# Pacemaker insertion

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**Abstract:** A pacemaker (PM) (or artificial PM, so as not to be confused with the heart's natural PM) is a medical device that uses electrical impulses, delivered by electrodes contracting the heart muscles, to regulate the beating of the heart. The primary purpose of this device is to maintain an adequate heart rate, either because the heart's natural PM is not fast enough, or there is a block in the heart's electrical conduction system. Modern PMs are externally programmable and allow the cardiologist to select the optimum pacing modes for individual patients. Some combine a PM and defibrillator in a single implantable device. PMs can be temporary or permanent. Temporary PMs are used to treat short-term heart problems, such as a slow heartbeat that's caused by a heart attack, heart surgery, or an overdose of medicine. Permanent PMs are used to control long-term heart rhythm problems. A PM can relieve some arrhythmia symptoms, such as fatigue and fainting. A PM also can help a person who has abnormal HRs resume a more active lifestyle. In the current mini review we will focus on the insertion of a PM and the possible pneumothorax that can be caused.

**Keywords:** Pneumothorax; VATS; pacemaker (PM)

Submitted Jan 14, 2015. Accepted for publication Jan 28, 2015.
doi: 10.3978/j.issn.2305-5839.2015.02.06
**View this article at:** http://dx.doi.org/10.3978/j.issn.2305-5839.2015.02.06

## Introduction

Artificial cardiac pacemakers (PMs) are small electronic devices, approximately the size of a matchbox and weight of 20-50 g that sense intrinsic heart rhythm and transmit electrical impulses, if indicated, to stimulate the heart and replace the defective natural PM, the sinus node.

Dr. Ake Senning was the first to implant a PM in a human being in 1958; it lasted for only a few hours. Since then, for more than 50 years, PMs have been the treatment for choice for bradyarrhythmia and heart block (1-4).

The rate of implantation is increasing annually. For PMs the 10-year average growth rate is 4.7% and for implantable cardioverter defibrillator (ICD) is 15.1% in the UK (5).

PMs can be either temporary or permanent. Temporary PMs are used for short-term heart problems, such as arrhythmias caused by myocardial infraction and also in emergencies. Permanent are for chronic cardiac rhythm dysfunction. In this chapter, permanent PMs are the ones to be discussed. There are three different kind of

permanent cardiac pacing devices: (I) single-chamber PMs-VVI: one pacing lead is implanted in the right ventricle or right atrium; (II) dual-chamber PMs-DDD: two leads are implanted (in the right ventricle and in the right atrium); this is the most common type of implanted PM, (III) biventricular PMs-BiV, also called cardiac resynchronization therapy (CRT): in addition to single- or dual-chamber right heart pacing leads, a lead is advanced to the coronary sinus for left ventricular epicardial pacing. CRT-P includes pacing and CRT-D includes defibrillation. CRT is mainly implanted to patients with heart failure, improving symptoms and quality of life (3,4). Indications for implantation of permanent PMs divided into three classes, as defined by the ACC/AHA/HRS guidelines for device-based therapy of cardiac rhythm abnormalities (6-8). Absolute and relative indications are shown in *Table 1*.

An ICD is recommended as primary therapy in survivors of cardiac arrest due to ventricular fibrillation or hemodynamically unstable ventricular tachycardia. ICD indications are secondary prophylaxis against sudden cardiac death and primary prophylaxis (9).

**Table 1** Absolute and relative indications

| |
|---|
| Absolute indications |
| Sick sinus syndrome |
| Symptomatic sinus bradycardia |
| Tachycardia-bradycardia syndrome |
| Atrial fibrillation with sinus node dysfunction |
| Complete atrioventricular block (third-degree block) |
| Chronotropic incompetence |
| Prolonged QT syndrome |
| Cardiac resynchronization therapy with biventricular pacing |
| Relative indications |
| Cardiomyopathy (hypertrophic or dilated) |
| Severe refractory neurocardiogenic syncope |

## Technique of implantation

A PM consists of: (I) a pulse generator which contains all the computerized information to sense the intrinsic cardiac electric potentials and to stimulate cardiac contraction, and a battery; (II) leads, which are wires with electrodes at their tips. These leads connect the heart to the generator and transfer all the data between them (2).

Implantation of permanent PM is performed in a cardiac catheterization laboratory under local or less common general anesthesia and is considered to be a minimally invasive procedure. Transvenous access to the heart chambers is the preferable technique, commonly via a percutaneous approach of the subclavian vein, the cephalic vein (cut-down technique), or rarely the axillary vein, the internal jugular vein or the femoral vein (4). In some cases both subclavian vein and cephalic vein are punctured. The most common transvenous route is the left or right subclavian vein, entered at the junction of the middle and inner thirds, where the first rib and the clavicle are joined. The vein is usually blindly punctured, unless there are certain anatomical abnormalities, such as chest wall or clavicle deformation. In these cases an initial brief intravenous contrast injection-venography is attempted in the peripheral arm vein. After the puncture, a small incision 3.8-5.1 cm is made in the infraclavicular area and a subcutaneous pocket is created, where the generator will be implanted. After successful vein access, a guide wire is advanced and placed on the right atrium or the vena caval area under fluoroscopy. A second guide wire can be positioned, if necessary, via the same route either by a second puncture or by a double-wire technique in which two guide wires are inserted through the first sheath.

A sheath and dilator are advanced, and when sheath is set in the right place the guide wire and the dilator are retracted. Then the lead is inserted into the sheath and advanced under fluoroscopy to the appropriate heart chamber, where is attached to the endocardium either passively with tines or actively via screw-in leads. When implanting a DDD, the ventricular lead is the first to be placed. When leads are securely placed, then the sheath is removed. Specifics tests for sensing and pacing are held and to avoid stimulation of the diaphragm, pacing is set at 10 V. The lead is sewn with a nonabsorbable suture to the underlying tissue and afterwards, the generator is placed to the pocket and connected to the lead. Last, the incision is closed with absorbable sutures and an arm immobilizer is applied for 12-24 hours. The cut-down technique of the cephalic vein demands extensive skin and muscle dissection to visualize the vein. Occasionally, PM can be implanted surgically via a thoracotomy, and the generator is placed in the abdominal area. Antibiotic prophylaxis is compulsory for device implantation, routinely cefazolin 1 g i.v. 1 hour prior to the procedure, or alternatively 1 g vancomycin i.v. in case of allergy to penicillin and/or cephalosporins. The day following the implantation, a chest radiograph in standing position anteroposterior and lateral is performed,

 

to confirm lead position and exclude the complication of pneumothorax (4,10-12).

## Complications

From 1993 to 2009, 2.9 million patients received a primary PM in the US (13). Although implantation of PM is a minimal invasive procedure, there is the potential for complications during or after implantation (14-32). The rate for the early complications is 4-5% and for the late complications is 2.7% (14); however these rates can be presented within a wider range in literature due to difficulties in defining and identifying the complications in different studies, which could raise up to 12.6% (31). The technological progress and the increasing experience of the operators have resulted in a significant reduction in frequency of complications (15). These complications can be divided into early (postoperative, during hospitalization and within 30 days) and late [in literature short-term complications are also defined as those, which occur in <3 months (31)], according to implantation time and also procedure- and device-based, as seen on tables. Complications are related to venous access (e.g., pneumothorax), to leads (e.g., lead dislodgement) and the generator pocket (e.g., hematoma) and can be defined as major (e.g., death, cardiac perforation) and minor (e.g., drug reaction, hematoma). Mortality rarely occurs in a rate of 0.08-1.1% (18,24,29,30). Most frequent complications are those related to implantation procedure, such as lead dislodgement and pneumothorax. Implantation of dual chamber devices may be more challenging, however, the difference in complication rates between single and complex pacing is not consistent in all studies probably because of different use of technology and variable experience of operators (16-27). The most common complication is lead dislodgement (higher rate atrial dislodgment than ventricular dislodgment), followed by pneumothorax, infection, bleeding/pocket hematoma, and heart perforation, not necessarily in that order, depending on the study (15-29) (*Tables 2,3*).

**Table 2** Early complications

| |
|---|
| Early procedure-related complications |
| Bleeding/pocket hematoma |
| Phlebitis/thrombophlebitis |
| Lead dislodgement |
| Pacemaker infection |
| Pneumothorax |
| Hemothorax |
| Myocardial perforation |
| Anaphylaxis |
| Air embolism |
| Early device-related complications |
| Infection |
| Malfunction-failure to sense, failure to capture |
| PM syndrome |

**Table 3** Delayed complications

| |
|---|
| Late procedure-related complication |
| Pocket erosion |
| Lead dislodgement |
| Hematoma |
| Phlebitis/deep vein thrombosis |
| Infection |
| Hemothorax |
| Atrioventricular fistula |
| “Subclavian crush” syndrome |
| Late device-related complications |
| Infection of pacer lead/generator |
| Systemic infection |
| Myocardial perforation |
| Pacer malfunction |
| Twiddler-syndrome |
| Pacemaker syndrome |
| Allergy or sensitivity to the device |
| Lead fracture |
| Pectoral muscle stimulation |
| Intercostal or diaphragm pacing |
| Access vein thrombosis |
| Endocarditis |
| Inferior vena cava/right atrial thrombus |

## Pneumothorax

Pneumothorax is the presence of gas in the pleural space. A spontaneous pneumothorax is one that occurs without antecedent trauma to the thorax. A primary spontaneous pneumothorax occurs in the absence of underlying lung disease, whereas a secondary pneumothorax occurs in

its presence. A traumatic pneumothorax results from penetrating or nonpenetrating chest injuries. A tension pneumothorax is a pneumothorax in which the pressure in the pleural space is positive throughout the respiratory cycle (33). Pneumothorax is a major complication of PM implantation, mainly after subclavian puncture technique that can cause patient morbidity and increase the cost of hospitalization (24). Pneumothorax usually develops during the implantation procedure or during the first 48 hours after the implantation.

The incidence of pneumothorax after subclavian vein access varies in the literature from low 0.6-1% to high 5.2% with an average of 2% (11,21,22,24,25,31,32,34-43); the upgrade of the PM involves greater risk than the primal procedure (44). The reasons for this variation are the small sample sizes, the exact definition and clinical recognition of pneumothorax and the identification and report of PM implantation complications (11,42). In a study of short-term implantation-related complications of cardiac rhythm management device therapy in Helsinki, Finland, pneumothorax was defined as "the absence of lung markings over the lung field ipsilateral to the PM pocket assessed from the predischarge X-ray" (31).

Pneumothorax, after subclavian vein puncture attempts, is usually ipsilateral. Contralateral pneumothorax is also reported in the literature, occurring due to the perforation caused by the endocardial atrial lead, which is a rare complication. The screw-in atrial leads increase the risk of perforation through the wall of the right atrial appendage. Operators must be very careful of the anatomy of the right atrial wall and avoid overs crewing the screw-in leds, so the complication of pneumothorax is eliminated (45-47). A pneumothorax could also be involved with pneumopericardium, pneumomediastinum and subcutaneous emphysema.

### *Risk factors*

A population-based cohort study of 28,860 Danish patients (42) identified the risk factors for pneumothorax in cardiac pacing, treated with a chest tube. The most important risk factor appears to be the venous access; blind subclavian vein puncture attempt is of the highest risk followed by the utilization of both subclavian and cephalic cut-down technique. The risk of pneumothorax is higher in female patients (42,48,49), probably because of anatomical characteristics and in patients over 80 years old (18,42) irrelevant to the technique of venous access. Findings revealed an increased risk in 20 to 59 years old patients, because of higher preference in subclavian vein puncture (42). Dual chamber PM implantation is associated with higher rates of incidences of pneumothorax; however it is shown that CRT-P device implantation is not. That could be explained by the fact that high experienced operators perform CRT-P insertions (42). Dual-chamber pacing involves a second subclavian puncture, so that the passage of two leads is accomplished and that is the reason for the higher risk noticed (27). Medical history of chronic obstructive pulmonary disease (COPD) results in a higher risk of pneumothorax. Patients suffering from COPD, most times, demonstrate severe symptoms, so clinicians are more alert, which helps to a greater rate of pneumothorax identification and treatment with a chest tube. Furthermore, COPD itself can cause spontaneous pneumothorax (42,50-52). Longer procedure duration and implantation being performed in a non-university hospital, which probably means less experienced operators, can both influence the risk of pneumothorax and increase it (42). The risk of pneumothorax could be eliminated by puncturing the axillary vein or if the cut-down technique of the cephalic vein is used, however this technique is not the appropriate one for all cases and furthermore, it demands extensive skin and muscle dissection. A fluoroscopic guidance of the subclavian vein puncture instead of the blind one is also helpful and could reduce the risk. Good knowledge of the anatomy of the patient (aware of any deformation of the clavicle or chest abnormality) and careful handlings are essential for the safe accomplishment of the implantation.

### *Indications of pneumothorax*

A chest radiography in standing and in two directions (anteroposterior and lateral), the day after the PM implantation, could prove if the patient has developed pneumothorax, however not all centres perform the radiography as a routine. When a patient demonstrates symptoms of pneumothorax, the chest radiography is obligatory. The chest radiographs should be reviewed for the presence of pneumothorax, preferably by a radiologist. There is a significant possibility that a pneumothorax is underdiagnosed by a chest radiography (11,53). Clinical signs that should mean an alert for a pneumothorax event could be shortness of breath, hypoxia, pleuritic pain and hypotension. If the pneumothorax occurs during the implantation procedure, then the symptoms are sudden; sudden chest pain, respiratory distress, air aspiration during

 

subclavian vein puncture and sudden hypotension. If any of the former signs is present, then an urgent fluoroscopy of the upper lung and critical monitoring should be performed. If the saturation, measured from the fingertip, is less than 90% and/or patient presents hypotension, then the procedure should be terminated (11). Pneumothorax could also be asymptomatic and the only notification of it would be the routine chest radiography.

### *Treatment of pneumothorax*

Treatment for pneumothorax varies from simple aspiration, chest tube drainage to thoracoscopy and thoracotomy. If a tension pneumothorax is developed, then an urgent treatment, mainly with a chest tube is necessary. A small pneumothorax, estimated to involve less than 10% of the lung parenchyma, with a normal physical examination except maybe from tachycardia, should be treated conservatively. A conservative treatment with simple aspiration could be also applied even when there is less than 30% reduction of the lung tissue, as long as there is no haemothorax or severe symptoms. Conservative therapy can reduce time of hospitalization and patient's morbidity and by avoiding the invasive treatments of chest tube, thoracoscopy and thoracotomy, the complications of pneumothorax are reduced.

When a partial pneumothorax occurs, then the selective treatment is chest tube drainage (11,15,27,54-69). The rate of pneumothorax events, after PM implantation, that demand a chest tube is low (42,70-79) and so is the morbidity that pneumothorax causes (11). The invasive procedures rise the pain and delay rehabilitation, increase hospitalization duration, cost of therapy and radiography exposure (27,80-98).

## Acknowledgements

*Disclosure:* The authors declare no conflict of interest.

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**Cite this article as:** Kotsakou M, Kioumis I, Lazaridis G, Pitsiou G, Lampaki S, Papaiwannou A, Karavergou A, Tsakiridis K, Katsikogiannis N, Karapantzos I, Karapantzou C, Baka S, Mpoukovinas I, Karavasilis V, Rapti A, Trakada G, Zissimopoulos A, Zarogoulidis K, Zarogoulidis P. Pacemaker insertion. Ann Transl Med 2015;3(3):42. doi: 10.3978/j.issn.2305-5839.2015.02.06

 