPORARY AND PERMANENT PACEMAKERS

THE HEART'S CONDUCTION SYSTEM AND "NATURAL PACEMAKER" — The heart has its own built-in electrical system, called the conduction system. The conduction system sends electrical signals throughout the heart that determine the timing of the heartbeat and cause the heart to beat in a coordinated, rhythmic pattern. The conduction system stimulates precise contractions of the heart's chambers to ensure that blood is pumped effectively.



The electrical signals, or impulses, of the heart are generated by specialized tissue called the sinoatrial (SA) or sinus node. The sinus node is sometimes called the heart's "natural pacemaker." Each time the sinus node generates a new electrical impulse; that impulse spreads out through the heart's upper chambers, called the right atrium and the left atrium. This electrical impulse, as it spreads across the two atria, stimulates them to contract, pumping blood into the right and left ventricles.

The electrical impulse then spreads to the atrioventricular (AV) node, which is another area of specialized tissue located between the atria and the ventricles. The AV node momentarily slows down the spread of the electrical impulse, to allow the left and right atria to finish contracting.

From the AV node, the impulse spreads into a system of specialized fibers called the His bundle, or bundle of His, and the right and left bundle branches. These fibers distribute the electrical impulse rapidly to all areas of the right and left ventricles, stimulating them to contract in a coordinated way. With this contraction, blood is pumped from the right ventricle to the lungs, and from the left ventricle throughout the body.

ARRHYTHMIAS — The heart's conduction system must function normally for the heart to beat properly and to pump blood effectively to meet the body's needs. Problems with the flow of electrical impulses in the heart are called arrhythmias, which is a general term meaning a deviation from the normal pattern of electrical conduction or electrical rhythm. Bradyarrhythmias are arrhythmias that cause an abnormally slow heartbeat. Tachyarrhythmias are arrhythmias that cause an abnormally fast heartbeat.

Arrhythmia symptoms — The symptoms of arrhythmias vary, depending upon the specific arrhythmia and other factors, especially if there is underlying heart disease. While some patients may have no symptoms (asymptomatic), others may have various symptoms and signs. In some patients, such symptoms may include:

- Fainting episodes (syncope)
- Dizziness or lightheadedness (presyncope)
- Palpitations (a sensation of the heart pounding)
- Confusion
- Extreme fatigue
- Shortness of breath

- Impaired ability of the heart to pump enough blood to meet the body's needs (heart failure)

The decision to treat an arrhythmia with a pacemaker (or any other treatment) may depend in part on whether the patient has symptoms or not.

Underlying causes — A variety of conditions can lead to the development of cardiac arrhythmias. Some of the more common causes include:

- Coronary artery disease, where there is a malfunction or damage of the heart due to narrowing or blockage of arteries supplying blood to heart muscle.
- Damage from a heart attack (an acute myocardial infarction), and the development of scar tissue in the muscle of the heart.
- Certain structural heart malformations present at birth (congenital heart defects)
- Inherited genetic abnormalities that are not necessarily associated with a structural problem of the heart, but may result in an arrhythmia (such as the long QT syndrome)
- Abnormalities in the control and regulation of the heartbeat by the nervous system, leading to fainting (called "neurocardiogenic syncope").
- Diseases of heart muscle tissue, called cardiomyopathies.
- Therapy with certain medications that may alter the heart's normal rhythm.
- Normal aging of heart muscle

TEMPORARY AND PERMANENT PACEMAKERS — Artificial pacemakers are electronic devices that stimulate the heart with electrical impulses to maintain or restore a normal rhythm in patients with slow heart rhythms. There are many situations in which doctors may recommend the use of an artificial pacemaker. Most commonly, a pacemaker is used for a slow heart rate (bradyarrhythmia) as described above. The decision to use such a device—as well as which specific type—will depend upon multiple factors, including:

- The exact nature and underlying cause of the arrhythmia
- Whether the condition is temporary or permanent
- The presence or absence of symptoms as described above
- The potential risk of complications from a pacemaker

How they work — An artificial pacemaker provides an electrical impulse (or "discharge") that can stimulate the heart, thus restoring or maintaining a regular heartbeat for patients with abnormalities in cardiac impulse formation and/or transmission. Although various types of artificial pacemaker devices are available, they generally include the following components:

- A thin metal box or case called a pulse generator. The pulse generator contains the power source producing the electrical impulses of the pacemaker. In addition, the pulse generator contains a small computer processor that can be programmed to set the rate of

the pacemaker, the pattern of pacing, the energy output, and various other parameters. The pulse generator for most modern permanent pacemakers weighs one to two ounces.

- Flexible insulated wires or "leads" carry electrical impulses from the generator to the heart muscle and relay information concerning the heart's natural activities back to the pacemaker. There may be several such wires, or leads, placed within the heart, but most commonly they are placed in the right atrium and right ventricle. If the pulse generator is capable of pacing both the right and the left ventricle (for the treatment of heart failure), a total of 3 leads are usually placed.

- One or more electrodes at the tips of the leads transmit electrical impulses to the heart muscle and also sense the heart's own electrical activity.

Types of pacemakers — A variety of different types of pacemakers have been developed to restore or sustain a regular heartbeat in different ways. "Demand" pacemakers are pacemakers that monitor the heart's natural electrical activity and discharge only when the heart's own rate is too slow or the heart misses a beat. "Fixed-rate" pacemakers discharge impulses at a single, steady rate, regardless of the heart's own electrical activity. "Rate-responsive" pacemakers are designed to raise or lower the pacing rate to help meet the body's needs during physical activity or rest.

Pacemakers may also be single-, dual-, or triple-chambered:

- Single-chamber pacemakers normally have one lead to carry impulses to and from either the right atrium or right ventricle.

- A dual-chamber pacemaker usually has two leads, one to the right atrium and one to the right ventricle, that can monitor and carry impulses to one or both chambers; these can produce an atrial contraction followed closely by ventricular contraction, thus more naturally resembling the normal activities of the heart.

- Triple-chambered pacemakers typically have one lead in the right atrium and one each in the right and left ventricles. These pacemakers are inserted in patients who have weakened heart muscle (which results in heart failure) and have delay in the time for contraction between the right and left ventricles (often measured in an electrocardiogram as a bundle branch block), causing problems with shortness of breath and inability to tolerate physical activity. These pacemakers "resynchronize" the ventricles and may improve the efficiency of the contraction of the heart, improving its blood flow.

Temporary pacemakers — Temporary pacemakers are intended for short-term use, usually during hospitalization. They are used because the patient's arrhythmia is expected to be temporary and eventually resolve, or because the patient requires temporary treatment until a permanent pacemaker can be placed.

The pulse generator of a temporary pacemaker is located outside the body, and may be taped to the skin or attached to a belt or to the patient's bed. The leads for a temporary pacemaker may be positioned in a number of ways depending upon the circumstances:

- Inserted through a vein (transvenously) and positioned on the inside of the heart (endocardially)

- Attached to the outside surface of the heart (epicardially), which is usually done during cardiac surgery

- Inserted through the skin (transcutaneously), such as via a needle placed directly through the chest wall

- (More rarely), placed via the esophagus

- (In emergency situations) with the use of large surface, high impedance electrodes applied to the chest walls (external pacing)

Temporary pacing is most frequently used for symptomatic bradyarrhythmias. Less commonly, it may be used for certain patients with tachyarrhythmias, usually providing stimulation at a rate more rapid than the tachycardia (called intermittent overdrive pacing) to terminate the arrhythmia and prevent its recurrence.

The use of temporary pacing may be considered necessary or appropriate under a variety of circumstances. Experts advise that, as a general rule, any condition for which a permanent pacemaker is appropriate may also be an indication for temporary pacing. Specific settings include:

- When a bradyarrhythmia causes severe impairment in proper blood circulation, yet the use of a permanent pacemaker is not immediately indicated, is unavailable, or is considered risky.

- For patients with a bradyarrhythmia from a temporary condition that usually improves over time and thus will not likely require permanent pacing. Examples include drug toxicity from therapy with certain heart medications; damage to the conduction system due to coronary bypass surgery or heart transplantation; heart trauma, such as occurs after a motor vehicle accident with associated chest trauma; or Lyme disease.

- To determine whether a patient's condition will improve with a pacemaker when the cause for symptoms is not clear.

- For certain patients with bradyarrhythmias due to acute myocardial infarction even when permanent pacing is not required. Occasionally, temporary pacemakers are used in patients who are felt to be at high risk for heart block and symptomatic bradycardia.

- In patients who are dependent upon permanent pacemakers, temporary pacing may be used if the permanent pacemaker needs to be removed due to infection, if there is a pacemaker or lead failure, or during a lead revision or pacemaker generator change.

- To help prevent a tachycardia from occurring (through the use of rapid pacing, as discussed above).

Patients with temporary pacemakers require hospitalization with continuous monitoring. Members of the patient's healthcare team will perform regular physical examinations to help prevent and detect any possible complications, conduct routine checks of pacemaker function, change bandage dressing daily at the site of pacemaker insertion, and apply antibiotic ointment to prevent infection.

Permanent pacemakers — Permanent pacemakers are pacemakers that are intended for long-term use.

Indications — Specific guidelines have been established for doctors concerning the conditions in which implantation of permanent pacemakers is definitely beneficial, useful, and effective; may be indicated; or is not useful or effective and, in some cases, may be harmful. These guidelines were established by the American College of Cardiology, the Heart Rhythm Society, and the American Heart Association. Patients should speak with their doctors concerning these guidelines and how they apply to their specific case.

As a general rule, permanent pacing may be indicated for certain conditions that are chronic or recurrent and not due to a transient cause. Permanent pacing may be considered necessary or appropriate for certain patients with symptomatic bradyarrhythmia or, less commonly, to help prevent or terminate tachyarrhythmia.

Implantation — The pulse generator of a permanent pacemaker is implanted into soft tissue beneath the skin, which is known as prepectoral implantation; this is located under the skin and fat tissue but above the pectoral or breast muscle. The pacemaker leads are typically inserted into a major vein (transvenously) and advanced until the electrodes are secured within the proper region(s) of heart muscle. The other ends of the leads are attached to the generator, which is typically implanted under the skin and fat tissues in the upper outer portion of the chest.

Less commonly, leads may be placed onto the heart's surface, known as epicardial implantation; this may occur if other cardiac surgery is being performed and/or if permanent pacing cannot be performed transvenously. During such a procedure, the pulse generator is typically fitted under the skin of the upper abdomen.

Generally the pacemaker is implanted in a sterile laboratory or operating room by a specialist with experience in this procedure. Local anesthesia is used to make the procedure as pain-free as possible. In some cases, sedation or even general anesthesia may be used. The position of the pacemaker leads is usually checked using X-ray imaging (called fluoroscopy). The procedure can take as little as 15 minutes, or as long as three hours or more if a triple-chambered pacemaker for heart failure is being implanted.

Recovery from the procedure is rapid, but there may be some restrictions on arm movement and activities for the first few weeks. The hospital stay is usually brief, and in some cases the procedure can be done on an outpatient basis. Risks associated with permanent pacemaker implantation include collapsed lung (pneumothorax), infection, and bleeding.

Follow-up care — Patients who receive a permanent pacemaker will require periodic clinical check-ups, including certain tests such as ECGs, which record the electrical activity of the heart. In addition, the status of the pacemaker will be regularly checked to evaluate the battery and electronic circuitry functioning and the effectiveness of any programmed settings.

All contemporary devices are programmable, with information and settings that can be altered and stored. Information is obtained by transmitting data from the pulse generator to the programmer, usually done during a follow-up office visit. However, with newer pulse generators it may be possible to obtain information about the pacemaker's performance by downloading data from the patient's device to the internet and then to the caregiver's office. Pacemaker activity can also be checked routinely via the telephone, using a telephone-transmitting device.

The pulse generators are usually powered by lithium batteries that function for five to eight years before they need to be replaced. Replacing the generator usually requires a simple procedure in which a repeat incision is made, the old generator is removed, and a new generator is implanted and joined with the existing leads.

The pacemaker leads are usually used indefinitely, unless a specific problem occurs such as dislodgement (in which the lead loses contact with the heart), fracture (in which the lead breaks), or insulation damage (which may interfere with the proper function of the lead). In such circumstances, the lead may require replacement. Typically, the old lead is left in place but disconnected from the pulse generator, and a new lead is inserted. Removal of an old lead is feasible but difficult in most cases, because of the formation of scar tissue binding the lead to the blood vessels and heart muscle. Lead removal may be necessary if the system has become infected.

AVOIDING POSSIBLE ELECTROMAGNETIC INTERFERENCE — Although certain design changes have made modern pacemakers less susceptible to interference, electromagnetic emissions from a variety of external devices may disrupt the functioning of artificial pacemakers. Thus, to help avoid electromagnetic interference, experts advise that patients with artificial pacemakers should be aware of the following:

Household appliances — Although there are no studies that have systematically evaluated the effect of household microwave energy on implanted devices, it is widely accepted that modern pacemakers are adequately shielded from the microwave energy produced by modern appliances. Pacemaker manufacturers do not recommend any special precautions when using common household appliances such as televisions, radios, toasters, and electric blankets.

Cellular phones — Due to the growing use of hand-held cellular phones, patients must be aware of their potential adverse effects. As examples:

- Evidence suggests that, when held in a normal position over the ear, cellular phones do not appear to cause interference with permanent pacemakers. Yet they can cause interference when placed directly over the pulse generator. Thus, patients must avoid placing a cell phone over the pacemaker (especially the antenna of the phone), and should not carry it in a pocket close to or over the pacemaker while the phone is on.

- Because temporary pacemakers are used mainly in intensive care units, the risk of electromagnetic interference is limited. However, one study found a potential risk of interference of temporary transvenous pacemakers from cellular digital phones and walkie-talkies, which persisted at a range of up to 200 cm. Therefore, the use of such communication devices must be avoided in the vicinity of patients with temporary pacemakers.

Security systems — Electromagnetic security systems are often found in or near the workplace, at airports, in shopping malls, at courthouses, or in other high-security areas. Such exposure has been shown to cause interference in some cases and may be related to duration of exposure and/or distance between the security system and the pacemaker. Based upon several studies and observations, experts advise that patients with pacemakers should:

- Be aware of the location of security systems and move through them at a normal pace.
- Avoid sitting or standing close to a security system.

External electrical equipment — In workplaces that contain welding equipment or motor-generator systems, the effects of external electrical fields do not seem to cause a problem for persons wearing a pacemaker. However, because interference remains a concern, experts recommend that patients remain at least two feet from external electrical equipment, verify that the equipment is properly grounded, wear insulated gloves when using electrical devices, and leave the work area immediately if they experience lightheadedness or other concerning symptoms.

Diagnostic or therapeutic procedures — Certain diagnostic or treatment procedures may interfere with pacemakers. Thus, clinicians recommend avoiding these procedures or using special precautions, such as reprogramming of the pacemaker. Such procedures include:

- Magnetic resonance imaging (MRI), a noninvasive diagnostic imaging procedure that uses a strong magnetic field that is pulsed on and off at a rapid rate.

- Transcutaneous electrical nerve/muscle stimulators, a method of pain control involving the application of electrical impulses to muscle or nerve via electrodes placed on the skin

- Diathermy, the production of heat in body tissues for therapeutic purposes through high-frequency electromagnetic radiation or microwaves

- Extracorporeal shock wave lithotripsy, the use of sound waves to break up stones (calculi) in the urinary tract or gallbladder

- Therapeutic radiation for cancer or tumors, which can cause permanent pacemaker damage from the radiation

Thus, patients should inform all doctors, dentists, and other healthcare providers about their pacemakers; discuss the possible benefits, risks, and alternatives before undergoing diagnostic or therapeutic procedures, if possible; and carry a patient ID card for emergencies.