Permanent pacing in patients without upper limb venous access: a review of current techniques

Swee-Chong Seow, Toon-Wei Lim, Devinder Singh, Wee-Tiong Yeo, Pipin Kojodjojo

Cardiology Department, National University Heart Centre, Singapore, Singapore

Correspondence to
Dr Swee-Chong Seow, Cardiology Department, National University Heart Centre, 1E Kent Ridge Road, NUHS Tower Block, Level 9, 119228 Singapore, Singapore; swee_chong_seow@nuhs.edu.sg

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ABSTRACT
Permanent transvenous cardiac pacing is usually accomplished through the upper limb veins. When these are occluded, several other vascular access options exist which include the internal jugular, external jugular, femoral and iliac veins as well as more proximal access of the subclavian veins. Anterograde and retrograde techniques to restore subclavian venous patency has been described. A review of these approaches is undertaken, with a discussion of their pros and cons. Familiarity with these techniques will enable the implanter to perform transvenous pacing when faced with limited vascular access.

INTRODUCTION
Permanent transvenous cardiac pacing has traditionally been achieved using vascular access via the upper limbs. Achieving venous access through the axillary, subclavian or cephalic veins is straightforward, requires minimal dissection and is associated with a low risk of minor complications. This also allows for placement of the pulse generator in the infraclavicular region; an ideal location due to its limited movement, accessibility, relative cleanliness and patient comfort.

However, venous occlusion or thrombosis is not an uncommon finding in patients undergoing device implantation or revision.[1] The incidence is estimated to be as high as 13.7% in de novo implants[2] and 26–64% in system upgrades.[1 3 4] In patients undergoing their first pacemaker implantation, venous occlusions are usually attributed to prior instrumentation with central lines for long-term infusion therapy and haemodialysis. Risk factors for venous occlusion in patients with existing pacemakers include the number of leads previously implanted, absence of antiplatelet or anticoagulant therapy, a history of myocardial infarction, prior temporary cardiac pacing, heart failure, history of infection and smoking.[1 5 6] As more device implants are performed globally for ever-expanding indications including bradycardia, cardiac resynchronisation therapy and prevention of sudden cardiac death, the magnitude of this problem is expected to increase.

While surgical epicardial pacing via a thoracotomy has been traditionally viewed as the 'bail-out' option, it is not preferred due to its invasiveness. Even with minimally invasive surgery, there is significant morbidity, increased peri-operative mortality and prolonged hospital stay averaging 4–5 days.[7 8] Epicardial leads also have higher pacing thresholds and greater incidence of lead fractures compared with transvenous leads.[9 10]

In this article, we review techniques that can be used to perform permanent transvenous pacing in patients without or restricted upper limb venous access. These approaches can be divided into three groups: alternative supraclavicular venous access routes, alternative infraclavicular venous access routes and restoration of subclavian venous patency.

ALTERNATIVE SUPRACLAVICULAR VENOUS ACCESS SITES
An important consideration with supraclavicular approaches is that in most instances, the pulse generator remains in the conventional infraclavicular space. While leads placed via the conventional subclavian/axillary/cephalic veins have a short, unobstructed course to the pulse generator, leads placed via supraclavicular routes will double back on themselves before descending either over or under the clavicle to connect to the pulse generator. Leads traversing over the clavicle can result in skin erosion or pain and are more prone to crush fracture. Tunnelling the leads under the clavicle overcomes some of these limitations but necessitates more extensive surgical dissection.

Vascular access options above the clavicle include the internal jugular vein (IJV), external jugular vein (EJV), and supraclavicular puncture of the subclavian vein (SCV).

Internal jugular vein
The IJV has been used by surgeons since the 1960s for placement of permanent pacing leads.[11 12] Its deep location within the neck and its close relationship to vital structures like the carotid artery, vagus nerve, phrenic nerve and recurrent laryngeal nerve make it challenging to access using surgical cut-down without causing unintended collateral damage to neighbouring structures. Despite concerns about potential upstream central nervous system effects due to thrombosis and occlusion of the IJV, there appears to be no apparent clinical consequence of permanent pacing through the IJV, even in a few patients in whom both IJVs were utilised.[12–14]

Accessing the IJV percutaneously using Seldinger technique needle puncture is safer since it allows entry into the venous lumen at some distance from the surface and avoids extensive dissection in the neck. Using standard landmarks, the IJV is cannulated with a needle in the triangle between the sternal and clavicular heads of the sternocleidomastoid (SCM) muscle where it is located lateral to the carotid artery. The Seldinger technique is used to introduce a guidewire into the IJV, which is retained while the needle is removed. A small

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vertical incision is made over the guidewire and the subcutaneous tissues divided using blunt dissection down to the level of the SCM muscle. For each lead required, a separate peelable sheath is introduced into the IJV and the pacing lead is advanced to the target area where it is fixed in position. The lead is secured by tying the suture sleeve to the SCM muscle. To position the pulse generator infraclavicularly, a second skin incision is made horizontally inferior to the clavicle. The subcutaneous pocket for the pulse generator is then created. Coursing the pacing lead over the clavicle requires only minimal subcutaneous dissection, but is not preferred because of the high likelihood of skin erosion over the lead due to the thin skin covering over the clavicle. In our institution, we prefer to tunnel the lead under (posterior and inferior to) the clavicle to reach the pocket created in the pre-pectoral area. After administrating liberal quantities of local anaesthesia, a set of haemostat forceps is used to create a tunnel subcutaneously using blunt dissection from the first incision towards the superior aspect of the clavicle. With the curve of the jaws facing anteriorly, the forceps are directed under the clavicle to exit into the infraclavicular pocket while dividing the muscle layers. Hugging close to the posterior and inferior surface of the clavicle, the only structures that are traversed are the subclavius muscle inferiorly and the pectoralis major muscle attachment anteriorly upon exiting into the pocket. There is minimal bleeding with such blunt dissection, hence to avoid cutting the muscle layers. The subclavian vessels, brachial plexus and the pleura lie a fair distance away posteriorly of this tunnel, thus minimising any chance of injuring these structures using blunt dissection. The proximal end of the pacing lead is secured with a 1/0 silk suture over a latex sleeve to protect the lead (we improvised using the cut 'finger' of a sterile glove). This is then pulled through the tissue tunnel beneath the clavicle to the infraclavicular pocket where it is connected to the pulse generator. Both the incisions are then closed using absorbable sutures. An example is shown in figure 1.

Some authors have described using an 18 G needle to puncture from the supraclavicular to infraclavicular space, passing a guidewire, followed by a sheath through the tract created before finally pulling the lead through this tract. We feel that such a blind approach is more likely to cause injury to surrounding neurovascular structures and pneumothorax than the method we have described above.

Apart from the standard location in the infraclavicular space, some operators have implanted the pulse generator in the supraclavicular fossa (thus avoiding the need to create a tunnel under the clavicle); and even posteriorly under the latissimus dorsi muscle.[15] Placing the generator in these locations results in more discomfort for the patient compared with the conventional infraclavicular position.

External jugular vein

The EJV is another option for transvenous pacing because of its superficial location which makes it easy to access using cut-down techniques.[16 17] Placing the patient in the Trendelenburg position, occluding venous drainage with finger pressure over the medial end of the clavicle or getting the patient to perform the Valsalva manoeuvre are various methods to distend the vein to make it more prominent so that its course can be traced prior to cut-down.

However, the EJV has never been a popular choice because it is often tortuous, sometimes small in calibre and tends to join the SCV at a sharp angle. Furthermore, there is usually a valve located at its junction with the SCV. All these obstacles make it difficult to place a pacing lead through the EJV to the right ventricle, in addition to the above-mentioned disadvantages of its supraclavicular location.

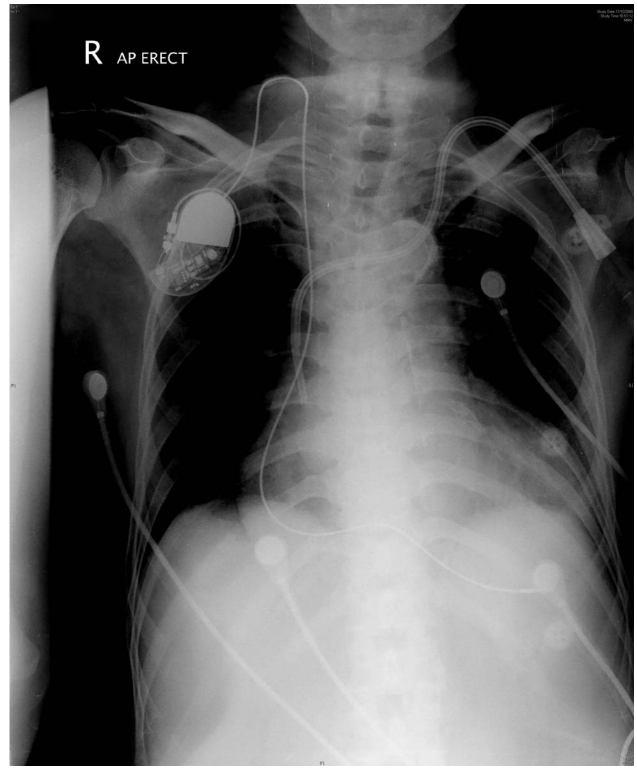

Figure 1 Permanent pacing via the right internal jugular vein, with ventricular lead tunnelled under the clavicle. The subject was an older man with a dialysis catheter in the left subclavian vein, occluded right subclavian vein, and bilateral lower limb deep vein thromboses. Note the proximal course of the lead transversing beneath the clavicle to reach the infraclavicular pulse generator.

Supraclavicular access of the SCV

Although access to the SCV is usually obtained infraclavicularly, it can also be cannulated from above the clavicle.[18–21] With this supraclavicular approach, the SCV is punctured more medially, at its junction with the IJV. This can be a valuable option in patients with more distal occlusion of the SCV. This approach to subclavian access has been extensively used for placement of indwelling central venous catheters.[22]

The introducer needle is inserted 1 cm lateral to the lateral head of the SCM muscle and 1 cm posterior to the clavicle. It is directed at a 45° angle to the sagittal and transverse planes (bisecting the 90° angle between the lateral head of the SCM and the superior border of the clavicle) and 15° below the coronal plane aiming toward the contralateral nipple. The vein is very close to the skin at that point and often accessible even with a 4 cm, 21-gauge needle. The subclavian artery is situated just behind the SCV over the first rib, and its pulsation can be used to direct the introducer needle away from it and toward the junction of the subclavian and IJVs.

Once the vein has been punctured, leads can be inserted into the vein and manipulated into position in the usual manner. The leads can then be tunnelled either over or under the clavicle to the pulse generator placed in the infraclavicular space.

ALTERNATIVE INFRACLAVICULAR VENOUS ACCESS

Transvenous pacing can also be performed using iliac or femoral venous access. The femoral vein continues as the external iliac vein when it crosses under the inguinal ligament, joins the internal iliac vein to form the common iliac vein before draining into the inferior vena cava.

Various authors have described placement of pacing leads in the femoral or iliac vein, depending on whether the access site is below or above the inguinal ligament. For most intents and purposes, the technique is similar. In fact, Ellestad *et al*, who have the largest experience of 90 patients with pacemakers implanted via this route, changed their terminology from 'Permanent pacemaker implantation using the femoral vein' in their original paper[23] to 'Iliac vein approach to permanent pacemaker implantation'[24] in their second paper upon realisation that the lead technically enters the iliac vein using their method. In theory, accessing the femoral vein is safer since it lies outside the peritoneal cavity unlike the iliac vein. It is therefore easier to achieve haemostasis in the event of bleeding with manual compression and there is a lower chance of injury to the intra-abdominal structures during vascular access.

A case example of permanent pacing using the iliac venous route can be seen in figure 2. Our approach is similar to that described by Ellestad *et al*.[23 24] Following infiltration of the skin and subcutaneous tissue with local anaesthetic, an introducer needle is used to puncture the right external iliac vein just above the inguinal crease and medial to the palpable pulsatile femoral artery. The Seldinger technique is used to place a guidewire in the vein. Using the retained guidewire technique, a second guidewire is placed in the external iliac vein for the atrial lead. Some operators perform a variation whereby the femoral vein is accessed below the inguinal ligament and a guidewire is inserted to act as a fluoroscopic marker for the puncture of the iliac vein above the inguinal ligament.

A 2 cm long skin incision is made where the guidewire exits the skin, parallel to the inguinal crease. Dissection is performed until the fascia overlying the muscular layer is reached. A second incision is made horizontally just below and to the right of the umbilicus. Care is taken to make the incision below the line where the waist seam of the trousers sits so as to avoid pressure over the device from clothing. The subcutaneous pocket for the pulse generator is created inferiorly of the second incision. A 100 cm active fixation lead (5076–100, Medtronic, Minnesota, USA) is delivered via a peel-away sheath (6207 BTKL-1, Medtronic) into the right ventricle. A second 100 cm active lead is fixed at the anterolateral right atrium. The leads were sutured down to the muscle layer. A tunnelling tool was used to create a tract from the inguinal incision to the incision next to the umbilicus. The proximal ends of the two leads were secured within a latex sleeve (Penrose drain or the cut-off finger of a sterile glove) using a 1/0 silk suture. This was pulled through the tract to the pocket where the leads were connected to the pulse generator. It is important to suture the pulse generator to the fascia layer to prevent migration. At the inguinal incision, sutures were placed to secure the lead as it turns upwards from the groyne and ascends the abdominal wall.

Garcia Guerrero *et al*[25] described a similar technique except that the pulse generator was implanted in the thigh instead of the abdominal wall. Placing the pulse generator in the abdomen above the inguinal crease avoids stress placed on the leads due to hip flexion but necessitates placing the leads through in a sharp U-turn as they exit from the iliac vein. This is circumvented when the pulse generator is implanted instead in the anterior thigh. It is uncertain whether locating the generator in the anterior thigh or the anterior abdominal wall is less likely to produce conductor fracture due to repeat flexion and angulation stresses on the leads.

Although fairly simple to perform, the Achilles' heel of this transfemoral approach is the high lead dislodgement rate of 11–21% for the atrial and 5–7% for ventricular leads.[23 24 26] Lead fracture does not appear to be a clinically significant problem in the adult population despite the leads having to make a U-turn from the inguinal region and up the abdominal wall to the pulse generator as described above.[24]

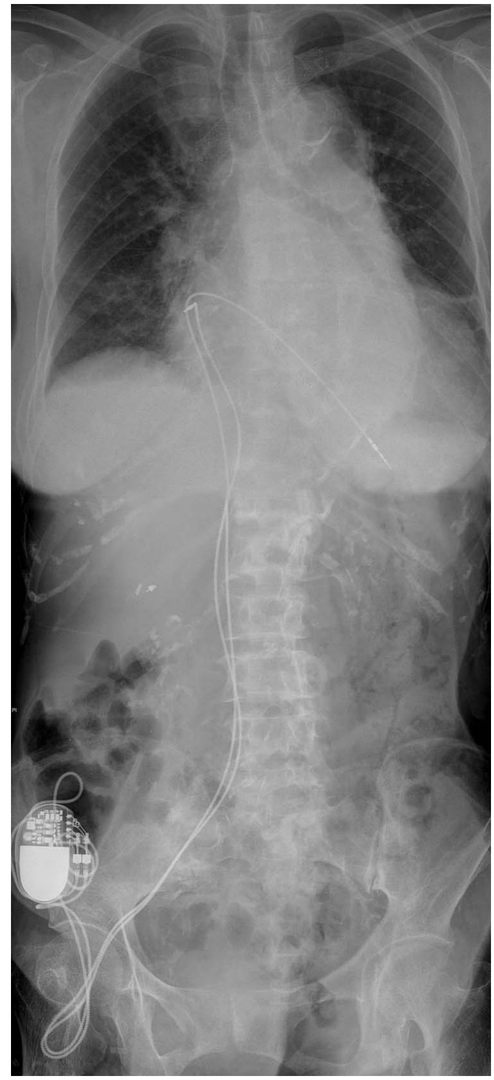

Figure 2 Dual-chamber pacing via the iliac vein. The subject was an older female patient with an arteriovenous haemodialysis fistula on the right upper limb and an infected pacemaker system in the left upper limb which had recently been removed. Following intravenous antibiotic therapy to eradicate her pacemaker infection, a dual-chamber pacemaker was implanted through the right external iliac vein. The pulse generator is secured in a subcutaneous pocket inferior to and right of the umbilicus.

In a cohort of 99 paediatric patients aged from newborn to 13 years old who underwent pacing lead implantation via the femoral route, the 2-year, 5-year and 10-year actuarial survivals of transfemoral leads were 87.6%, 73.8% and 31.8%, respectively.[27] However, it is important to note that, in this series, leads were abandoned largely not because of pace-sense failure (in fact this only occurred in 5 out of 106 leads over a mean follow-up period of 5.3+5.0 years), but also due to lead/body size incompatibility as a result of the child's growth, infections and elective decisions to revise the pacing system.

The location of the vascular access site and skin incision in the groin may theoretically predispose the patient to a higher risk of device infection. There is also concern about femoral vein thrombosis, which can be as high as 30% following temporary transfemoral pacing[28 29]; with the attendant theoretical risk of pulmonary embolism. Although there is paucity of data in the literature, the infection and thromboembolic risks, in our experience, do not appear to be any higher than in patients undergoing conventional pectoral pacemaker implantation.

RESTORING PATENCY OF THE SCVS

In patients with pre-existing leads in the SCVs, repeated venous access may be necessary to implant additional leads during a device upgrade procedure or to replace non-functioning leads. In such scenarios, it is not uncommon to encounter subclavian stenoses or occlusions. Successful extraction of the existing leads using simple or complex techniques whilst maintaining vascular access will allow for anterograde recanalisation of the occluded SCV or superior vena cava. According to Heart Rhythm Society Expert Consensus on transvenous lead extraction, this is a Class IIa indication for lead extraction.[30] The various techniques for lead extraction have been reviewed extensively and is beyond the scope of this review.[31]

More recently, Elayi and colleagues[32] described a novel 'inside-out' or retrograde method of re-achieving vascular access for device implants in patients with central venous occlusions. In their approach, right femoral venous access was obtained following which a sharpened 0.018 inch wire, loaded over a transeptal needle, sheath and dilator, is used to cross the occluded vein segment. This wire will cross the occlusion either through the lumen or adventitially until it exits the skin in the infraclavicular region. The transeptal needle, sheath and dilator is then sequentially pulled through such that a 0.035 inch guidewire passed from the femoral vein can now exit in the infraclavicular region. This channel is progressively dilated and the required leads are implanted anterogradely as per usual practice.

WILL LEADLESS PACEMAKERS SUPPLANT THESE TECHNIQUES?

The introduction of leadless pacemakers (which are inserted using deployment catheters via transfemoral venous access) is set to change the paradigm for patients without upper limb venous access requiring single chamber pacing. However, it will require several more years of technological advancement before leadless systems are able to provide multi-chamber synchronisation. Until then, these alternative techniques described above will remain relevant and important tools in the armamentarium of the implanting electrophysiologist.

CONCLUSIONS

In patients with occluded upper limb veins, numerous techniques exist to allow the operators to achieve successful transvenous pacing. Mastering these techniques could prevent patients from undergoing unwarranted open surgery for pacing indications.

Contributors All authors contributed to the drafting and approval of the final article, in addition to the clinical practice of managing these patients in the National University Hospital Pacemaker Clinic.

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