Transvenous Cardiac Pacing. Experience of a Percutaneous Supraclavicular Approach

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Summary: A detailed description is given of a technique for the introduction of cardiac pacing catheters using a percutaneous supraclavicular route through the subclavian vein. In 91 attempts there was only one failure and the frequency of complications was low. Surface landmarks for the procedure were easy to define precisely, and stable pacing could usually be established rapidly without distress to the patient or subsequent immobilization of any limb. It is suggested that operators with little experience of cardiac catheterization might find this approach valuable in the emergency pacing of acute heart block. Subclavian venepuncture does not appear to be as hazardous as has previously been suggested.

Introduction

Transvenous cardiac pacing has been an established procedure in both the emergency and long-term management of chronic heart block for some years (Bluestone *et al.*, 1965; Furman, 1967). More recently evidence has accumulated that emergency pacing can diminish the high mortality associated with complete heart block complicating acute myocardial infarction, particularly now that "on-demand" pacing systems are available (Epstein *et al.*, 1966; Chatterjee *et al.*, 1969; Chamberlain and Leinbach, 1970). Intensive care units for the management of myocardial infarction are being developed in many hospitals remote from specialist cardiac centres, so there is a growing need for a relatively swift and simple technique for introducing pacing catheters into desperately ill patients. We describe here our experience of introducing pacing catheters by a percutaneous supraclavicular route.

Anatomical Considerations.—These are described in detail elsewhere (Davidson *et al.*, 1963; Yoffa, 1965; Romanes, 1967). The subclavian is a large vein (often up to 2 cm. in diameter) which arches anteriorly across the first rib, behind the clavicle, uniting with the internal jugular behind the sternoclavicular joint to form the innominate vein. It is separated from the subclavian artery by the scalenus anterior muscle, and between subclavian vein and skin at the point of venepuncture lies only fascial tissue. As a result of cadaver dissection and subclavian venography we have found that the junction of the subclavian vein with the internal jugular vein is a little lower behind the sternoclavicular joint than is illustrated in most anatomical texts (see Fig.).

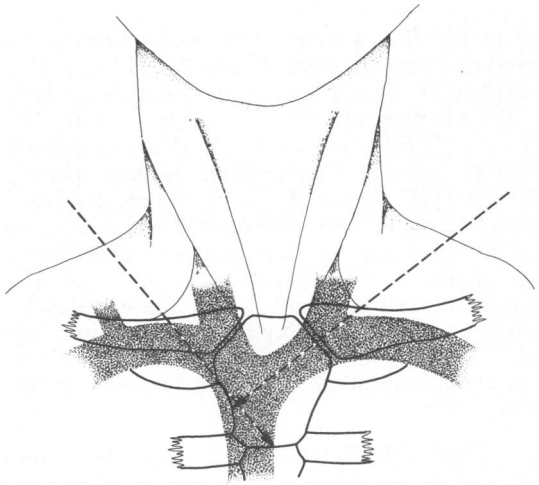
Method

We usually carry out this procedure under conditions of surgical asepsis in the resuscitation room of the coronary intensive care unit. The electrocardiogram (E.C.G.) is monitored on an oscilloscope and the heart screened with a portable image intensifier. A direct current (D.C.) defibrillator is present and ready throughout. An intravenous drip is set up for all patients, and where ventricular arrhythmias threaten lignocaine is run through at a rate of 1 mg./min. Higher doses carry the risk of increasing the heart block and are avoided if possible until pacing is established. Lignocaine 50 mg. is kept ready in a syringe so that it may be injected rapidly if the first contact of the catheter tip with the right ventricular wall provokes an arrhythmia.

Equipment.—A sterile trolley is set up for venous cut-down with the addition of the following special equipment: (1) a No. 18 Seldinger needle, 7·7 cm. long (U.S.C.I. P.N.35, catalogue No. 9135), which is made up of an external cannula, an internal needle with a short sharp bevelled point, and a fitted stylet; (2) a fine stainless steel spring guide wire 80 cm. long with an external diameter of 0·889 mm.; (3) a compound percutaneous catheter introducer (U.S.C.I. 6F, catalogue No. 7536), which is made up of an 8·5 F.G. outer sheath 16·8 cm. long fitting snugly over a 6 F.G. catheter 30·5 cm. long whose tip is tapered down to the size of the guide wire; (4) a 6 F.G. bipolar pacing catheter; (5) an external pacemaker of the R-wave inhibited type, with twin flex and junction box to connect up to the catheter; and (6) a small screwdriver. The operator should check the equipment before venepuncture, ensuring in particular that the guide wire will pass through the outer cannula of the Seldinger needle and through the inner catheter of the introducer, and that the pacing catheter will pass through the outer sheath of the introducer.

Surface Markings.—The patient is laid as flat as possible with the head turned slightly to the left and supported by one pillow. After careful skin cleansing gentian violet on a swab stick serves to mark the mid-point of the sternomanubrial joint, the right sternoclavicular joint, the medial two-thirds of the right clavicle, and the posterior border of the clavicular head of the right sternomastoid muscle (this muscle can be made more prominent in conscious patients by asking them to raise their head against resistance). Sterile towels are then applied.

Venepuncture.—Local anaesthetic is infiltrated into the skin and subcutaneous tissues at the apex of the triangle formed by the clavicle and the clavicular head of the sternomastoid and a small stab incision made there. Blunt dissection with a closed pair of fine artery forceps in the direction of venepuncture at this stage will facilitate the later passage of



Schematic diagram showing surface anatomy of the subclavian, internal jugular, and innominate veins, and the line of approach for subclavian venepuncture.

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the catheter introducer. The intact Seldinger needle, held horizontally for the supine patient, is then advanced through the incision, deep to the clavicle, along a line which passes through the inferior border of the sternoclavicular joint and continues towards the mid-point of the sternomanubrial joint (see Fig.). The subclavian vein, or its junction with the internal jugular vein to form the innominate vein, is entered at a variable depth, and this entry can often be felt. The stylet and inner needle are withdrawn from the cannula; if blood does not drip from the hub the needle should be withdrawn slowly, since the vein may have been transfixed. Free flow of blood can be confirmed in cases of doubt by aspirating with a 20-ml. syringe half filled with heparinized saline. The puncture can be safely repeated if the vein is not entered first time. Once the needle is in the vein a thumb should be held firmly over the hub between manoeuvres as an extra precaution against air embolus.

Passage of Guide Wire.—The guide wire is now passed gently through the cannula and into the vein. These wires have one stiff end and one flexible end, and it is essential to ensure that the soft flexible end leads. Under no circumstances must any force be applied. If the wire will not pass the tip of the cannula, though the operator is satisfied that it is in the vein, changing the cannula angle will often bring success. The wire will normally pass easily down towards the right atrium, and its position should be checked on the screen. It is preferable to leave the tip resting in the superior or inferior vena cava rather than in the atrium itself, as it is then less likely to be inadvertently introduced into the ventricle during the manipulations which follow.

Passage of Catheter Introducer.—The Seldinger cannula is now pulled backwards out of the neck and off the wire, care being taken not to dislodge the wire simultaneously. Some pressure may be necessary over the neck wound at this stage to prevent bleeding. The compound catheter introducer is threaded over the guide wire, the pointed end of the inner catheter leading, the blunt end of the inner catheter just emerging at the hub of the outer sheath, and passed through the neck tissues into the vein. It is, of course, essential that the leading end of the inner catheter should not enter the neck until the guide wire has emerged from its aftercoming end. Firm pressure may be necessary during this procedure, particularly as the outer sheath passes through the neck fascia. The outer sheath should not be inserted for more than two-thirds of its length, as it may otherwise reach as far as the mid-right atrium, and handicap subsequent catheter manipulation. The wire and inner catheter are removed and a thumb is placed firmly over the hub of the outer sheath to arrest the very free flow of blood which otherwise occurs.

Passage of Pacing Catheter.—The pacing catheter is now easily introduced into the right atrium. At this stage it should be connected to the pacing box, for occasionally the first contact of the catheter tip with the right ventricular wall provokes a run of ectopic beats followed by asystole, requiring immediate pacing. The catheter is now manipulated across the tricuspid valve under direct vision. Usually it has to be looped in the atrium, then slowly withdrawn until its tip is seen to flip across the valve and pass to the left side of the spinal column. If the catheter has a suitable curve it may be possible to advance it directly across the valve, and if difficulty arises the manoeuvre may be facilitated by turning the patient on to his left side. The tip of the catheter should be wedged in a stable position as near to the apex of the right ventricle as possible.

Checking Pacing Threshold.—With the voltage control at zero the pacemaker box is switched on in its demand phase. The rate is set at 10-20 beats/minute above the spontaneous heart rate, and the voltage is gradually increased until "capture" occurs. Capture is recognized on the E.C.G. monitor by a change in the ventricular rate and the QRS pattern, and by the presence of a pacing "blip" before each ventricular complex. The voltage is then gradually reduced until capture is lost. This point (not necessarily the same as that at which capture was first achieved) is the threshold, and if this is much above one volt it is likely that the catheter tip is not correctly positioned. In patients with tachycardia alternating with block it may be undesirable to attempt to outpace a fast spontaneous rate. In such cases satisfactory contact of the electrode tip with the ventricular wall can be confirmed either by demonstrating an intracardiac current of injury pattern on an E.C.G. recorded from the wire connected to the tip electrode of the catheter (identified by its longer metal end) or by observing that the indicator needle on the pacing box shows complete suppression of pacing stimuli at rates slower than the spontaneous cardiac activity. Once the threshold has been established the pacing voltage should be set at not more than one volt above threshold level, since higher voltages may increase the risk of ventricular fibrillation should inappropriate stimulation occur.

Securing the Catheter.—The catheter introducer is now withdrawn from the neck, the catheter being observed on the screen simultaneously to ensure that it is not dislodged. The introducer is withdrawn the full length of the catheter but cannot be removed. Pressure is applied over the puncture site, and during this time the stability of the catheter can be checked during deep breathing and coughing. The line of the catheter should present a smooth curve from its entry into the atrium to the tip of the ventricle, as any looping in the atrium applies torque to the catheter tip and may later displace it. The catheter is secured with two skin sutures, one at the incision and the second about 1 cm. laterally. The wound is covered with gauze, the redundant catheter coiled on this and strapped down. The whole is covered with a further piece of gauze and secured with broad elastic strapping. The junction box is then strapped to the upper arm. The patient's head and shoulders are raised as soon as possible after the procedure to reduce venous back pressure, and no attempt is made to immobilize the arm.

Unipolar Pacing Catheters.—This technique has proved equally suitable for the introduction of unipolar catheters. We have used these where permanent transvenous pacing is required, enlarging the neck wound after insertion, anchoring a loop of catheter subcutaneously, and bringing the catheter over the clavicle subcutaneously and out to the axilla for connexion to an implanted box.

Results

Venepuncture and Pacing.—Between June 1968 and April 1970 pacing was attempted by this method 91 times in 85 patients. Many of these were seriously ill and some required external cardiac massage during the procedure. In all cases venepuncture was achieved, and in all except one pacing was successfully established. Indications for pacing and outcome are shown in the Table.

Indications for and Outcome of Pacing

Indication	No.	Deaths in Hospital
Chronic heart block:		
Emergency	20	1
Prophylactic	15	0
Permanent (St. George's catheter)	6	0
Myocardial infarction:		
Complete block	28	15
Intermittent complete or partial block	15	0
Other	3	3
Asystole following cardiac arrest	4	4
Total	91	23

Ventricular Arrhythmias.—Ventricular premature beats occurred frequently as the catheter made first contact with the right ventricular wall. These usually settled quickly either spontaneously or after injection of 50 mg. of lignocaine intravenously. Ventricular tachycardia was produced in three patients. Two responded to lignocaine and one to D.C. shock. Ventricular fibrillation was produced in another three patients and was intractable in one. The other two were rapidly defibrillated, but one died 12 hours later. Both deaths occurred in patients with acute infarcts and complete heart block who were already shocked, and the patient who died during the procedure was unconscious before pacing was attempted.

Pacing Failure.—Pacing failures were usually due to simple electrical faults, such as a loose wire in the junction box, which could be corrected at the bedside. Failure due to displacement of the catheter tip occurred at varying periods after insertion on 14 occasions (15%). It always proved possible to reposition the catheter under fluoroscopic control without removing it. On eight further occasions (9%) the catheter tip perforated the wall of the ventricle. When this happens pacing fails, a pericardial rub may appear, the diaphragm or upper abdominal muscles may be "paced," and an epicardial E.C.G. complex can be recorded from the catheter tip, resembling a transitional complex in the conventional E.C.G. Withdrawal and repositioning of the catheter was never followed by any clinical evidence of tamponade.

Other Complications.—On one occasion the flexible end of a guide wire sheared off. The patient was subsequently paced satisfactorily, but died within 12 hours. He had presented in a state of shock with myocardial infarct and complete heart block. It was not thought that the accident contributed to his death, for the small segment of wire remained in the soft tissue of the neck. On another occasion a right-sided pneumothorax occurred in a patient who had been resuscitated from asystolic cardiac arrest. This patient was deeply unconscious and on intermittent positive-pressure ventilation from the time of his original arrest until death, and it was not certain whether the pacing procedure or the earlier cardiac massage had been responsible for the pneumothorax. On two occasions the Seldinger needle entered an artery, once in a patient who was well anticoagulated, but without any ill effect. Minor infections occasionally occurred at the entry wound, and once it was necessary to remove a catheter for this reason. These infections all responded to antibiotic therapy and there were no cases of septicaemia. No serious neck haematoma developed, though many of the patients with myocardial infarction were on anticoagulants at the time of insertion of the catheter. There were no cases of thrombophlebitis, air embolus, or brachial plexus injury.

Discussion

The technique described here combines the advantages of percutaneous pacing and the supraclavicular approach to the subclavian vein. Pacing can be established remarkably quickly, and the small stab incision in a relatively clean area has kept infection to a minimum. The subclavian vein has proved excellent both for venepuncture and for catheterization; it is large and always patent, and can be used more than once. The landmarks for approaching it can be easily defined, and like Yoffa (1965), who used a left-sided approach, we have had no failure of venepuncture. It has also proved a satisfactory route for transseptal puncture (Epstein, 1970). Catheter manipulation has been simple, this being the shortest and most direct transvenous route to the heart. Inexperienced operators under training have had little difficulty either in venepuncture or in obtaining a satisfactory catheter position in the right ventricle.

Many vital structures are crowded together in the root of the neck, but the experience of both Yoffa (1965) and ourselves suggests that if a fine needle and the correct supraclavicular line of approach are used none of these will be encountered. The subclavian vein is separated from the artery by the anterior scalenus muscle, and the needle is directed away from the pleura into the region immediately behind the sternoclavicular joint, where there are no other vital structures. Two inadvertent arterial punctures occurred early in the series before the landmarks were clearly defined, but the fine gauge of the needle ensured that no serious damage occurred. Possibly the one case of pneumothorax was also due to an incorrect line of approach.

A major advantage of the supraclavicular method is the stability of the catheter, in contrast to the antecubital approach, where stability can be achieved only by strapping the patient's arm to his side (Chatterjee *et al.*, 1969). The catheter can be left in position for several weeks if necessary. The approach has proved particularly useful in shocked and anxious patients where the speed of insertion and ease of manipulation contrast with our previous experience with an antecubital approach. Peripheral venoconstriction causing difficulty with the location of a vein and painful negotiation through the shoulder area are avoided, making the procedure easier for operators inexperienced in cardiac catheter techniques.

A major potential hazard lies in the use of a guide wire, which requires special care. The flexible end must be threaded first and wires should be used only once. The use of guide wire and introducer could be avoided altogether by carrying out the initial venepuncture with a needle and cannula large enough to pass a pacing catheter directly, but we have considered it safer to use a fine needle for this puncture.

We believe that the results justify recommending this technique for use in situations requiring emergency cardiac pacing. Our experience in teaching the procedure to other members of the hospital staff has suggested that it is readily mastered by those with little or no previous experience of cardiac catheterization. Cardiac pacing itself, however, carries hazards, particularly after acute myocardial infarction, as our six cases of serious ventricular arrhythmia show, and it should not be attempted without having fluoroscopic screening, E.C.G. monitoring, and a D.C. defibrillator immediately available.

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