Surgical Aspects of ICD Implantation

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Summary

The use of implantable cardioverter defibrillator (ICD) therapy has dramatically changed the treatment of severe ventricular arrhythmias. Since 1980, ICD insertion has changed greatly. At first, thoracotomy and epicardial placement of defibrillation patches were the standard methods to ensure low defibrillation thresholds. However, morbidity was high and mortality occasionally occurred. Due to these and other risks, researchers sought to develop techniques that averted a transthoracic incision. Technological improvements in leads, electrode tips, and batteries led to the production of smaller ICD generators, and have resulted in simplified implantation techniques. In most cases, ICD implantation can be performed without a thoracotomy through a single infraclavicular incision. This results in fewer complications, reduced costs, and increased patient comfort.

Key Words

ICD, implantation technique, surgical complications

Introduction

In the last two decades, the treatment of severe ventricular arrhythmias has dramatically changed with the use of implantable cardioverter-defibrillator (ICD) therapy. The approach to the insertion of ICDs has changed greatly since the first implantation in 1980 [1]. The earliest implantations were performed through a thoracotomy whereby epicardial placement of defibrillation patches became a standard method to ensure low defibrillation thresholds (DFT). This resulted in an appreciable morbidity and an occasional death.

Because of the discomfort and risks of thoracotomy, researchers were encouraged to renew efforts in developing an ICD implantation technique that averted a transthoracic incision [2,3]. Technological improvements in leads have resulted in electrodes that could be placed transvenously and positioned in the apex of the right ventricle. This leads consisted of a platinium-tipped electrode and two coiled titanium shocking electrodes. Rate sensing occurred between the tipped electrode and the distal shocking electrode, and the path of defibrillation was between the distal and proximal coil electrodes.

In addition, advances in the battery have permitted the production of smaller ICD pulse generators that can be implanted in an infraclavicular position, superficial or deep to the pectoralis major muscle [4]. Pectoral placement avoids long-distance tunneling that requires insertion through the abdominal wall. With the recent single transvenous coil positioned in the right ventricular apex and an active pulse generator inserted beneath the pectoral muscle, satisfactory DFTs may be achieved in over 95% of patients [4,5]. When acceptable DFTs cannot be achieved, an additional electrode can be placed within the left chest wall or a chest wall patch.

As a result of these developments, the technique for ICD implantation has been simplified, and can be performed in most cases without a thoracotomy through a single infraclavicular incision. The benefits of this method with regard to complications, cost, and patient comfort are obvious.

Preoperative Considerations

Equipment and personal requirements

In the early period of ICD implantation (thoracotomy, abdominal wall) the procedure was carried out in the operating room. It is a common experience that access to the operating room is often limited by previously scheduled operations or by an urgent procedure that takes priority. On the other side, the catheterization lab offers a number of benefits for ICD insertion [6,7]. Almost all of the necessary equipment to implant an ICD is already present. One of the strongest arguments for moving ICD implants to the catheterization lab is the marked reduction in hospital costs. Otherwise, lighting and space limitation issues have been raised as a possible drawback. Strickberger and colleagues recently published a prospective comparison of ICDs implanted in the catheterization lab or in the operating room [8]. It was shown that there was no difference regarding rates of successful operations and complications between the two groups. An intracardiac electrogram monitoring system capable of multichannel display with recall, and an X-ray system capable of multiple angle views are advisable in the confirmation of endocardial lead placement. Two external defibrillation systems are critical for safe implantation of ICDs. For patients receiving general anesthesia, a ventilator is also necessary.

The individuals who are involved in ICD surgery should be thoroughly familiar with all of the equipment and with the general laboratory environment. In addition to the surgeon and the electrophysiologist, support staff should include a circulating nurse, a scrub nurse, an anesthesiologist, a nurse trained in administering analgesics, and a technical representative [9].

Choice of anesthesia

The choice of general anesthesia versus conscious sedation needs to be based on a number of factors. Because the surgical procedure is much more limited and requires no tunnelling, implantation as an outpatient procedure without general anesthesia is more reasonable. If the patient has multiple factors, e.g. left ventricle function is poor, multiorgan failure is present, or DFT has been defined, general anesthesia and intubation are a better alternative to conscious sedation. They allow for better airway control minimizing the risk of aspiration. However, if there are few ventricular fibrillation (VF) inductions and a modest surgical procedure is planned, local anesthesia for pocket formation and conscious sedation are reasonable and cost-effective options. This would include midazolam and fentanyl with local 1% lidocaine at the incision site (10). Prior to VF induction, an ultra-short-acting barbiturate is ideal for sedation. However, the dosage is highly variable, therefore, care needs to be taken in its administration. Occasionally, patients may require assisted ventilation while awaiting the metabolism of this compound.

Surgical Technique

Incision and ICD pocket formation

After premedication, the patient is brought into the operative suite where electrocardiographic electrodes are secured outside of the operative field. Adhesive defibrillation patches may be placed on the chest at this time without encroaching on the operative field. Intravenous and arterial lines are inserted, and a prophylactic antibiotic is administered. Generally, implants are performed along the left pectoral region. If this side is anatomically not appropriate, the right pectoral region can be used.

However at this time we cannot clinically recommend this approach [11]. The initial incision is made approximately 2-4 cm below the clavicle, extending from the mid-clavicular region to just above the humeral-pectoral groove. The lateral extent of the incision is designed to allow for cephalic dissection as well as the puncture of the subclavian vein.

A pocket for the ICD device is generally formed prior to the insertion of the transvenous leads. The size of the device and the thickness of the patient's subcutaneous layer will determine whether the pocket is subcutaneous or submuscular. A subcutaneous pocket inferior to the incision is easily made by sharp and blunt dissection along the plane of the pectoral fascia. A submuscular pocket is created by bluntly separating the transverse muscle fibers of the pectoralis major and entering in front of the pectoralis minor. At this deeper level the pocket is created inferior to the incision by using blunt dissection. Care should be taken to avoid tearing the fascia and fibers as this can cause bleeding and pocket hematoma formation. In the course of submuscular pocket formation, the thoracoacromial neurovascular bundle should be identified because damage to this bundle will result in pectoralis atroph. For both pockets, care is taken to develop the pocket in an inferomedial direction avoiding extension laterally to prevent the device from migrating into the axilla. Hemostasis within the pocket should be ensured.

Transvenous lead insertion, ICD testing, pulse generator implantation

Transvenous endocardial and rate-sensing leads are inserted in the same manner as permanent pacemaker leads. Access to the venous system is obtained through the cephalic vein or by puncture of the left subclavian vein. Many implanting surgeons favor the cephalic vein technique because it avoids the risks imposed by needle punctures in the infraclavicular area. Unfortunately, in some patients the cephalic vein cannot be identified or is too small to accommodate a transvenous electrode. In this case and when more than one electrode is required, another form of venous access is necessary. The cephalic vein is identified by using blunt dissection along the fat pad that overlies the humeral-pectoral groove.

If a subclavian puncture is necessary for a second lead, this is performed prior to cephalic vein cannulation, using a modified Seldinger approach. Puncture of the subclavian vein after cephalic vein cannulation carries the risk of lead injury.

Access to the subclavian vein can also be achieved by a blunt subclavian introducer technique. In contrast to commonly descriptions, a more lateral approach avoiding lead entrapment is recommended for subclavian vein puncture [12]. If an additional insertion is anticipated, the retained guide wire can be used in the placement of an additional introducer through which a second lead can be inserted into the subclavian vein. Once the lead has been introduced into the superior vena cava, it is guided into the right ventricular apex by X-ray examination. It typically has a straight stylet in place. It is often worth retracting the stylet several centimeters so that the tip of the lead is flexible and the body of the lead can be advanced through the tricuspid valve into the right ventricle. If the lead is an active fixation type with a small screw at its tip, the screw is advanced into the endocardium.

Once the lead is in place and the appropriate amount of tension is set, the lead should be fixed at the level of the muscular fascia. The leads should be anchored in such a way that a gentle curve exists at the exit site of the vein in order to avoid kinking of the lead and subsequent fracture.

When the position is satisfactory, the electrode configuration is tested. Sensing and pacing thresholds are determined for the endocardial lead. The detected R wave amplitude should be at least 5 mV, the pacing threshold should be less than 1.5 V. If any of these measurements are unsatisfactory, the lead should be repositioned and retested. DFTs can now be determined by a sequence of repeated fibrillation-defibrillation trials at successively decreasing defibrillation energies. For an adequate safety margin, the DFT must be at least 10 J less than the maximum output of the ICD device.

The active housing is positioned either subcutaneously or submuscularly. The position is very important because the housing serves as an active electrode. The housing should lie parallel to the long axis of the body with the midline of the housing approximately in line with the midline of the clavicle. Care must be taken in positioning the lateral margin of the housing. It should be at least 2 cm from the pectoral-humeral groove to avoid mechanical limitation of shoulder motion. The lead should be positioned clockwise along the edge of the housing.

Surgical Complications

The potential morbidity and mortality of ICD surgery has been greatly reduced as a result of new devices and techniques [13]. However, the potential for serious complications of ICD surgery still exists related to the subclavian puncture technique, to the ICD leads, and to the pocket formation. Complications resulting from the subclavian stick technique are: pneumothorax, hemothorax, air embolism, and bleeding. But the incidence of complications are relatively rare in experienced hands. Lead complications were briefly mentioned previously [14]. Lead dislodgement usually occurs soon after the operation and may be due to improper lead positioning, or poor lead fixation. Lead displacement is best avoided by adequate anchoring. The occurrence of lead perforation is minimized by using a gentle technique during lead positioning. Micro-dislocation is the situation in which the endocardial lead appears to be in an anatomically correct position soon after the implantation, but pacing thresholds are unacceptably high, or failure to capture occurs. Sensing may or may not be satisfactory. In this situation, lead repositioning is required and an active fixation electrode should be considered to prevent recurrence of micro-dislocation.

The most serious complications are related to the pulse generator and pocket formation [15]. Erosion of the pulse generator may occur at any time postoperatively and is more frequent with ICDs than with pacemakers. Pocket hematomas occur occasionally whereby elderly patients are particularly susceptible to this complication [16]. Management of pocket hematomas should be conservative, i.e. surgical intervention is required only if the hematoma enlarges dramatically. The hematoma predisposes to seroma formation and secondary infection. Therefore, care should be exercised during the operation to cauterize all bleeding vessels and ensure that the pocket is dry prior to wound closure. Pocket infection is a serious complication, the incidence of which has been variously reported in the literature to be between 1% and 7%. It is not possible to cure by antibiotics alone. Pocket infection should always be assumed to involve the endocardial leads. Endocarditis of the tricuspid valve may be a complication of the lead infection. Therefore a cure may be effected only by removal of the entire ICD system.

Conclusion

With the development of small pulse generators, more than 95% of patients can have a pectoral implant which minimizes the extent of surgery and possibly reduces the long term complication rate of ICD implants. ICDs have revolutionized the therapy for sudden arrhythmic cardiac death and have resulted in improved prognosis and quality of life.

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