The number of patients with permanent pacemaker are increasing and may present into the emergency department with a variety of complications and malfunctions. The presence of a pacemaker may also affect management of unrelated medical issues. This article review the complications of the implant procedure, the causes, diagnosis and management of pacemaker malfunction, the pacemaker syndrome, Twiddler's syndrome. Interaction of permanent pacemaker with other medical condition and its implication in Emergency Department environment are also discussed. (Hong Kong j.emerg.med. 2001;8:169-175)

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Introduction

Pacemaker therapy has transformed the lives of many bradyarrhythmic patients both in terms of quality and long term survival. The pacemaker implantation rate in Hong Kong is not as high as western countries (UK 20,000, USA 115,000 cases) annually. Nevertheless it is increasing due to expanded indications of pacing and aging of the population. The progressively increased number of patients with permanent pacemaker has considerable impact on emergency medicine practices as they will attend emergency department for various pacemaker complications and malfunction. Most of them are elderly, the average age being 60. Co-morbidities among them are not uncommon. In addition, the presenting symptoms of pacemaker malfunction and complications occasionally are subtle, non-specific and mimic other medical diseases. Emergency physicians need to have high index of suspicion to diagnose pacemaker related problems.

The presence of pacemaker may complicate management of unrelated medical problems such as trauma, acute coronary syndrome and the institution of advanced cardiac life support. On the other hand, the emergency department environment may pose potential hazard by interfering with the functioning of pacemaker.

Early complications

Complications arising within 6 weeks after implantation are regarded as early. Although this differentiation is arbitrary, the duration after implantation provide useful clues to the underlying causes of pacemaker malfunction. This will be further discussed in the pacemaker malfunction and diagnosis.

Early complications of permanent pacemaker implantation relate mainly to surgical procedures, venous access, lead positioning or displacement. The incidence is about 6.7%. The most important determinant of complication is the experience of the operators. Whether single or dual chamber systems are more likely to cause problems remains unclear.

Permanent pacemakers are generally implanted under local anaesthesia. The electrical leads are placed transvenously (either via cephalic cut down or subclavian vein puncture) into right atrial appendage, right ventricular apex or both. The pacing and sensing thresholds are assessed and the pacemaker is programmed accordingly. After the leads are secured, the generator is attached and implanted in a subcutaneous pectoral

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pocket. The surgical procedures carry the risks of haemopneumothorax, bleeding, venous thrombosis and air embolism.

**Pneumohaemothorax**

The subclavian approach is most commonly associated with pneumothorax. The overall incidence is approximately 2%. Initially both the clinical and radiographic features may be normal but will become apparent 48 hours following implantation. Any unexplained dyspnoea in patients with recent pacemaker insertion should be assessed by chest x-ray in deep expiration to exclude this complication. Respiratory distress, haemothorax or pneumothorax greater than 10% are indications for intervention.

**Venous thrombosis**

Venous thrombosis induced by transvenous permanent pacemakers is common, although many of them are subclinical. It may be early or late. Pain, swelling with venous engorgement in ipsilateral extremities should be investigated by venography or isotope studies. Thrombosis should be treated by anticoagulation, thrombolytic treatment or angioplasty. Rarely the superior vena cava may be involved. It is a medical emergency and presents with plethora of face, swelling of face, neck and upper trunk together with distended veins of neck and upper chest. Severe dyspnoea and shock may be developed. Immediate anticoagulation by intravenous heparin should be started in emergency department after confirming the diagnosis by duplex ultrasound. Low molecular weight heparin is a new alternative. In addition to thrombolytic treatment and angioplasty, surgical bypass may be required for severe cases of superior vena cava obstruction.

**Haematoma**

Early complication involving the pocket commonly include haematoma, infection or wound dehiscence. Haematoma of the pocket was a common problem due to residual bleeding from the dissection of the fascial plane when creating pocket, leakage of venous blood along the pocket leads or arterial bleeding may also cause the haematoma. A small haematoma does not require treatment but if it is large enough to be palpated, surgical exploration is required to treat the underlying causes. Simple aspiration is not effective and electrocautery should be avoided to prevent damaging the pacemaker.

**Infection**

Infectious complication is not common but may occasionally be severe and life threatening. Patients with diabetes, malignancy, on steroid or anticoagulant therapy are at higher risk. It is also more common in longer procedures, reoperation and in patients with a temporary pacing lead in situ. Infection of pacemaker may occur at any part of the pacing system but generator pockets are most commonly involved. They are mainly due to local contamination during insertion and can occur as early or late complications. Early infection is more aggressive and may present as septicaemia. Rarely it can cause endocarditis, pneumonia or pyrexia of unknown origin. It is usually due to staphylococcus aureus whereas staphylococcus epidermidis is associated with more indolent late infection.

Electrode lead infection is unusual but have a high mortality. It frequently cause vegetation or thrombus along the lead. The spectrum of casual organisms is similar to pocket infection. Clinically it usually present as fever, chills and may progress to septicemia. Chest involvement both clinically and radiologically is also common. The diagnosis by conventional imaging methods is difficult. However along with the blood culture, transoesophageal ultrasound can facilitate the diagnosis by visualisation of the vegetation. Generally antibiotic together with complete removal of the infected system is needed. Emergency physicians should consider pacing systems as a potential source of infection and promptly recognise it.

**Lead problems**

Lead displacement is the commonest cause of early revision of implant, especially in system requiring atrial lead. Nevertheless the frequency is very low due to improved fixation. It may occur in the first 4-6 weeks after implantation. Clinical suspicion should
be raised when there is recurrence of bradycardia with its associated symptoms. ECG may reveal failure to capture or sense. Alternatively, it may be complicated by thromboembolism, cardiac perforation or electrode lead induced arrhythmia. Diaphragmatic twitching will occur if displaced lead lie close to diaphragm. A change in axis of ECG (from left axis deviation to right axis deviation), suggest dislodgement and migration of lead.12

A rare but life threatening complication is cardiac tamponade resulting from inadvertent puncture through ventricular wall by the lead during implantation. Generally most perforation are benign and self limiting but rarely it may progress to tamponade and haemodynamic compromise.13

Post cardiotomy like syndrome secondary to pacemaker insertion was first described in 1975. This is characterised by fever, pleuropericarditis and pericardial effusion. It usually present 1-4 weeks after implantation. The diagnosis is by exclusion of other systemic infection and inflammation. Overall prognosis is good and respond well to non steroidal anti inflammatory drugs with or without pericardiocentesis.14 Although ventricular perforation was not recognised, inadvertent cardiac perforation as an aetiology is postulated. Such syndrome rarely occur but it should be considered in the differential causes of fever and lethargy after implantation.

Lead malposition is a rare complication but may occasionally be missed. They may present incidentally or be complicated by thromboembolism. Diagnosis is suggested by a RBBB pattern of the QRS complex (normally it is a LBBB like pattern) in ECG and atypical lead position in chest x-ray. Echocardiogram will confirm the diagnosis. Revision of lead placement is needed.12

**Late complications**

The overall incidence is low and compares favourably with early complication rates. Lead fracture is the most common late complication. Others include erosion and infection.15

Lead insulation break is not usually associated with severe failure of the pacing system. However the current leak may induce pectoral or diaphragmatic twitching, oversensing and failure to capture. It is characterised by very low lead impedance and replacement of lead is required.

Lead fracture is much more serious and present with pacemaker failure. It often result from blunt trauma, from sport injuries, road traffic accidents and domestic falls1 Occassionally, damage to a pacemaker is self inflicted by patient who repeatedly manipulate the pacemaker. This is called "Twiddler's Syndrome".16 Fracture may result in oversense, undersense or failure to capture due to the electrical noise.

Thin elderly are particularly vulnerable to mechanical erosion. Patients who participate in strenuous sport activities may displace pacemaker from its implant site and accelerate erosion. Repositioning of generator may be necessary.

Sudden battery depletion and generator failure are uncommon as the pacing system is regularly assessed and it is possible to check battery life with accuracy. Fibrosis around tip of electrode within the heart sometimes causes elevation in pacing threshold and result in failure to pace. This is referred to as "exit block". More often the threshold is changed by concurrent medication, myocardial ischaemia and electrolyte disturbane.

The problems discussed above found in both single and dual chamber systems. Other pacemaker related conditions are discussed in the next section.

**Pacemaker syndrome**

It is a collection of signs and symptoms in patients with otherwise normal functioning pacemaker systems but with suboptimal pacing modes. Pathologically it is due to loss of AV synchrony and is commonly seen in VVI patients. Clinically it is non specific and presents with fatigue, weakness, headache and syncope.16 They should be referred to cardiologist for changing to a dual chamber system.
Paradoxically, pacemakers can be a source of arrhythmia which may occasionally be potentially life threatening. It include pacemaker mediated tachycardia, runaway pacemaker, lead induced arrhythmia, sensor induced arrhythmia.

**Pacemaker mediated tachycardia (PMT)**

It is a re-entry arrhythmia that occur in dual chamber pacemaker using the pacemaker itself as part of re-entry circuit. PMT usually is precipitated by a premature ventricular contraction but may also occur spontaneously or after the removal of an applied magnet. It is characterised by rapid, wide complex tachycardia with each ventricular beat being initiated by a pacing spike. Its rate is variable but below the preset upper limit of programme.

The simplest method to diagnosis and treat PMT in emergency department is to apply a magnet to the pacemaker. The magnet interrupts sensing and breaks PMT. Alternatively intarevous ATP can block retrograde as well as anterograde conduction through AV node. Other methods include carotid sinus message, chest thump and transcutaneous pacing for refractory cases.

**Runaway pacemaker**

This is a rare condition occurring in older type of pacemaker. It is a medical emergency caused by inappropriately rapid discharges exceeding the upper limit of pacemaker. It can potentially induce ventricular fibrillation. It cannot be controlled by defibrillation or medication but may respond to magnet application or overdrive pacing. Emergency interrogation and reprogramming may also be successful. If it fails, urgent surgical intervention to cut the lead is necessary.

**Dysrhythmia due to lead dislodgement**

A lead tip may potentially bounce against the ventricular wall as a result of dislodgement and migration can act as a focus for ventricular dysrhythmias. They should be treated according to the ACLS protocol. Definitive treatment involves repositioning or removal of the leads.

**Sensor induced tachycardia**

Pacemaker capable of rate modulator may pace inappropriately if the sensor that regulate the pacemaker is stimulated by nonphysiologic parameters. They are easily broken with the application of a magnet that convert it to asynchronous pacing without sensing. Helicopter aeromedical transport may activate these sensor by loud noises and vibrations which result in tachycardia during transport.

**Pacing system malfunction and diagnosis**

Permanent cardiac pacemaker malfunction may be in form of failure to pace, failure to sense or failure to capture. They are usually due to lead problems or less commonly generator defect and inappropriate programming. The importance of history and physical examination cannot be overemphasised in making the diagnosis. In addition, ECG can facilitate the diagnosis of underlying problems.

A modified approach from Karkal & Syverud is outlined for evaluating suspected pacemaker malfunction in emergency department.

1. Check 12 lead electrocardiogram. Is the patient in their own rhythm or are paced beats evident? Paced beat are identified by pacing spike. If pacing spikes are present, do they capture? If it is absent, can it be accounted by higher intrinsic rate or inappropriate erratic variation in the timing of the pacing spikes (oversense)?
2. Assess sensing function – do inappropriate pacing spikes occur in the presence of intrinsic rhythm (undersense).
3. Check magnet rate by applying a magnet over generator – if the magnet rate is slower by more than 10% of the expected rate, battery depletion is likely.
Spike present: failure to capture

If it occur in first few days after implantation, lead dislodgement or inadequate tightening of the set screw on the generator head is likely. Problems with capture weeks or months later are often due to elevated pacing threshold above preset limit. They may due to exit block, medication, electrolytic disturbance, metabolic acidosis, myocardial infarction and defibrillator. Capture failure that happened many months or years after implantation is result of lead damage either due to insulation defect or fracture. Pacing spike may fail to capture if they fall in normal refractory period of native beat in which case the problem is due to undersensing.

Inappropriate presence of stimuli: undersensing

The native intracardiac signal may change over time, during exercise or because of myocardial ischaemia, drug treatment, or electrolyte imbalance. Lead fracture and insulation defect will attenuate the signal reaching the generator but it may also be caused by inappropriate programming.

Inappropriate absence of stimuli: oversensing

Pseudomalfuction must first be excluded as small bipolar spike may not be well seen.

Either there no stimuli are sent from the generator or when sent, they fail to reach the heart. The former condition is oversensing which may be due to interference from skeletal myo-potentials, normal cardiac potentials, make-break signals from lead fracture or insulation defects. Lead fracture or dislodgement may block pacing stimuli from reaching the heart. Oversensing are readily corrected by magnet application but this is not the case with the latter.

Management of unstable patient in emergency departments

For patients who are pacemaker dependent, in heart failure and haemodynamically unstable as a pacemaker failure, the priority is to restore haemodynamic status before evaluating the pacemaker. Methods of choice include:

1. Temporary pacing by transcutaneous means especially those with 3rd degree AV block and Mobitz II block.
2. Medication - atropine may be effective in patient with bradycardia especially those with high vagal tone and narrow QRS complex.
3. Application of magnet can treat arrhythmia due to PMT, sensor induced tachycardia, runaway pacemaker.
4. Cardioversion and defibrillation can be performed when indicated but some precaution should be taken.

Special consideration in patients with pacemaker presenting to emergency departments

Resuscitation

There is no contraindication to perform cardio-pulmonary resuscitation and institute advanced cardiac life support for pacemaker patients in cardiac arrest. However, the new semi-automatic defibrillation used by paramedics may fail to discharge in the presence of ventricular fibrillation as it oversense the pacing spike as acceptable rhythm. Defibrillation or cardioversion can be done under standard indication. But the current may damage pacing and sensing circuit. The incidence of failure to capture in patients with permanent pacemaker was as high as 50%. To minimise this, the defibrillator paddle should be placed as far away as possible from the generator. As there is risk of pacemaker malfunction after defibrillator or cardioversion, external pacing should be readily available. After successful defibrillation and stabilisation, the pacemaker should be interrogated and reprogrammed if necessary. Many antiarrhythmic drug – pacemaker interactions will elevate pacing threshold and result in failure to capture. But only class IC drugs (Flecainide – like) are of clinical significance at therapeutic drug concentration. It can be reversed with isoproterenol which lowers the pacing threshold. Alternatively the patients can be
temporarily paced with transcutaneous pacing. Finally the decision to terminate resuscitation should not be influenced by the presence or absence of pacing stimuli.

**Acute coronary syndrome**

Pacemaker patients are generally elderly and have a high prevalence of ischaemic heart disease. ECG diagnosis of AMI in the presence of ventricular pacing can be very difficult because of pacing artifact and changes in depolarisation rector (widened and LBBB like QRS complex) that obscure the classic ECG finding of AMI. In addition ST and T wave abnormalities can be misleading because ischaemic injuries cannot be differentiated reliably from ECG changes secondary to cardiac pacing. Sgarbossa et al developed 3 criteria from GUSTO-trail which may have some value in diagnosis of AMI in ventricular paced rhythms.

1. ST elevation 5 mm discordant with QRS
2. ST elevation 1 mm concordant with QRS
3. ST depression 1 mm in lead V1 V2 V3

Other useful methods include comparing current ECG to a previous ECG or looking for ST-T waves abnormalities in serial electrocardiograms.

**Trauma**

Trauma may rarely have adverse effect on pacemakers function which are commonly due to road traffic accidents, sporting injuries and domestic falls. It can cause generator failure, lead fracture, lead migration and pocket erosion. In managing trauma in such patient at emergency department, pacemaker pocket and its function must be fully assessed.

**Emergency departments**

The procedures and investigation carried out in emergency department may pose as electromagnetic interference, affecting pacemaker function. Electrocautery can cause pacemaker inhibition and damage the lead. So the ground plate and diathermy should be placed as far as possible and away from the pacemaker. The strength should be kept low and continuous burst avoided. Standard radiography, CT and isotope scanning procedure carry no risk but MRI may be hazardous.

**Conclusion**

This review has discussed the complications, malfunction of pacemakers and its treatment in emergency departments. The special conditions that are related to pacemakers’ presence have been highlighted.

**References**

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