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ARRHYTHMIAS

Permanent pacemaker implantation technique: part I

Kim Rajappan

Although device therapy is increasingly a subspeciality in its own right, permanent pacemaker (PPM) implantation remains one of the core skills of cardiologists. Most trainees will require at least basic skills in PPM implantation and the aim of this article (in two parts) is to provide a guide to the steps involved, and some of the fundamentals of technique. No article on this subject can be totally comprehensive and cover all the subtle nuances of technique used by different operators. Furthermore, like any practical skill it is only possible to give a flavour of the methodology in writing, and nothing can replace the practical tuition of an experienced implanter in the pacing theatre during a number of PPM implants. That having been said, before outlining some of the practical aspects of PPM implantation, the first step is to identify whether a patient needs a PPM. This may be straightforward, but there can be some complex cases. For this information the reader is referred to the various guidelines widely available.1–3 When it comes to the actual implant the following provides a step-by-step account.

PATIENT PREPARATION

For any patient undergoing PPM implantation, appropriate informed consent should first be obtained. This includes the indication for implantation (often to prevent syncope secondary to bradycardia) and the risks associated with the procedure (table 1), which may be tailored to one’s own practice/institutional figures; also it is increasingly important to document other important information given to the patient—for example, rules regarding driving.4 Placement of an intravenous cannula is routine for administration of prophylactic antibiotics, administration of intravenous analgesia/sedation, and potentially to perform venography (see section on central venous access techniques). For this latter reason it is the author’s practice to make this at least a 20 G cannula in the left antecubital fossa (assuming a left sided implant) to allow adequate contrast flow to visualise the venous anatomy. Pre-procedure sedation may be given before the patient is moved to the operating theatre, but if sedation is used at all, it is often simply given in the theatre itself. Most PPMs are implanted on the left side. This is because it is more natural for right handed operators and it is easier to position the leads (especially the atrial lead). There may be good reason to implant on the right side—for example, the patient recently had an infected system removed from the left—but handedness is not a determining factor (although 90% of patients are right handed anyway).

The choice of sedation and antibiotic prophylaxis will often be determined by local guidelines/practice. It is of interest (and will no doubt be recognised by all implanters) that there is a distinct lack of either national or international guidance in this latter area. This mainly stems from the conflicting evidence regarding its use; however, meta-analysis does suggest a benefit from pre-procedure intravenous antibiotics.5 In general protection against staphylococcal organisms is required whichever antibiotic is used, and local microbiological advice is often helpful to ensure adequate cover against identified pathogens. In most cases this will be either a single dose of a penicillin-type antibiotic—for example, flucloxacillin 1–2 g or a cephalosporin given within 2 h before the implant itself—but vancomycin and gentamicin are increasingly used in cases that are deemed to be higher risk—for example, in patients with a recent, unrelated infective illness.

Preparing the procedure field is also crucial to minimising complications. Sterility is obviously of paramount importance, and the technique for this is best learnt from an experienced scrub nurse. Of note, some units will use disposable drapes that are pre-fashioned, while others retain conventional reusable drapes. Whichever is being used, the operator needs to ensure that these are placed in a position that enables them to access all parts of...
the field that they desire (fig 1). Movement of these drapes during the procedure should be kept to an absolute minimum, and if possible avoided altogether. Some operators will use a transparent adhesive dressing over the operation field to assist in holding the drapes in position, as well as maintaining skin tension.

**EQUIPMENT**

Apart from the fluoroscopy equipment and vital observation monitors—for example, automated blood pressure cuff and oxygen saturation probe—there are a number of sterile surgical instruments and equipment that are needed. Figure 2 shows a standard PPM trolley set up for implantation. The quality of the instruments is important in determining the ease and speed of the procedure, and where necessary inadequate equipment should be replaced.

**INCISION**

There are at least three different recognised incisions that are used for PPM implantation (fig 1). Most operators will develop a preference for one of these or a slight variation on them. Each of them has advantages and disadvantages (shown in fig 1) and the way in which the incision is made can again determine the ease of implant. A poorly made incision can hamper access to the vein, make fashioning the pocket problematic, and potentially lead to a poor cosmetic result. For the “deltopectoral” incision, the incision is made from approximately 1 cm below the clavicle, in the deltopectoral groove (indentation between the clavicular head of the pectoralis major medially and the deltoid laterally). For the “horizontal” incision the cut is made starting approximately 1–2 cm below the junction of the middle and lateral thirds of the clavicle and extending directly laterally to cross the deltopectoral groove by approximately 1 cm. The “oblique” incision is made running parallel to and approximately 1–2 cm below the lateral third of the clavicle. The total length of the incision (commonly 4–5 cm) will vary according to: (1) the size of the device; and (2) the thickness of the subcutaneous layer (a longer incision is required if thicker tissue is present). Before performing the incision, local anaesthetic is infiltrated along the length of the intended incision as well as more deeply and slightly medially in preparation for the PPM pocket formation. Although guidelines suggest a maximum 5 mg/kg of 1% lignocaine (so in a 50 kg person this is only 15 ml), more may need to be used to achieve adequate anaesthesia.

**POCKET FORMATION**

Although the pocket may be formed in the axilla (in children in particular) or in the abdomen (for epicardial or femoral systems), the most common site is the pectoral region. Debate exists about some aspects of PPM pocket formation. The first is whether to fashion a subcutaneous pocket (at the level of the pectoral fascia), or submuscular pocket (this could be either an intramuscular pocket between the pectoralis major and minor, or a subpectoral pocket below both the pectoralis major and minor and above the ribcage). The subcutaneous pocket is the easiest and least painful to form, although it is imperative to get into the correct plane of prepectoral fascial tissue. Once in the correct plane, the pocket is made simply by using one or two fingers to gently spread the tissues apart slightly medially and caudally, after infiltration of local anaesthetic; note that in a...
young, muscular patient this tissue plane may still be fairly tight and require some effort to separate the layers, whereas in a more elderly patient it often spreads apart with minimal pressure. The submuscular pockets are formed by a shallow incision in the pectoralis major muscle and then blunt dissection, either through both muscle layers (subpectoral) or just down to the pectoralis minor (intramuscular, although this plane can be quite difficult to identify). This is more painful than subcutaneous pocket formation, but can be done with conscious sedation. With the size of current devices the subcutaneous pocket is sufficient for the vast majority of people undergoing PPM implantation; however, for those with little adipose tissue the submuscular pocket offers increased protection against device erosion. Other perceived advantages of a subcutaneous pocket are that generator changes are easier and there is less risk of neurovascular damage when forming the pocket than if one dissects through the muscle, while submuscular pockets give a better cosmetic result and reduce the risk of migration. In reality, there are little definitive data to support any of these suggestions and ultimately the choice of pocket will lie with the operator, or in some cases with the patient (either through patient choice or because of the body habitus).

The pocket may be fashioned at the start of the procedure before any lead placement, or at the end once the leads are secured (see section on lead placement techniques in part II). There are some specific reasons why the pocket may be made later in the procedure. If an axillary or submuscular pocket is being used it may be easier to gauge the final optimal position of the pocket after securing the leads. In routine practice the advantage of making the pocket (particularly a subcutaneous one) early in the procedure is that there is less chance of inadvertently displacing the leads once they are in place. The disadvantage is that there is a small chance that venous access will be impossible on the ipsilateral side and a redundant pocket then exists. However, this finding is relatively rare and therefore most operators will make the pocket early in the procedure.

### CENTRAL VENOUS ACCESS TECHNIQUES

This fundamental step can be broadly divided into those techniques involving direct visualisation of the target vein by a cut down technique (most commonly the cephalic vein), or those involving needle puncture of the vein. Advantages and disadvantages of each are shown in table 2.

#### Cephalic vein cut down

The usual course of the cephalic vein is in the delto-pectoral groove, penetrating the clavipectoral fascia to join the axillary vein medial to the pectoralis minor muscle. An occasional variant runs over the superficial surface of the clavicle to join the external jugular vein. When dissecting in the groove towards the lateral border of the pectoral muscle it is common to see an area of adipose tissue caudal to the lateral end of the clavicle. Dissection through this tissue, between the pectoralis major muscle on the medial side and the deltoid muscle on the lateral side, may reveal the cephalic vein at the bottom. It is worth noting that sometimes it lies just under the edge of the muscle so it is important to explore the margins carefully. Once the vein has been identified it is freed from the surrounding tissue by careful dissection. Ideally a 1–2 cm length of vein needs to be freed. An accompanying arteriole is common and one should be alert to this, carefully dissecting the vein away and ensuring cannulation of the correct vessel. Also, there may be a plexus of veins rather than a single vein. In this case it may be possible to cannulate the largest branch, but if they are all of similar small calibre it may be better not to attempt this route. The vein may lie deep, and the difficulty this creates may again mean that the operator does not pursue this access route, particularly in patients with a large body habitus. Once the vein is freed it is tied off at the distal end (farther away from the patient and closer to the operator). Care needs to be taken not to twist the vein as this is done because this makes venotomy

| Table 2 Advantages and disadvantages of different venous access routes |
|------------------------|------------------|------------------|
|                        | Cephalic vein    | Subclavian vein  | Extrathoracic subclavian/axillary vein |
| Surgical skill required| Most skill needed| Average          | Average                          |
| Pneumothorax risk      | <0.1%            | 1–2%             | <0.1%                            |
| Risk of lead crush     | Very low         | Highest          | Low                             |
| Amount of fluoroscopy required to gain access | Minimal | Minimal | More than other 2 methods |
| Ease of passage of multiple leads | May be difficult | Easier | Easiest |
| Ease of extraction if required | May be difficult | Easier | Easier |

**Figure 3** In panel A the cephalic vein has been isolated with silk ties at either end, and is lifted up by a clip to demonstrate it more clearly. The location of the deltopectoral groove in relation to this has been marked. In panel B, after an incision was made with iris scissors, the vein lifter (inset) has been used to open the cephalic vein lumen and a pacemaker lead has been inserted.
Heart position, theoretically making the risk of a pneumothorax almost zero. The area in red represents the target area for puncture of the vein in an extrathoracic approach through the clavicle. This reduces the risk of inadvertent lung puncture but may increase the risk of damage to the inserted pacemaker lead from pressure of the clavicle (“subclavian crush”).

Although some operators perform this puncture without any form of extra imaging, the fact that the subclavian often runs under the clavicle means that fluoroscopy can be used to help guide the needle (fig 4). An extrathoracic subclavian vein puncture is performed over the first rib. The puncture through the muscle is made slightly more medially than the conventional subclavian puncture, but importantly the angle of the needle is much steeper (in some cases almost 90°) and it is advanced in a superficial-to-deep and anterior-to-posterior direction. This is done under fluoroscopy and it is important that the needle always remains over the first rib in the standard postero-anterior (PA) projection, and specifically never passes medial to the rib (fig 4). The needle is advanced (gently aspirating on an attached syringe as with any other indirect puncture), aiming for the space below the clavicle and over the first rib until either the vein is cannulated or the rib is struck (supplemental video 1). If the rib is struck the needle should be gently withdrawn 1–2 cm while still aspirating and, if there is still no flashback of blood, the caudo-cephalad angle of the needle is changed to aim for either a slightly more cephalic or caudal position on the first rib and the same process repeated. The steep angle of the needle may mean the vein collapses on the needle, making passage of the guidewire difficult.

### Other access sites

Axillary vein puncture is performed by cannulating the vein over the second rib. Usually a venogram is performed to help guide puncture as the course of the axillary vein is more variable than the subclavian vein (fig 4, supplemental video 2). This technique is described in more detail elsewhere. The internal jugular vein and femoral vein may also be used in certain circumstances, but neither of these is used routinely as the first choice for lead implantation and is reserved for cases where the other access sites are not possible.
**Permanent pacemaker implantation I: key points**

- Documentation of consent and any advice given to the patient before permanent pacemaker implantation is essential.
- Be meticulous over aseptic technique from start to finish.
- A poorly made incision can affect the entire procedure.
- Where access is proving difficult, perform a venogram and consider manoeuvres to increase venous filling.

**Troubleshooting difficult central access**

As with axillary vein puncture, where it is proving difficult to cannulate the subclavian vein it is often worth performing a venogram from the ipsilateral arm (usually through a cannula in the antecubital fossa) to delineate the exact course of the vein over the first rib and under the clavicle (fig 4, supplemental video 2). Also, with patients in a sedated state and having often been left relatively dehydrated before the implant procedure, it may be worth giving fluid intravenously to increase central venous filling, and using a wedge under the legs as well as head-down tilt to increase venous return. Where there is difficulty in passing the guidewire from the subclavian into the superior vena cava (SCV), it is possible to place the dilator from the introducer sheath into the subclavian and inject contrast to visualise this area clearly and look for obstruction/stenosis, particularly where there are leads already in the vein. If bleeding from the puncture site into the pocket is a problem after the leads have been positioned, a purse string suture around the leads into the muscle and pocket can help.

**Multiple lead access**

Where access is required for more than a single pacemaker lead, the operator has to make a decision how to best achieve this. With the cephalic vein, for example, it is theoretically possible to provide unlimited venous access through the venotomy. However, the size of the vessel will limit this to some extent. Where the size of the vein allows, some operators will simply pass two (or more) leads via the cephalic vein without any guidewires or sheaths. Alternatively two guidewires may be positioned through the cephalic vein into the subclavian vein. This is achieved by passing an introducer sheath down the first guidewire, taking out the dilator from the sheath while retaining the guidewire in the sheath, passing an extra guidewire next to the existing one down the introducer sheath, and then taking out the introducer sheath without removing any of the guidewires. Introducer sheaths are then used for each lead in turn. With a dual chamber pacemaker the right ventricular lead is conventionally positioned first, and then the right atrial lead. Friction between adjacent leads can hamper manipulation in this situation, causing inadvertent lead dislodgement. To minimise interaction of the two leads, while positioning the second lead the introducer sheath may be left in situ until both leads are in a satisfactory position. Where multiple access is through a subclavian or axillary vein puncture a similar “double wiring” technique may be used, particularly if the puncture has been difficult and the risk of a pneumothorax may be increased by multiple attempts. However, there may be a slightly increased risk of bleeding from the larger hole created, so if the puncture is straightforward, a second puncture should be performed, which also makes individual lead manipulation easier.

This concludes the first part of this two part article. In part II further aspects of the implant process including lead placement techniques will be considered.

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reduce infection rates after PPM implantation, which, despite the limitations of some of the studies included, demonstrated a benefit in the use of pre-procedure parenteral antibiotics to prevent short term pocket infection, skin erosion or septicemia.

