Permanent pacemaker implantation technique: part II

Kim Rajappan

Heart 2009;95;334-342
doi:10.1136/hrt.2008.156372

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ARRHYTHMIAS

Permanent pacemaker implantation technique: part II

Kim Rajappan

Having addressed equipment requirements and some of the early steps in the process of permanent pacemaker (PPM) implantation in part I of this two part series, this section continues with the rest of the PPM implantation procedure and some aspects of post-procedural management/care.

LEAD PLACEMENT TECHNIQUES

Before discussing lead placement itself, it is important to briefly explain the structure of a permanent pacing lead. The leads themselves are very floppy and intrinsically have very little stiffness. This means that as the lead is moved around, the tip moves freely without any significant ability to steer it. To overcome this there is a central lumen to the lead which will allow passage of a stiffer thin wire known as a “stylet”. The further the stylet is passed down the lead (potentially almost to the tip), the more of the lead body is stiffened (fig 1). These stylets may also be “reshaped” easily to allow the tip of the lead to be further steered in a specific direction (fig 1). It is important to keep this stylet clean and free of debris, particularly blood, as this can block the central lumen and prevents the stylet from passing far enough down the lead to give any useful support. Also, the different lead positioning techniques described below are not mutually exclusive. A competent operator will be comfortable with most of them to adapt to different situations, although they may have a preference for which one they use first. The fixation method of the lead also has important implications. Lead tips may fixate “passively” or “actively”. Passive fixation leads have “tines” at the end of the lead (fig 1) which act as an anchor to hold the lead tip in place acutely. Over a period of time (weeks to months) the tip of the myocardium around the lead tip will fibrose to secure it further.

An active fixation lead has a retractable screw at the tip of the lead which is deployed when the lead is in position (fig 1). To do this the lead is first placed in the desired position (see below), using a stylet to support the lead tip against the myocardium. A clip-on tool (“A-frame”) is then attached to the distal pin of the lead and slow clockwise rotation of the distal pin transmits torque to extend the screw. This can be directly visualised under fluoroscopy (for some leads there is ring tip separation, and on others the rings come together) and slight resistance may be felt when rotating the distal pin as the myocardium is entered. Rotation of the distal tip too rapidly may build up torque within a lead such that the whole lead simply coils up and the screw is not extended. To check the stability of the lead tip, the stylet is then pulled back to see that the lead stays in place before lead testing. Specific instances where an active fixation lead may be used is when placing the right ventricular (RV) lead in the outflow tract/on the high septum, or in patients where the right atrial (RA) lead needs to be secured to the tissue for stability (some operators will use an active fixation RA lead in any patient who has previously had cardiac surgery, as the RA appendage may have been ligated when the patient is placed on cardiopulmonary bypass). It is felt that active fixation leads are easier to extract (although when the lead has been in for a long period of time any lead extraction may be difficult); therefore many operators will electively use these in younger patients, knowing that over time there is a moderate chance that new leads will be needed and the old ones will need to be removed.

RIGHT VENTRICULAR LEAD PLACEMENT

Traditionally most RV leads have been positioned in the apex; however, there is a growing trend to place the RV lead on the septum or in the RV outflow tract (RVOT). The discussion of the relative merits of these different positions has been performed elsewhere and comparisons are outlined in table 1. The first component of placing the RV lead is common to both positions and entails crossing the tricuspid valve (TV) to enter the RV itself. Broadly speaking, three techniques for this are commonly practised and are shown in fig 2 diagrammatically. The first is by “prolapsing” the lead across the TV. The lead is advanced into the RA with the stylet withdrawn 5–10 cm from the tip. As it is further advanced reasonably rapidly the tip may “catch” on the tricuspid annulus. If not, then slight reshaping of the stylet can help. Once caught, the lead is advanced with the stylet still withdrawn 5–10 cm from the tip and a loop of lead generated in the right atrium (RA). A straight stylet is then advanced (and initially the lead itself is slightly retracted), prolapsing a portion of the lead 5–10 cm from the tip through the TV. As the stylet is advanced further the lead tip may then flick through the TV or it may get caught on the TV with the rest of the body of the lead continuing to prolapse through. If the latter occurs the stylet may be advanced further to try to force the tip off...
of the TV; however, often it is firmly caught on trabeculation. In this instance the stylet can be withdrawn a few centimetres within the lead and the lead retracted and advanced to try to free the tip, still maintaining the prolapsed configuration—a small degree of caution is needed here because vigorous manipulation and particularly rotation of the lead can cause the tip to become entangled in the TV apparatus, and make freeing the tip more difficult. Ultimately if the tip is caught it may be necessary to pull the entire lead back into the RA and start again; if this occurs repeatedly, the “direct crossing” or “drop down” techniques should be used.

These techniques may be used in the first instance, particularly with larger French leads. With the direct crossing technique the stylet is reshaped and advanced towards the tip of the lead to help point it at the TV. The lead is then passed directly across the TV. This may take small adjustments in the direction of the tip, both by rotating the lead clockwise and anticlockwise to aim anteriorly and posteriorly, respectively, as well as advancing or retracting the stylet to aim superiorly or inferiorly. If the lead still does not directly cross it may be necessary to reshape the stylet again. Once across the TV the stylet may be slightly withdrawn to allow the tip of the lead to fall towards the apex. Sometimes the tip of the lead will continue towards the RVOT once the TV has been crossed, particularly if a curved stylet is advanced all the way into the lead before crossing the TV. If the final desired position of the RV lead is apical then the stylet is replaced with a straight one; as it is advanced through the lead across the TV, the lead itself may be gradually withdrawn causing the tip to “drop down” to the apex. It can then be advanced into a more apical position if necessary. If the final position of the RV lead is to be in the RVOT, or high septum at least, then the TV should be crossed with a shaped stylet akin to the direct crossing technique, but with the stylet advanced all the way into the lead. The lead may then naturally cross the TV and go straight onto the high septum/RVOT as it is advanced further. However, if the tip of the lead goes further up into the RVOT it may be necessary to withdraw the lead gradually and then advance again when at the correct level. This may need a slightly different shaped stylet. Once in position in the RVOT/high septum it is important to ensure the lead is actually posterior and septal rather than anterior and on the free wall. This is done by moving to an LAO projection and confirming the posterior position (fig 5).

There are a few important points and pitfalls that are common to RV lead positioning to be aware of. The proximity of the coronary sinus (CS) os to the TV means that it is possible to place the lead in the CS inadvertently; however, there are ways to avoid this. The occurrence of ventricular ectopics is a useful indicator that the lead is across the TV and in contact with RV myocardium rather than in the CS. Also, the lead position may be checked in the LAO projection—if in the CS or a branch of it, the lead will pass more posteriorly than expected. Another visual clue is that the lead tip appears to be at the RV apex, but the lead body appears excessively straight in the RV cavity and advancing it forward does not result in a classical “shoulder” of the lead across the TV. This suggests the lead may be in the middle cardiac vein or a posterolateral branch of the CS. Pacing on a lead in the CS will also reveal a right bundle branch block pattern rather than a left bundle pattern, but as the precordial leads are generally not available at implant, a clue can be the presence of a notably leftward axis in the limb leads which are usually used. When testing the lead, if parameters are not good despite excellent lead–myocardium contact and an apparently good anatomical position, check all connections from the analyser to the lead for any correctable problems (see below); however, if none are found the lead should be moved as this reflects a position that will chronically be poor. Also, if parameters unexpectedly deteriorate without any apparent lead dislodgement, consider the possibility of lead migration and perforation through the RV. Often this has no clinical sequelae and the lead can simply be pulled back and positioned again, but it is worth ensuring haemodynamic stability and performing echocardiography to confirm the absence of any pericardial effusion. Finally, one should pull back the stylet.

Figure 1 Lead types, stylets, and use of the stylet to change the shape of the lead tip. A passive fixation lead tip (A), and active fixation lead tip with screw retracted (B) and deployed (C) are shown. A J shaped (D) and straight (E) stylet may be used to stiffen the lead. Panels F, G and H show a pre-shaped J lead initially with the stylet advanced all the way to the tip (F) straightening the lead, but as the stylet is withdrawn the lead flexes (G) and eventually takes up its pre-formed shape (H).
Education in Heart

Table 1  A comparison of right ventricular (RV) apical and septum/outflow tract pacing

<table>
<thead>
<tr>
<th></th>
<th>RV apical pacing</th>
<th>RV septum/outflow tract pacing</th>
</tr>
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<tbody>
<tr>
<td>Ease of positioning</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Risk of perforation</td>
<td>More likely with RV apical pacing but still low overall incidence, and mainly because of thin tissue at the apex in some patients</td>
<td>More common with septal/outflow tract leads even when active fixation leads are used</td>
</tr>
<tr>
<td>Displacement risk</td>
<td>More common with septal/outflow tract leads even when active fixation leads are used</td>
<td></td>
</tr>
<tr>
<td>Pacing characteristics</td>
<td>Satisfactory in the majority</td>
<td>May be more physiological</td>
</tr>
</tbody>
</table>

into the portion of the lead that is in the superior vena cava (SVC) or subclavian before assessing the pacing characteristics of the lead to minimise the chance of false readings—this will also help to confirm the final position of the lead, as the stylet will affect the lead shape.

**RIGHT ATRIAL LEAD PLACEMENT**

Apart from passive and active fixation RA leads, there are also those that have a pre-shaped “J” shape, which is straightened by introducing a straight stylet, and those leads that are inherently straight and require a “J” shaped stylet to curve the tip (fig 1). The passive fixation RA leads are all pre-shaped, while active fixation leads come in either form (depending on manufacturer). Traditionally the RA lead is placed in the RA appendage (RAA). In some patients where the RAA position is not suitable (usually because of poor pacing characteristics) the lead may be placed anywhere else within the RA, but most commonly on the lateral wall. Like RV lead positioning there are standard manoeuvres that are used to position the RA lead, and again one should be aware of and have some experience of them all (fig 4).

The first technique involves placing the distal tip of the lead in the middle of the RA. If a pre-shaped lead is being used, the straight stylet is gradually withdrawn to allow the tip to rise into the RAA. If a straight lead is being used, a J shaped stylet is introduced at this point—be aware that if the cephalic vein has been used for access and/or there is tortuosity in the subclavian, then the lead may need to be gently advanced and retracted as the J shaped stylet is inserted to allow smooth passage. The lead is then gently withdrawn to try to intubate the RAA os. If too low the lead may prolapse on itself and simply withdraw into the superior vena cava (SVC). If this happens the pre-shaped lead is straightened again with the stylet (or the J shaped stylet is withdrawn from the straight lead) and the procedure repeated, but starting a little higher in the RA itself. If too high initially, then as the straight stylet is withdrawn form the pre-shaped lead (or a J shaped stylet is inserted into a straight lead) the tip catches in a flatter orientation. By advancing the lead it may intubate the RAA. It is important to be aware that the RAA position varies and can appear different in the standard postero-anterior (PA) projection. Therefore, it may be necessary to check the lead position in different fluoroscopic projections (for example, in LAO the lead tip should generally point anteriorly). Furthermore, the classical “wind-screen wiper” or “figure-of-eight” movement of the lead tip suggests a good position in the RAA—but be aware that this motion is absent in atrial fibrillation. When it is decided to place the RA lead in a position other than the RAA, it is generally advisable to use an active fixation lead. Positioning is often on the lateral wall. Again the lead is placed in the mid RA and then rotated clockwise to spin the lead laterally. Sometimes to keep the lead tip free in the RA, the whole lead will need to be advanced or retracted as the lead is rotated. Ideally the tip of the lead should be as close to perpendicular to the wall as possible to maximise the chance of getting good fixation, but care is needed as there is a small risk of perforation.

**PACING CHECKS**

Once the lead is in what is felt to be a good anatomical position, the pacing parameters need to be checked to ensure that these are also satisfactory. The testing cables are connected at one end to an analyser. At the other end a pair of coloured crocodile clips are used to test the lead. With a bipolar lead there are two rings on the lead and the black clip goes to the distal ring, the red to the proximal (fig 5). If a unipolar lead is being used (rare at implant these days for single/dual chamber pacemakers but may be encountered at the time of generator changes (see below)) then the lead only has a single distal ring so the black clip is connected to this, and the red clip needs to be connected to subcutaneous tissue to reproduce the effect of the generator acting as the other electrode. The simplest way to do this is either to attach the clip to tissue within the pocket, to use a specially designed plate which is included in some pacing packs, or my own preference is to attach an artery clip to the inside of the pocket and then attach the red crocodile clip to this. Once connected, and before formally testing the pacing characteristics of the lead, the “injury current” is checked (fig 5). If this is large it suggests good contact between the lead tip electrode and the myocardium.

In the presence of a large injury current, an initially high pacing threshold (see below) will tend to come down substantially within 5 min, so it is worth waiting before repositioning a lead that otherwise appears to be in a good anatomical position. Routinely the following parameters are then tested (acceptable values are shown in table 2):

- **Sensing**—Measured in millivolts (mV), this is the intrinsic signal that the pacemaker will detect on the lead. It is accepted that the larger the signal is, the better. In the case of the RV lead if the R wave (the sensed signal on the RV lead) is too small then the pacemaker may not sense intrinsic rhythm and start to pace inappropriately, with a small risk of R-on-T arrhythmias. More importantly, if the R wave is too small and the device is programmed to try to account for this, it is then possible that the lead will detect artefact that is not
ventricular activity and inappropriately NOT pace the ventricle when the patient is potentially asystolic. In the case of the RA lead it is not only the size of the atrial signal (the P wave) that is important but also the presence of ventricular activity that is distant but still detected by the atrial lead (so called “far field” sensing). If the far field activity is too large relative to the P wave on the atrial lead then the pacemaker may see both of these and count two atrial signals where there is only one. Most pacemakers to varying extents can be programmed around this problem. However, careful positioning of the lead at the time of implantation to minimise the far field component can save significant future problems, specifically the possible need to reposition the lead at a later date. Ultimately a smaller amplitude signal may be accepted if multiple sites have been tested, but this decision generally needs experience to know when to stop searching for a better position.

Figure 2  Diagrams showing three different techniques for right ventricular lead placement (see main text).
Figure 3  Diagrams showing two different techniques for placing the right ventricular lead on the septum/in the right ventricular outflow tract (see main text). The fluoroscopic images show the right ventricular lead in the apical position on the left (in the right anterior oblique (RAO) and left anterior oblique (LAO) projections), and in the high septal position on the right. Particularly note the LAO projection of the septally placed lead—it is important that the lead points as posteriorly as possible to ensure placement on the septum (marked with a dashed line) rather than the free wall, where perforation and displacement risk are higher.
Impedance—Measured in ohms (Ω), the impedance measured though the lead is a reflection of all the factors that oppose flow of electric current through the lead. This includes the lead conductor (conductor resistance), the resistance to current flow from the electrode to the myocardium (electrode resistance), and the accumulation of charges of opposite polarity in the myocardium at the electrode–tissue interface (polarisation impedance). Again acceptable values are shown in table 2. This measurement may be more important during PPM follow-up where a high impedance value suggests a fracture in the lead conductor or a loose set-screw at the proximal connector, while a low lead impedance value suggests a break in the lead conductor insulation, either of which may necessitate replacement.

Pacing threshold—Measured in volts (V) and pulse width (in milliseconds (ms)), this is the minimum amount of energy needed to capture the myocardial tissue electrically. The lower this value is the better, as the battery depletion is proportional to the amount of energy needed. In most cases the pulse width is fixed (at 0.5 ms, for example) and then the voltage is gradually reduced until capture is lost (fig 5). The threshold in this case is 0.6 V at 0.5 ms. The specifics of voltage and pulse width measurement and their implications may be studied in more detail elsewhere. Maximal output pacing (usually 10 V) is also performed on each lead to ensure there is no stimulation of extracardiac structures (normally indicated by diaphragmatic twitching).

Stability testing—The pacing characteristics of the leads are tested under conditions that might cause a loss of capture. To perform this at the time of the implant it is most straightforward to ask the patient to breathe in deeply, cough, sniff, or pant. Some operators will use fluoroscopy to check the amount of movement of the lead during deep inspiration and ensure there is enough slack in the lead to allow for straightening during this manoeuvre without displacing the lead tip.

LEAD CONNECTION, GENERATOR PLACEMENT IN POCKET, AND WOUND CLOSURE

Once a satisfactory position and lead parameters have been achieved, the lead is secured with non-absorbable sutures around the collar. It is important to secure the leads to muscle—if secured to subcutaneous tissue the lead may slip. If the cephalic vein has been used the silk tie around the proximal end and the lead(s) is tied tight enough onto the lead(s) to stop any residual blood flow from the vein, but not so tight as to damage the outer lead insulation or coils. Once the leads are secured the pacemaker generator is connected to the leads and placed in the pocket. Caution should be taken at this stage to make sure that:

1. If there is more than one lead—for example, right atrial and ventricular—the correct lead is placed in the correct port on the header. Checking the serial number on the lead and where it has been inserted with the technician/physiologist is the most reliable method.
2. The leads are inserted all the way into the header—check that the distal end of the pin is showing past the distal connector.
3. ALL set screws are tightened adequately—the screwdriver is turned clockwise to tighten. Some manufacturers have one set screw for a bipolar lead, while others have two.
4. When placing the generator in the pocket ensure the redundant length of the leads are coiled and placed behind the generator, otherwise there is a greater risk of damage at the time of future generator changes. Ideally, the generator should be placed in the pocket with the logo face up. Sometimes the pulse generator is secured to the muscle using a stitch through a hole on the header. This may help prevent migration in certain patients—for example, elderly patients with loose subcutaneous tissue or where the generator has migrated caudally at the time of a generator change.

Wound closure may be performed in different ways—interrupted sutures, continuous suture, locking stitch, etc. However, common to all techniques is that one or two layers of absorbable sutures are used to close the deeper subcutaneous layer, while a single layer (either absorbable or non-absorbable) is used in the subcuticular plane. Some operators use tissue glue—for example, Dermabond—to replace the subcuticular suture,
but this can only be used if there is good haemostasis and skin apposition with the deeper sutures. It is important to get the tension in these sutures correct (too tight will cause puckering of the skin, and too loose will allow gaping of the wound).

**POST-PROCEDURE CARE**

Controversy remains over the use of topical antibiotics in the pocket (commonly gentamicin) and the routine use of antibiotics parenterally and/or orally after the procedure. This will, like the pre-procedure antibiotic regimen, be guided by local protocols/guidelines and individual operator preference. Chest radiography should be performed in any patient who has had a subclavian puncture to exclude a significant pneumothorax, and in many institutions may be performed in all patients routinely irrespective of venous access route. Also, increasingly these procedures are performed in patients who are discharged the same day (day case) as evidence for many years has shown that this is safe,

![Figure 5](image.png)

**Figure 5** Panel A shows the IS-1 connection (the current standard connector tip) of a bipolar pacing lead. (The proximal ring electrode is indicated by the red arrow and the distal electrode by the black arrow; this corresponds to the electrodes at the tip of the lead itself.) Below this the cable for testing the lead parameters at implant have been connected. The “crocodile” clips used are colour coded with red being attached to the proximal electrode and black to the distal electrode. Panel B shows recordings of the signal from the pacing lead known as the intracardiac electrogram (EGM). The top strip is taken immediately at implant and attention is drawn to what may be described as ST elevation (circled) if this were a normal ECG—this is known as the “injury current” and suggests the lead is in good contact with the myocardial surface. Within a relatively short period of time (minutes to hours) this “injury current” disappears and a more simple EGM spike (circled in the lower strip) is left. In panel C a printout is shown from the analyser during ventricular lead testing. The top row shows the pacing output in volts (V) at that particular time, and can be seen to gradually decrement from 2.0 V on the left to 0.3 V on the right. The next line shows the intracardiac EGM recorded (as in panel B); the next line is the marker channel which shows when a pacing impulse is produced by the generator (denoted by a VP in this case); and the final line is an ECG recording. On the left of the strip with every pacing impulse (VP on the marker channel) there is a corresponding intracardiac EGM and a QRS complex on the ECG (solid black arrows). This continues down to 0.6 V, but at 0.5 V there is a pacing impulse (VP again on the marker channel) but no intracardiac EGM and no QRS on the ECG (red arrows), indicating failure to capture the ventricular tissue at this output. Subsequently there is the patient’s own intrinsic QRS complex (VR on the marker channel indicates that this signal falls in the “refractory” period of the pacemaker setup) and different intracardiac EGM and QRS on the ECG are seen (dashed black arrows). The threshold—that is, the minimum pacing output at which the ventricular tissue is captured with the pacing lead in this position—is in this instance 0.6 V (with a pulse width of 0.5 ms).

<table>
<thead>
<tr>
<th>Pacing parameters and normal ranges</th>
<th>Threshold (volts, V)</th>
<th>Impedance (ohms, Ω)</th>
<th>Sensing (millivolts, mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave ≥1.5 mV</td>
<td>&lt;1 V at 0.5 ms</td>
<td>400–1000 Ω</td>
<td></td>
</tr>
<tr>
<td>R wave ≥5.0 mV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May accept lower values if multiple sites have already been tried and found unacceptable</td>
<td>Will vary for different leads—refer to manufacturer’s guidance for the specific lead</td>
<td>The lower the threshold is the better, but like sensing, sometimes one will need to accept higher values</td>
<td></td>
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</table>
Permanent pacemaker implantation II: key points

- When positioning a lead, be careful not to introduce blood, etc, into the central lumen—eventually the lumen will occlude and make passage of the stylet impossible.
- The presence of far field sensing can be problematic and is best dealt with at the time of implant by careful lead positioning.
- Once the leads are in position, use fluoroscopy intermittently while securing them to ensure they do not move. This includes briefly screening with fluoroscopy after the generator is in the pocket.
- The use of peri-procedure antibiotics and anticoagulation management varies widely—there are often local protocols and it is important to be familiar with these.

this subject are available. The main issue surrounds how to manage a patient who is taking warfarin. Clearly the indication for warfarin and the risks of stopping it will largely determine what is done in this respect. An increasing number of operators are performing these procedures without stopping the warfarin, aiming to keep the international normalised ratio (INR) between 2 and 3, as well as being meticulous with haemostasis. Results with this approach suggest it is safe with fewer complications as a result of under anticoagulation, but with no increase in bleeding complications.

GENERATOR CHANGES, IMPLANTABLE CARDIOVERTER DEФФИBRILLATORS, AND CARDIAC RESYNCHRONISATION THERAPY

The elective generator change is often incorrectly perceived as a more straightforward procedure than the implant itself. Infection rates are higher, lead damage is possible, and unexpected findings are not uncommon—for example, sudden changes in pacing thresholds/impedances. Some simple steps can be taken to minimise the risk of problems. First is to be absolutely certain about the implanted hardware (number of leads, unipolar or bipolar). Second is to check if the patient is “pacing dependent”—if there is absolutely no underlying rhythm (often one can only program a pacemaker to a minimum of 30 beats/min) then a decision has to be made: one may try to remove the lead quickly and connect to an analyser which is already set to pace (but this may be a nervous process); or a temporary pacing wire is inserted (usually from the groin) before the generator change which can then be removed at the end of the procedure with probably negligible infection risk; or one can use high dose isoprenaline infusions to try to encourage underlying rhythm. Third is to use fluoroscopy where necessary to help identify the course of the leads in relation to the generator. Finally, to make the incision to remove the generator in a position that makes this easy (for example, just over the most cephalic portion of the generator) which may be distant to the original implant incision. Where it is recognised beforehand that a new lead needs to be implanted at the time of a generator change, then performing a venogram will confirm vein patency, and if the generator has migrated caudally it may even be necessary to make two incisions—one to remove the generator and one to gain venous access.

Implantable cardioverter-defibrillator (ICD) implantation and cardiac resynchronisation therapy (CRT) are seen to be more complex device procedures. In fact, implantation of an ICD is similar to a standard pacemaker, particularly now that ventricular leads with shock coils are of a similar French size to standard pace/sense leads, albeit slightly heavier and stiffer. However, the fact that these patients often have structurally abnormal hearts (dilated and scarred) may make finding a position with adequate pacing and, more importantly, sensing characteristics difficult. Also the generators are larger, and the position and size of the pocket needs to be adjusted accordingly. CRT similarly shares a number of common components with standard bradycardia pacing, but placement of a lead to pace the left ventricle requires training and experience.

SUMMARY

PPM implantation remains a core skill of trainee cardiologists, despite increasing subspecialisation. This two part article is aimed at giving the inexperienced implanter a framework on which to develop their skills. There are now also a number of courses available that offer the opportunity to learn about PPM implantation in a controlled teaching environment, many using virtual technology for components such as lead placement. Ultimately the technique for implantation can be best learnt in a pacing theatre/laboratory under the guidance of an experienced implanter.
Acknowledgements: My thanks to Dr Ernest Lau for allowing me to use his line drawings on lead placement. Thanks also to Drs Joseph De Bono, John Paisey, David Tomlinson, and Zaheer Yousef for their contributions.

Competing interests: In compliance with EBAC/EACCME guidelines, all authors participating in Education in Heart have disclosed potential conflicts of interest that might cause a bias in the article. The author has no competing interests.

REFERENCES

Useful reference books

  – the most widely used concise textbook for device therapy.
  – excellent pocket sized book for quick reference on all aspects of pacing.
  – the basics of pacing explained in a clear, illustrative format.