Artificial pacemaker

A pacemaker, scale in centimeters An artificial pacemaker with electrode for transvenous insertion (from St. Jude Medical). The body of the device is about 4 centimeters long, the electrode measures between 50 and 60 centimeters (20 to 24 inches).

A pacemaker (or artificial pacemaker, so as not to be confused with the heart's natural pacemaker) is a medical device which uses electrical impulses, delivered by electrodes contacting the heart muscles, to regulate the beating of the heart. The primary purpose of a pacemaker is to maintain an adequate heart rate, either because the heart's native pacemaker is not fast enough, or there is a block in the heart's electrical conduction system. Modern pacemakers are externally programmable and allow the cardiologist to select the optimum pacing modes for individual patients. Some combine a pacemaker and defibrillator in a single implantable device. Others have multiple electrodes stimulating differing positions within the heart to improve synchronisation of the lower chambers of the heart.

History

The first implantable pacemaker.
In 1958, Arne Larsson (1915-2001) became the first to receive an implantable pacemaker. He had a total of 26 devices during his life and campaigned for other patients needing pacemakers.

In 1899, J A McWilliam reported in the British Medical Journal of his experiments in which application of an electrical impulse to the human heart in asystole caused a ventricular contraction and that a heart rhythm of 60-70 beats per minute could be evoked by impulses applied at spacings equal to 60-70/minute.\[1\]

In 1926, Dr Mark C Lidwell of the Royal Prince Alfred Hospital of Sydney, supported by physicist Edgar H Booth of the University of Sydney, devised a portable apparatus which "plugged into a lighting point" and in which "One pole was applied to a skin pad soaked in strong salt solution" while the other pole "consisted of a needle insulated except at its point, and was plunged into the appropriate cardiac chamber". "The pacemaker rate was variable from about 80 to 120 pulses per minute, and likewise the voltage variable from 1.5 to 120 volts" In 1928, the apparatus was used to revive a stillborn infant at Crown Street Women's Hospital, Sydney whose heart continued "to beat on its own accord", "at the end of 10 minutes" of stimulation.\[2\][3]

In 1932, American physiologist Albert Hyman, working independently, described an electro-mechanical instrument of his own, powered by a spring-wound hand-cranked motor. Hyman himself referred to his invention as an "artificial pacemaker", the term continuing in use to this day.\[4\][5]

An apparent hiatus in publication of research conducted between the early 1930s and World War II may be attributed to the public perception of interfering with nature by 'reviving the dead'. For example, "Hyman did not publish data on the use of his pacemaker in humans because of adverse publicity, both among his fellow physicians, and due to newspaper reporting at the time. Lidwell may have been aware of this and did not proceed with his experiments in humans".\[3\]

An external pacemaker was designed and built by the Canadian electrical engineer John Hopps in 1950 based upon observations by cardio-thoracic surgeon Wilfred Gorden Bigelow at Toronto General Hospital. A substantial external device using vacuum tube technology to provide transcutaneous pacing, it was somewhat crude and painful to the patient in use and, being powered from an AC wall socket, carried a potential hazard of electrocution of the patient by inducing ventricular fibrillation.

A number of innovators, including Paul Zoll, made smaller but still bulky transcutaneous pacing devices in the following years using a large rechargeable battery as the power supply.\[6\]

In 1957, Dr. William L. Weirich published the results of research performed at the University of Minnesota. These studies demonstrated the restoration of heart rate, cardiac output and mean aortic pressures in animal subjects with complete heart block through the use of a myocardial electrode. This effective control of postsurgical heart block proved to be a significant contribution to decreasing mortality of open heart surgery in this time period.\[7\]

The development of the silicon transistor and its first commercial availability in 1956 was the pivotal event which led to rapid development of practical cardiac pacemaking.

In 1958, engineer Earl Bakken of Minneapolis, Minnesota, produced the first wearable external pacemaker for a patient of Dr. C. Walton Lillehei. This transistorised pacemaker, housed in a small plastic box, had controls to permit adjustment of pacing heart rate and output voltage and was connected to electrode leads which passed through the skin of the patient to terminate in electrodes attached to the surface of the myocardium of the heart.
The first clinical implantation into a human of a fully implantable pacemaker was in 1958 at the Karolinska Institute in Solna, Sweden, using a pacemaker designed by Rune Elmqvist and surgeon Åke Senning, connected to electrodes attached to the myocardium of the heart by thoracotomy. The device failed after three hours. A second device was then implanted which lasted for two days. The world's first implantable pacemaker patient, Arne Larsson, went on to receive 26 different pacemakers during his lifetime. He died in 2001, at the age of 86, outliving the inventor as well as the surgeon.

In 1959, temporary transvenous pacing was first demonstrated by Furman et al., in which the catheter electrode was inserted via the patient's basilic vein.

In February 1960, an improved version of the Swedish Elmqvist design was implanted in Montevideo, Uruguay in the Casmu Hospital by Doctors Fiandra and Rubio. That device lasted until the patient died of other ailments, 9 months later. The early Swedish-designed devices used rechargeable batteries, which were charged by an induction coil from the outside.

Implantable pacemakers constructed by engineer Wilson Greatbatch entered use in humans from April 1960 following extensive animal testing. The Greatbatch innovation varied from the earlier Swedish devices in using primary cells (mercury battery) as the energy source. The first patient lived for a further 18 months.

The first use of transvenous pacing in conjunction with an implanted pacemaker was by Parsonnet in the USA, Lagergren in Sweden and Jean-Jaques Welti in France in 1962-63. The transvenous, or pervenous, procedure involved incision of a vein into which was inserted the catheter electrode lead under fluoroscopic guidance, until it was lodged within the trabeculae of the right ventricle. This method was to become the method of choice by the mid-1960s.

World's first Lithium-iodide cell powered pacemaker. Cardiac Pacemakers Inc. 1972

The preceding implantable devices all suffered from the unreliability and short lifetime of the available primary cell technology which was mainly that of the mercury battery.

In the late 1960s, several companies, including ARCO in the USA, developed isotope powered pacemakers, but this development was overtaken by the development in 1971 of the lithium-iodide cell by Wilson Greatbatch. Lithium-iodide or lithium anode cells became the standard for future pacemaker designs.

A further impediment to reliability of the early devices was the diffusion of water vapour from the body fluids through the epoxy resin encapsulation affecting the electronic circuitry. This phenomenon was overcome by encasing the pacemaker generator in an hermetically sealed metal case, initially by Telectronics of Australia in 1969 followed by Cardiac Pacemakers Inc of Minneapolis in 1972. This technology, using titanium as the encasing metal, became the standard by the mid-1970s.

Others who contributed significantly to the technological development of the pacemaker in the pioneering years were Bob Anderson of Medtronic Minneapolis, J.G (Geoffrey) Davies of St George's Hospital London, Barouh Berkovits and Sheldon Thaler of American Optical, Geoffrey Wickham of Teletronics Australia, Walter Keller of Cordis Corp. of Miami, Hans Thornander who joined previously mentioned Rune Elmqvist of Elema-Schonander in Sweden, Janwillem van den Berg of Holland and Anthony Adducci of Cardiac Pacemakers Inc. Guidant.

Methods of pacing
An ECG in a person with an atrial pacemaker. Note the circle around one of the sharp electrical spike in the position were one would expect the P wave.

**Percussive pacing**

Percussive pacing, also known as transthoracic mechanical pacing, is the use of the closed fist, usually on the left lower edge of the sternum over the right ventricle in the vena cava, striking from a distance of 20 – 30 cm to induce a ventricular beat (the British Journal of Anesthesia suggests this must be done to raise the ventricular pressure to 10 - 15mmHg to induce electrical activity). This is an old procedure used only as a life saving means until an electrical pacemaker is brought to the patient.[16]

**Transcutaneous pacing**

Transcutaneous pacing (TCP), also called external pacing, is recommended for the initial stabilization of hemodynamically significant bradycardias of all types. The procedure is performed by placing two pacing pads on the patient's chest, either in the anterior/lateral position or the anterior/posterior position. The rescuer selects the pacing rate, and gradually increases the pacing current (measured in mA) until electrical capture (characterized by a wide QRS complex with a tall, broad T wave on the ECG) is achieved, with a corresponding pulse. Pacing artifact on the ECG and severe muscle twitching may make this determination difficult. External pacing should not be relied upon for an extended period of time. It is an emergency procedure that acts as a bridge until transvenous pacing or other therapies can be applied.

**Epicardial pacing (temporary)**

ECG rhythm strip of a threshold determination in a patient with a temporary (epicardial) ventricular pacemaker. The epicardial pacemaker leads were placed after the patient collapsed during aortic valve surgery. In the first half of the tracing, pacemaker stimuli at 60 beats per minute result in a wide QRS complex with a right bundle branch block pattern. Progressively weaker pacing stimuli are administered, which results in asystole in the second half of the tracing. At the end of the tracing, distortion results from muscle contractions due to a (short) hypoxic seizure. Because decreased pacemaker stimuli do not result in a ventricular escape rhythm, the patient can be said to be pacemaker-dependent and needs a definitive pacemaker.

Temporary epicardial pacing is used during open heart surgery should the surgical procedure create atrioventricular block. The electrodes are placed in contact with the outer wall of the ventricle (epicardium) to maintain satisfactory cardiac output until a temporary transvenous electrode has been inserted.

**Transvenous pacing (temporary)**

Transvenous pacing, when used for temporary pacing, is an alternative to transcutaneous pacing. A pacemaker wire is placed into a vein, under sterile conditions, and then passed into either the right atrium or right ventricle. The pacing wire is then connected to an external pacemaker outside the body. Transvenous pacing is often used as a bridge to permanent pacemaker placement. It can be kept in place until a permanent pacemaker is implanted or until there is no longer a need for a pacemaker and then it is removed.

**Permanent pacing**
Permanent pacing with an implantable pacemaker involves transvenous placement of one or more pacing electrodes within a chamber, or chambers, of the heart. The procedure is performed by incision of a suitable vein into which the electrode lead is inserted and passed along the vein, through the valve of the heart, until positioned in the chamber. The procedure is facilitated by **fluoroscopy** which enables the physician or cardiologist to view the passage of the electrode lead. After satisfactory lodgement of the electrode is confirmed the opposite end of the electrode lead is connected to the pacemaker generator.

There are three basic types of permanent pacemakers, classified according to the number of **chambers** involved and their basic operating mechanism:

- **Single-chamber pacemaker.** In this type, only one pacing lead is placed into a chamber of the heart, either the atrium or the ventricle. 
- **Dual-chamber pacemaker.** Here, wires are placed in two chambers of the heart. One lead paces the atrium and one paces the ventricle. This type more closely resembles the natural pacing of the heart by assisting the heart in coordinating the function between the atria and ventricles.
- **Rate-responsive pacemaker.** This pacemaker has sensors that detect changes in the patient's physical activity and automatically adjust the pacing rate to fulfill the body's metabolic needs.

The pacemaker generator is a **hermetically sealed** device containing a power source, usually a **lithium battery**, a sensing amplifier which processes the electrical manifestation of naturally occurring heart beats as sensed by the heart electrodes, the **computer** logic for the pacemaker and the output circuitry which delivers the pacing impulse to the electrodes.

Most commonly, the generator is placed below the subcutaneous fat of the chest wall, above the muscles and bones of the chest. However, the placement may vary on a case by case basis.

The outer casing of pacemakers is so designed that it will rarely be rejected by the body's **immune system**. It is usually made of **titanium**, which is inert in the body. The whole thing will not be rejected, and will be encapsulated by **scar tissue**, in the same way a piercing is.

**Basic function**

Modern pacemakers usually have multiple functions. The most basic form monitors the heart's native electrical rhythm. When the pacemaker fails to sense a heartbeat within a normal beat-to-beat time period, it will stimulate the ventricle of the heart with a short low voltage pulse. This sensing and stimulating activity continues on a beat by beat basis.

The more complex forms include the ability to sense and/or stimulate both the atrial and ventricular chambers.
The revised NASPE/BPEG generic code for anti-bradycardia pacing

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chamber(s) paced</td>
<td>Chamber(s) sensed</td>
<td>Response to sensing</td>
<td>Rate modulation</td>
<td>Multisite pacing</td>
</tr>
<tr>
<td>O = None</td>
<td>O = None</td>
<td>O = None</td>
<td>O = None</td>
<td>O = None</td>
</tr>
<tr>
<td>A = Atrium</td>
<td>A = Atrium</td>
<td>T = Triggered</td>
<td>R = Rate modulation</td>
<td>A = Atrium</td>
</tr>
<tr>
<td>V = Ventricle</td>
<td>V = Ventricle</td>
<td>I = Inhibited</td>
<td></td>
<td>V = Ventricle</td>
</tr>
<tr>
<td>D = Dual (A+V)</td>
<td>D = Dual (A+V)</td>
<td>D = Dual (A+V)</td>
<td></td>
<td>D = Dual (A+V)</td>
</tr>
</tbody>
</table>

From this, the basic ventricular "on demand" pacing mode is VVI or with automatic rate adjustment for exercise. VVIR - this mode is suitable when no synchronization with the atrial beat is required, as in atrial fibrillation. The equivalent atrial pacing mode is AAI or AAIR which is the mode of choice when atrioventricular conduction is intact but the natural pacemaker the sinoatrial node is unreliable - sinus node disease (SND) or sick sinus syndrome. Where the problem is atrioventricular block (AVB) the pacemaker is required to detect (sense) the atrial beat and after a normal delay (0.1-0.2 seconds) trigger a ventricular beat, unless it has already happened - this is VDD mode and can be achieved with a single pacing lead with electrodes in the right atrium (to sense) and ventricle (to sense and pace). These modes AAIR and VDD are unusual in the US but widely used in Latin America and Europe. The DDDR mode is most commonly used as it covers all the options though the pacemakers require separate atrial and ventricular leads and are more complex, requiring careful programming of their functions for optimal results.

Biventricular pacing (BVP)

Three leads can be seen in this example of a cardiac resynchronization device: a right atrial lead (solid black arrow), a right ventricular lead (dashed black arrow), and a coronary sinus lead (red arrow). The coronary sinus lead wraps around the outside of the left ventricle, enabling pacing of the left ventricle. Note that the right ventricular lead in this case has 2 thickened aspects that represent conduction coils and that the generator is larger than typical pacemaker generators, demonstrating that this device is both a pacemaker and a cardioverter-defibrillator, capable of delivering electrical shocks for dangerously fast abnormal ventricular rhythms.

A biventricular pacemaker, also known as CRT (cardiac resynchronization therapy) is a type of pacemaker that can pace both the septal and lateral walls of the left ventricle. By pacing both sides of the left ventricle, the pacemaker
can resynchronize a heart whose opposing walls do not contract in synchrony, which occurs in approximately 25-50% of heart failure patients. CRT devices have at least two leads, one in the right ventricle to stimulate the septum, and another inserted through the coronary sinus to pace the lateral wall of the left ventricle. Often, for patients in normal sinus rhythm, there is also a lead in the right atrium to facilitate synchrony with the atrial contraction. Thus, timing between the atrial and ventricular contractions, as well as between the septal and lateral walls of the left ventricle can be adjusted to achieve optimal cardiac function. CRT devices have been shown to reduce mortality and improve quality of life in patients with heart failure symptoms; a LV ejection fraction less than or equal to 35% and QRS duration on EKG of 120 msec or greater. CRT can be combined with an implantable cardioverter-defibrillator (ICD).

**Advancements in function**

A major step forward in pacemaker function has been to attempt to mimic nature by utilizing various inputs to produce a rate-responsive pacemaker using parameters such as the QT interval, pO$_2$ - pCO$_2$ (dissolved oxygen or carbon dioxide levels) in the arterial-venous system, physical activity as determined by an accelerometer, body temperature, ATP levels, adrenaline, etc. Instead of producing a static, predetermined heart rate, or intermittent control, such a pacemaker, a 'Dynamic Pacemaker', could compensate for both actual respiratory loading and potentially anticipated respiratory loading. The first dynamic pacemaker was invented by Dr. Anthony Rickards of the National Health Hospital, London, UK, in 1982.

Dynamic pacemaking technology could also be applied to future artificial hearts. Advances in transitional tissue welding would support this and other artificial organ/joint/tissue replacement efforts. Stem cells may or may not be of interest to transitional tissue welding.

Many advancements have been made to improve the control of the pacemaker once implanted. Many of these have been made possible by the transition to microprocessor controlled pacemakers. Pacemakers that control not only the ventricles but the atria as well have become common. Pacemakers that control both the atria and ventricles are called dual-chamber pacemakers. Although these dual-chamber models are usually more expensive, timing the contractions of the atria to precede that of the ventricles improves the pumping efficiency of the heart and can be useful in congestive heart failure.

Rate responsive pacing allows the device to sense the physical activity of the patient and respond appropriately by increasing or decreasing the base pacing rate via rate response algorithms.

The DAVID trials have shown that unnecessary pacing of the right ventricle can lead to heart failure and an increased incidence of atrial fibrillation. The newer dual chamber devices can keep the amount of right ventricle pacing to a minimum and thus prevent worsening of the heart disease.

**Insertion**

A pacemaker is typically inserted into the patient through a simple surgery using either local anesthetic or a general anesthetic. The patient may be given a drug for relaxation before the surgery as well. An antibiotic is typically administered to prevent infection. In most cases the pacemaker is inserted in the left shoulder area where an incision is made below the collar bone creating a small pocket where the pacemaker is actually housed in the patient's body. The lead or leads (the number of leads varies depending on the type of pacemaker) are fed into the heart through a large vein using a fluoroscope to monitor the progress of lead insertion. The Right Ventricular
lead would be positioned away from the apex (tip) of the right ventricle and up on the interventricular septum, below the outflow tract, to prevent deterioration of the strength of the heart. The actual surgery may take about 30 to 90 minutes.

Following surgery the patient should exercise reasonable care about the wound as it heals. There is a followup session during which the pacemaker is checked using a "programmer" that can communicate with the device and allows a health care professional to evaluate the system's integrity and determine the settings such as pacing voltage output. The patient should have the strength of their heart analyzed frequently with echocardiography, every 1 or 2 years, to make sure that the placement of the right ventricular lead has not lead to weakening of the left ventricle.

The patient may want to consider some basic preparation before the surgery. The most basic preparation is that people who have body hair on the chest may want to remove the hair by shaving or using a depilatory agent as the surgery will involve bandages and monitoring equipment to be affixed to the body.

Since a pacemaker uses batteries, the device itself will need replacement as the batteries lose power. Device replacement is usually a simpler procedure than the original insertion as it does not normally require leads to be implanted. The typical replacement requires a surgery in which an incision is made to remove the existing device, the leads are removed from the existing device, the leads are attached to the new device, and the new device is inserted into the patient's body replacing the previous device.

**Pacemaker patient identification card**

International pacemaker patient identification cards carry information such as: patient data (between others, symptom primary, ECG, aetiology), pacemaker center (doctor, hospital), IPG (rate, mode, date of implantation, MFG, type) and lead site.

**Living with a pacemaker**

**Periodic pacemaker checkups**

Two types of remote monitoring devices used by pacemaker patients.

Once the pacemaker is implanted, it is periodically checked to ensure the device is operational and performing appropriately. Depending on the frequency set by the following physician, the device can be checked as often as is necessary. Routine pacemaker checks are typically done in-office every six (6) months, though will vary depending upon patient/device status and remote monitoring availability.

At the time of in-office follow-up, the device will be interrogated to perform diagnostic testing. These tests include:

- Sensing: the ability of the device to "see" intrinsic cardiac activity (Atrial and ventricular depolarization).
- Impedance: A test to measure lead integrity. Large and/or sudden increases in impedance can be indicative of a lead fracture while large and/or sudden decreases in impedance can signify a breach in lead insulation.
- Threshold: this test confirms the minimum amount of energy (Both volts and pulse width) required to reliably depolarize (capture) the chamber being tested. Determining the threshold allows the Allied Professional, Representative, or Physician to program an output that recognizes an appropriate safety margin while optimizing device longevity.

As modern pacemakers are "on-demand", meaning that they only pace when necessary, device longevity is affected by how much it is utilized. Other factors affecting device longevity include programmed output and algorithms (features) causing a higher level of current drain from the battery.
An additional aspect of the in-office check is to examine any events that were stored since the last follow-up. These are typically stored based on specific criteria set by the physician and specific to the patient. Some devices have the availability to display intracardiac electrograms of the onset of the event as well as the event itself. This is especially helpful in diagnosing the cause or origin of the event and making any necessary programming changes.

Lifestyle considerations

A patient’s lifestyle is usually not modified to any great degree after insertion of a pacemaker. There are a few activities that are unwise such as full contact sports and activities that involve intense magnetic fields.

The pacemaker patient may find that some types of everyday actions need to be modified. For instance, the shoulder harness of a vehicle seatbelt may be uncomfortable if the harness should fall across the pacemaker insertion site.

Any kind of an activity that involves intense magnetic fields should be avoided. This includes activities such as arc welding possibly, with certain types of equipment, or maintaining heavy equipment that may generate intense magnetic fields (such as an MRI (Magnetic Resonance Imaging Machine)).

However, in February 2011 the FDA approved a new pacemaker device called the Revo MRI SureScan which is the first to be proven safe for MRI use. There are several limitations to its use including certain patients qualifications, body parts, and scan settings.

A 2008 U.S. study has found that the magnets in some portable music players, when placed within an inch of pacemakers, may cause interference.

Some medical procedures may require the use of antibiotics to be administered before the procedure. The patient should inform all medical personnel that they have a pacemaker. Some standard medical procedures such as the use of Magnetic resonance imaging (MRI) may be ruled out by the patient having a pacemaker.

In addition, according to the American Heart Association, some home devices have a remote potential to cause interference by occasionally inhibiting a single beat. Cellphones available in the United States (less than 3 watts) do not seem to damage pulse generators or affect how the pacemaker works.

Turning off the pacemaker

According to a consensus statement by the Heart Rhythm Society, it is legal and ethical to honor requests by patients, or by those with legal authority to make decisions for patients, to deactivate implanted cardiac devices. Lawyers say that the legal situation is similar to removing a feeding tube. A patient has a right to refuse or discontinue treatment, including a pacemaker that keeps him or her alive. Physicians have a right to refuse to turn it off, but they should refer the patient to a physician who will. Some patients believe that hopeless, debilitating conditions like strokes, in combination with dementia, can cause so much suffering to themselves and their families that they would prefer not to prolong their lives with supportive measures, such as cardiac devices.

Privacy and security

Security and privacy concerns have been raised with pacemakers that allow wireless communication. Unauthorized third parties may be able to read patient records contained in the pacemaker, or reprogram the devices, as has been demonstrated by a team of researchers. The demonstration worked at short range; they did not attempt to develop a long range antenna. The proof of concept exploit helps demonstrate the need for better security and patient alerting measures in remotely accessible medical implants.

Complications

A possible complication of dual-chamber artificial pacemakers is pacemaker-mediated tachycardia (PMT), a form of reentrant tachycardia. In PMT, the artificial pacemaker forms the anterograde (atrium to ventricle) limb of the circuit and the atrioventricular (AV) node forms the retrograde limb (ventricle to atrium) of the circuit. Treatment of PMT typically involves reprogramming the pacemaker.

Other devices with pacemaker function
Sometimes devices resembling pacemakers, called implantable cardioverter-defibrillators (ICDs) are implanted. These devices are often used in the treatment of patients at risk from sudden cardiac death. An ICD has the ability to treat many types of heart rhythm disturbances by means of pacing, cardioversion, or defibrillation. Some ICD devices can distinguish between ventricular fibrillation and ventricular tachycardia (VT), and may try to pace the heart faster than its intrinsic rate in the case of VT, to try to break the tachycardia before it progresses to ventricular fibrillation. This is known as fast-pacing, overdrive pacing, or anti-tachycardia pacing (ATP). ATP is only effective if the underlying rhythm is ventricular tachycardia, and is never effective if the rhythm is ventricular fibrillation.

**NASPE / BPEG Defibrillator (NBD) code - 1993**

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shock chamber</td>
<td>Anti-tachycardia pacing chamber</td>
<td>Tachycardia detection</td>
<td>Antibradycardia pacing chamber</td>
</tr>
<tr>
<td>O = None</td>
<td>O = None</td>
<td>E = Electrogram</td>
<td>O = None</td>
</tr>
<tr>
<td>A = Atrium</td>
<td>A = Atrium</td>
<td>H = Hemodynamic</td>
<td>A = Atrium</td>
</tr>
<tr>
<td>V = Ventricle</td>
<td>V = Ventricle</td>
<td></td>
<td>V = Ventricle</td>
</tr>
<tr>
<td>D = Dual (A+V)</td>
<td>D = Dual (A+V)</td>
<td></td>
<td>D = Dual (A+V)</td>
</tr>
</tbody>
</table>

**Short form of the NASPE/BPEG Defibrillator (NBD) code**

- **ICD-S**  ICD with shock capability only
- **ICD-B**  ICD with bradycardia pacing as well as shock
- **ICD-T**  ICD with tachycardia (and bradycardia) pacing as well as shock