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The Subcutaneous Implantable Cardioverter-Defibrillator

Peter Magnusson, Joseph V. Pergolizzi and Jo Ann LeQuang

Abstract

The subcutaneous ICD (S-ICD) represents an important advancement in defibrillation therapy that obviates the need for a transvenous lead, the most frequent complication with transvenous devices. The S-ICD has been shown similarly safe and effective as transvenous ICD therapy, but the two devices are not interchangeable. The S-ICD is only suitable for patients who do not require bradycardia or antitachycardia pacing functionality. In patients with underlying diseases associated with polymorphic ventricular tachycardia and a long life expectancy, an S-ICD may be the preferred choice. Moreover, it is advantageous in the situation of increased risk of endocarditis, i.e., previous device system infection and immunosuppression, including hemodialysis. In patients with abnormal vascular access and/or right-sided heart structural abnormalities, it may be the only option. The S-ICD is bulkier, the battery longevity is shorter, and the device cost is higher, even though remote follow-up is possible. A two- or three-incision implant procedure has been described with a lateral placement of the device and a single subcutaneous lead. The rate of inappropriate therapy for both S-ICD and transvenous systems is similar, but S-ICD inappropriate shocks are more frequently attributable to oversensing, which can often be resolved with sensing adjustments.

Keywords: lead complications, subcutaneous ICD, sudden cardiac death, S-ICD, transvenous ICD, T-wave oversensing

1. Introduction

The subcutaneous implantable cardioverter defibrillator (S-ICD) offers an alternative rescue device for sudden cardiac death in the form of an implantable device that can offer defibrillation therapy without the need for a transvenous lead. Lead failure is the most frequent source of complication requiring surgical revision. Approximately 20% of transvenous leads fail within 10 years and extraction may lead to devastating complications, including death [1–5]. The S-ICD differs from conventional transvenous ICD systems in other important ways: an S-ICD requires no transvenous leads (the most frequent source of device complications) but S-ICDs do not offer bradycardia pacing, antitachycardia pacing, cardiac resynchronization, plus they have limited programmability. Approved in Europe in 2009, the S-ICD system (SQ-RX 1010, Boston Scientific, Natick, Massachusetts, USA) consists of a pulse generator and a tripolar defibrillation lead, both of which are implanted subcutaneously. In terms of size, weight, and footprint, the S-ICD device is larger and heavier than a conventional transvenous ICD (approximately 130 vs. 60 g, respectively).

S-ICDs are indicated for primary and secondary prevention but are seen as particularly useful for primary-prevention patients with a long life expectancy. The selection of an S-ICD system over a transvenous ICD may be based on a variety of factors. Transvenous ICD patients who experience device-related complications, such as lead problems, may be revised to an S-ICD device. In a German multicenter study, 25% of S-ICD patients had a previous transvenous system explanted because of device complications [6].

2. Implant techniques and considerations

The S-ICD system is composed of a tripolar parasternal lead, positioned to the left (about 1–2 cm) and parallel to the sternal midline; this lead plugs into the pulse generator, which is implanted over the fifth to sixth rib and positioned submuscularly between the midaxillarly and anterior axillary lines. The lead has three electrodes, two of which sense only. The defibrillation electrode is positioned between the two sensing electrodes. The sensing vector is created from the sensing electrode to the can, with the device automatically selecting the better electrode for the vector to assure optimal sensing. Device implantation may require minimal (to verify final position) to no fluoroscopy, as much of the technique relies on anatomical landmarks [7]. See **Figure 1**.

A three-incision technique (plus pocket formation) was originally pioneered for S-ICD implantation, and a newer two-incision approach has been described in the literature [8]. The two-incision approach creates an intermuscular pocket for the pulse generator rather than a subcutaneous pocket by incising the inframammary crease at the anterior border of the latissimus dorsi, allowing the generator to fit between the two muscles. Then a small incision at the xiphoid process (in the same direction as pocket incision) allows an electrode insertion device to tunnel the lead in place [8, 9]. In a study of 36 patients, the two-incision approach was found to be safe and effective and it may produce superior cosmetic results compared to the three-incision approach [9]. See **Figure 2**.
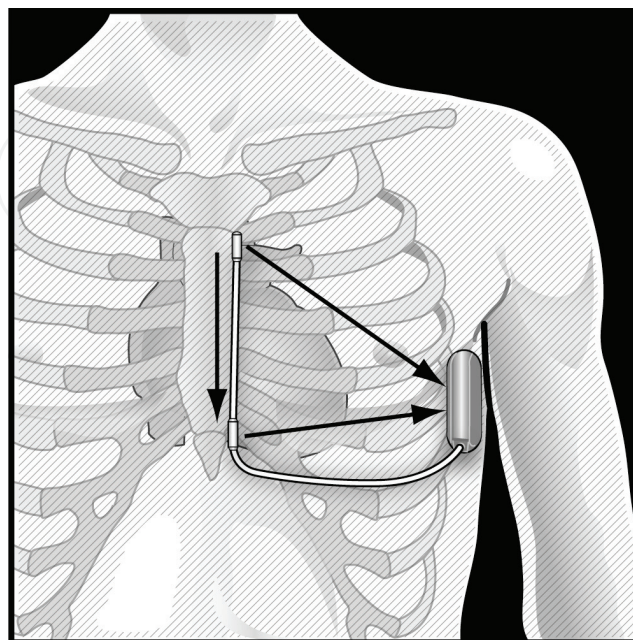

Figure 1.
The S-ICD device is implanted over the fifth to sixth rib and to the side; the parasternal lead senses the subcutaneous ECG and automatically determines which of two sensing vectors to use (top or bottom electrode to can). (Artwork by Todd Cooper, courtesy of Jo Ann LeQuang).

Figure 2.
Lateral view of a patient with an implanted S-ICD. (Courtesy of Dr. Peter Magnusson with permission of patient.).

The time required for device implantation has been recently reported as an average of 68 ± 20 minutes which includes intraoperative defibrillation threshold (DT) testing [10]. DT testing is of decreasing importance with transvenous ICDs but remains a much-discussed topic for S-ICD systems. Guidelines still recommend DT testing during S-ICD implantation, even though it is often used without intra-operative testing based on generalized findings from transvenous systems [11–13]. In a study of 98 S-ICD patients, 25% of patients failed to convert their induced arrhythmia with the first intraoperative 65 joule shock, necessitating further therapy delivery and/or external defibrillation. In this study, 24/25 patients could be successfully defibrillated following either reversal of shocking polarity or lead repo-sition although the desired 10 joules safety margin could not be achieved in 4/24 of these patients [14]. This suggests the importance of perioperative DT testing. However, 100% of patients could be converted from defibrillation with an internal 80 joule shock [14]. In a subsequent study of 110 consecutive S-ICD patients, 50% (n = 55) did not undergo defibrillation testing at implant for any of several reasons (including patient condition, age, and physician preference). In this group, 11% had episodes of sustained ventricular tachycardia (VT) or ventricular fibrillation (VF) necessitating therapy delivery and all of them were effectively converted with the first 80 joule shock [15]. Ventricular tachycardia is a rhythm disorder originating in the heart's lower chambers that has a rate of at least 100 beats per minute; ventricu-lar fibrillation is a much faster, chaotic heart rhythm that causes the heart to quiver rather than pump effectively. Thus, the notion that DT testing at implant is neces-sary for S-ICD patients has been challenged.

S-ICD implantation may be carried out under local anesthesia [16], conscious sedation, or general anesthesia (64.1% of U.S. implants of S-ICD systems [17]. The rate of complications at implant is low and the most commonly reported

complication is infection (1.8%) [18]. By dispensing with the transvenous leads, the S-ICD system avoids periprocedural and complications associated with conventional transvenous defibrillation leads, i.e. pericardial effusion, pneumothorax, accidental arterial puncture, nerve plexus injury, and tricuspid valve damage [19].

3. Safety and efficacy of S-ICDs

S-ICDs appear to have similar rates of infection and other complications as transvenous systems and to be similarly effective in rescuing patients from sudden cardiac death, but there are important distinctions between the two systems.

3.1 Safety

In a retrospective study of 1160 patients who received an implantable defibrillator (either transvenous system or S-ICD) at two centers in the Netherlands, patients were analyzed using propensity matching to yield 140 matched patient pairs. The rates of complications, infection, and inappropriate therapy were statistically similar between groups, but S-ICD patients had significantly fewer lead-related complications than the transvenous group (0.8 vs. 11.5%, p = 0.030) and more non-lead-related complications (9.9 vs. 2.2%, p = 0.047) [20]. The most frequently reported S-ICD complication involved device sensing.(20) Pooled data from the Investigational Device Exemption (IDE) and postmarket registry EFFORTLESS (n = 882) found S-ICD-related complications occurred at a rate of 11.1% at 3 years, but with no lead failures, S-ICD-related endocarditis, or bacteremia [21]. An IDE allows a device that is the subject of a clinical study to be used to collect data about safety and effectiveness that may be later used to submit to the U.S. Food and Drug Administration (FDA). Device-related complications were more frequent with transvenous systems when compared to S-ICD devices in a propensity-matched case–control study of 69 S-ICD and 69 transvenous ICD patients followed for a mean of 31 ± 19 or 32 ± 21 months, respectively. About 29% of transvenous ICD patients experienced a device-related complication compared to 6% of S-ICD patients, reducing the risk of complications for S-ICD patients by 70%; transvenous lead problems were the most frequently reported complication in the former group [22].

In the largest study of S-ICD patients (n = 3717) to date, complications were low at 1.2% overall. The most frequently reported complications were cardiac arrest (0.4%), hematoma (0.3%), death (0.3%), lead dislodgement (0.1%), myocardial infarction (0.1%), and hemothorax (<0.1%) [23]. Device revision during index hospitalization was infrequent (0.1%) [23]. Infections occur at roughly similar rates with S-ICD and transvenous systems but with the important distinction that S-ICD infections may sometimes be resolved with conservative therapy (course of antibiotics with device left in place), whereas most transvenous ICD infections necessitate the extraction of the device and the transvenous leads. In a survey from the U.K. reporting on data from 111 S-ICD patients, 11/111 (10%) of patients experienced infection, of whom 6 could be successfully treated conservatively without device extraction [24]. The EFFORTLESS registry (n = 472) reported a 4% rate of documented or suspected infections and complication-free rates at 30 and 360 days were 97 and 94%, respectively [25].

Once implanted, the S-ICD device delivers a nonprogrammable, high-energy rescue shock (80 joules) to the thorax compared to shocks of 45 joules to the heart administered by conventional transvenous systems. Notably the S-ICD delivers a 65 joule shock during implant testing. Therapy delivery differs markedly between S-ICD and transvenous systems in terms of the amount of energy delivered, location

of shocking vectors, and potential for damage to surrounding tissue or the heart. In a porcine study, the mean time to therapy delivery was significantly longer with an S-ICD than a transvenous system (19 vs. 9 seconds, p = 0.001) but the S-ICD shocks were associated with less elevation of cardiac biomarkers. The longer time to therapy may be advantageous in that device patients often experience short runs of non-sustained VT. On the other hand, S-ICD shocks were associated with more skeletal muscle injuries than transvenous device shocks owing to the energy patterns resulting from the device placement but the clinical relevance of this is likely negligible [26].

3.2 Efficacy

Effective shock therapy is often defined as conversion of an episode of VT/ VF within five shocks, differing from effective first-shock therapy which occurs when the initial shock converts the arrhythmia. In a study of 79 S-ICD patients at a tertiary center, 7.6% of patients experienced at least one appropriate shock for a ventricular tachyarrhythmia during the follow-up period (mean 12.8 ± 13.7 months) [27]. In a multicenter study from Germany (n = 40), shock efficacy was 96.4% [95% confidence interval (CI), 12.8–100%] and first-shock efficacy was 57.9% (95% CI, 35.6–77.4%) [6]. In an effort to analyze S-ICD efficacy in a large group of diverse patients, data from the Investigation Device Exemption (IDE) clinical study and the EFFORTLESS post-market registry were pooled to provide information about 882 patients followed for 651 ± 345 days. About 59 patients experienced therapy delivery for 111 spontaneous VT/VF episodes with first-shock efficacy in 90.1% of events and shock efficacy (termination with five or fewer shocks) in 98.2% of patients [21]. In the EFFORTLESS registry (n = 472), first-shock efficacy in discrete episodes of VT/VF was 88% and shock efficacy within five shocks was 100% [25].

4. Inappropriate shocks with S-ICDs

Inappropriate shock describes therapy delivery to treat an episode which the device inappropriately detects as a ventricular tachyarrhythmia. Inappropriate shocks have been recognized as a significant clinical challenge with transvenous systems as well as S-ICDs. In a tertiary care center study of 79 S-ICD patients, inappropriate shock occurred in 8.9% (n = 7) of patients, attributable to T-wave oversensing, atrial tachyarrhythmia with rapid atrioventricular conduction, exter-nal interference and/or baseline oversensing due to lead movement [27]. T-wave oversensing occurs when the device inappropriately senses ventricular repolar-izations (the T-waves on the electrocardiograph) counting them as ventricular events, leading to double counting of the intrinsic ventricular rate. In a multicenter German study (n = 40) with a median follow-up of 229 days, four patients (10%) experienced 21 arrhythmic episodes resulting in 28 therapy deliveries. Four of these episodes were inappropriately identified by the device as ventricular tachyarrhyth-mias, with the result that two patients received inappropriate shocks. This results in a rate of 10% inappropriately detected ventricular tachycardia and 5% delivery of inappropriate therapy [6]. In a study using pooled data from the IDE and EFFORTLESS post-market registry (n = 882), the three-year rate for inappropriate therapy delivery was 13.1% [21].

It does not appear there are statistically more cases of inappropriate therapy in S-ICD patients compared to transvenous ICD patients. A propensity-matched study (69 patients with a transvenous ICD and 69 with an S-ICD) found the rate of inap-propriate shocks was 9% in the transvenous and 3% in the S-ICD groups but this was not statistically significant (p = 0.49) [22]. In a study of 54 S-ICD patients in a

real-world prospective registry, the one-year rate for inappropriate therapy delivery was 17%, most of whom had single-zone programming [10].

Inappropriate shocks with S-ICDs may be minimized. Most of them are caused by T-wave oversensing. In a survey from the U.K. (n = 111 implanted patients covered), 24 appropriate shocks were delivered in 12% of the patients (n = 13) and 51 inappropriate shocks were delivered in 15% of the patients (n = 17), of which 80% could be traced to T-wave oversensing [24]. In the EFFORTLESS registry (n = 472), there was a 7% rate of inappropriate therapy delivery in 360 days, mainly due to oversensing [25]. The main causes of inappropriate therapy delivery have been reported to be supraventricular tachycardia (SVT) at a rate above the discrimination zone, T-wave oversensing, other types of oversensing (e.g. interference), SVT discrimination errors, and low-amplitude signals [21]. Inappropriate therapy delivery due to T-wave oversensing can often be remedied by adjusting the sensing vector or adding another discrimination zone (dual-zone programming) [10].

Certain patients may be at elevated risk for inappropriate shock. A single-center study of 18 hypertrophic cardiomyopathy (HCM) patients implanted with an S-ICD system and followed for a mean 31.7 ± 15.4 months concluded that HCM patients may be at elevated risk for T-wave oversensing which could lead to inappropriate therapy delivery. In this study, 39% of these HCM patients had T-wave oversensing and 22% of the study population (n = 4) experienced inappropriate therapy delivery [28]. An evaluation of 581 S-ICD patients found that inappropriate shocks caused by oversensing occurred in 8.3% of S-ICD patients and patients with HCM and/or a history of atrial fibrillation were at elevated risk for inappropriate therapy [29]. There is a paucity of data on the use of S-ICD devices in HCM patients, but a small study of 27 HCM patients screened for possible S-ICD therapy found 85% (n = 23) were deemed appropriate candidates and 15 had the device implanted [30]. At implant testing, all patients were successfully defibrillated with a 65 joules shock and most induced arrhythmias were terminated with a 50 joules shock (12/15). After the median follow-up period of 17.5 months (range 3–35 months), there were no appropriate shocks and one inappropriate shock, attributed to oversensing caused when the QRS amplitude was reduced while the patient bent forward. In this particular high-risk patient group of HCM patients without a pacing indication, the S-ICD was effective at detecting and terminating tachyarrhythmias [30].

5. Mortality

The mortality risk with S-ICD implantation is low, but merits scrutiny. On the one hand, S-ICD implantation is generally associated with fewer risks than transvenous ICD implantation in that no transvenous leads are required. On the other hand, patient selection for S-ICD may favor more high-risk patients (such as those with a prior infection, renal failure, comorbid conditions such as diabetes) but also includes many younger and generally fitter patients. Overall, mortality data from S-ICD studies appears favorable. In a pooled analysis combining IDE data and EFFORTLESS registry information, the one-year and two-year mortality rates were 1.6 and 3.2%, respectively [21]. In a study of real-world use of S-ICDs in 54 primary- and secondary-prevention patients, mortality at the mean follow-up duration of 2.6 ± 1.9 years was 11% but no patient died of sudden cardiac arrest [10]. In a six-month study comparing 91 S-ICD and 182 single-chamber transvenous ICD patients, mortality rates were similar although the S-ICD patients had more severe pre-existing illness at implant [31]. It may be that the similar mortality rates between transvenous and S-ICD populations reflects the patient populations rather than the implantation procedure or device characteristics [23].

6. Troubleshooting S-ICDs

The S-ICD device was designed to be a streamlined system with fewer than 10 programmable features (transvenous ICDs have over 100 programmable features) and to perform in a largely automated fashion in terms of device function. The recent introduction of dual-zone programming to S-ICDs added a degree of programmability and reduced inappropriate shock [32]. Arrhythmia detection in the S-ICD relies on a system of template matching, based on waveform morphology of the subcutaneous ECG obtained at implant [33]. Oversensing and sensing-related problems are the most frequently reported problems but are being addressed in terms of device design and programmability. T-wave oversensing occurs when the device incorrectly identifies a T-wave as a QRS complex and counts it as a native ventricular beat, which leads to double-counting the rate. The use of dual-zone device programming has reduced the incidence of inappropriate therapy as a result of double-counting caused by T-wave oversensing [34]. T-wave inversions and QRS complexes that are overly large or very small may be particularly vulnerable to sensing anomalies. Reprogramming the sensing vector or therapy zones may be helpful in such instances [35, 36]. In a propensity-matched study comparing transvenous ICDs to S-ICDs, there were three inappropriate shocks in the S-ICD group, all of which were due to T-wave oversensing in sinus rhythm and all of which could be eliminated with adjustment of the sensing vector [22]. Furthermore, it has been observed with increasing operator experience and better programming techniques, sensing problems have been reduced [21]. In a study using pooled data from the IDE and EFFORTLESS registry, the rate of inappropriate therapy associated with oversensing was <1% [21]. When inappropriate shock occurs, the stored electrograms will likely help identify the cause. If lead malposition is suspected, a chest X-ray may be appropriate. In case of oversensing, the sensing vector may be optimized, device programming may be revised to add a second detection zone, or pharmacological therapy may be added [32].

SVT discrimination likewise relies on template-matching (which is similar to transvenous systems) but the S-ICD may be able to accomplish this with a higher degree of resolution than transvenous ICDs [33]. The use of dual-zone programming appears advantageous.

7. Primary and secondary prevention

Primary- and secondary-prevention patients represent two distinct patient populations who may be treated with S-ICD therapy, although S-ICDs seem particularly well suited for primary-prevention patients. Secondary-prevention patients have a lower rate of comorbid conditions and significantly higher left-ventricular ejection fractions (LVEF) than primary-prevention patients (48 vs. 36%, p < 0.0001), while primary-prevention patients had a higher incidence of heart failure and were more likely to have had a transvenous ICD implanted before the S-ICD. Primary-prevention patients also have a higher rate of ischemic cardiomyopathy (41 vs. 33%) and nonischemic cardiomyopathy (28 vs. 12%) [18]. S-ICDs have been shown to be effective for both primary- and secondary-prevention patients. In a study of 856 S-ICD patients (mean follow-up 644 days), there were no significant differences between primary- and secondary-prevention populations in the rates of effective arrhythmia conversions, inappropriate therapy, mortality or complications although appropriate therapy delivery was delivered to significantly more secondary-prevention than primary prevention patients (11.9 vs. 5.0%, p = 0.0004) [18].

The freedom from any appropriate therapy delivery was 88.4% among primary-prevention patients with an LVEF ≤35 and 96.2% among primary-prevention patients with an LVEF >35%. The freedom from any appropriate therapy delivery among secondary-prevention patients was 92.1% [18]. Spontaneous conversion to sinus rhythm was more frequent among primary-prevention patients (about 48% of all ventricular tachyarrhythmias) compared to secondary-prevention patients (31%) [18]. However, the rates of inappropriate therapy delivery and complications were similar for both primary- and secondary-prevention patients [18].

8. The optimal candidates for S-ICD

S-ICD systems are indicated for patients who require rescue defibrillation but do not need bradycardia pacing support and would not benefit from antitachycardia pacing or cardiac resynchronization therapy. This includes primary- and secondary-prevention patients. By avoiding transvenous leads, the S-ICD is particularly appropriate for patients with occluded veins or limited venous access (who are not suitable candidates for transvenous systems) and the S-ICD may be beneficial for younger, fitter, and active patients. The generator position of the S-ICD patient may make it easier and safer for strong, fit patients to resume active lifestyles without jeopardizing lead position.

Despite the fact that S-ICD devices are larger than transvenous systems, their lateral placement may result in more pleasing esthetic results than a conventional transvenous ICD. Young device patients likely will have a lifetime of device therapy, resulting over time in much hardware in their vasculature; the S-ICD thus presents an advantage in that regard. It appears that S-ICDs are implanted in a younger patient population; a survey of multiple U.K. hospitals (n = 111 patients) found the median patient age was 33 (range 10–87 years) [24]. The mean age of patients in the EFFORTLESS registry was 49 ± 18 years (range 9–88 years) [25]. Younger patients with cardiomyopathy or channelopathy often have a high rate of complications with conventional transvenous ICDs [37] and it has been thought they may be better served with an S-ICD device [9].

In a multicenter case–control study, it was found that 59.4% of S-ICD patients were primary-prevention and the main underlying cardiac conditions were dilated cardio-myopathy (36.2%), ischemic cardiomyopathy (15.9%), and HCM (14.5%) [38]. In particular, these patients have been considered challenging to treat with a conventional transvenous ICD in that they may have an erratic electrical substrate in the heart and increased left-ventricular mass, which could contribute to an elevated DT. First-shock efficacy rates of up to 88% are promising in light of these challenges [25]. In a study of 50 hypertrophic cardiomyopathy patients implanted with S-ICDs, 96% of patients could be induced to an arrhythmia at implant and of the 73 episodes of VF induced, 98% were successfully converted with 65 joules from the S-ICD during DT testing. One patient in this study (2%) required rescue external defibrillation [39]. The patient who failed internal defibrillation had a body mass index of 36 and was successfully converted by an 80 joules shock with reversed polarity from the S-ICD [39].

9. Current guidelines

9.1 Indications

The most recent guidelines to address S-ICD were published by the American Heart Association, the American College of Cardiology, and the Heart Rhythm

Society in 2017 [40]. The An S-ICD is indicated (Class of Recommendation 1, level of evidence B) for patients who meet indication criteria for a transvenous ICD but who have inadequate vascular access or are at high risk of infection and for whom there is no anticipated need for bradycardia or antitachycardia pacing. Further, implantation of an S-ICD is deemed reasonable for patients with an ICD indication for whom there is no anticipated need for bradycardia or antitachycardia pacing (Class of Recommendation IIa, level of evidence B). An S-ICD is contraindicated in a patient who is indicated for bradycardia pacing, antitachycardia pacing for termination of ventricular tachyarrhythmias, and/or cardiac resynchronization therapy (Class of Recommendation III, level of evidence B) [40].

The European Society of Cardiology guidelines from 2015 report that S-ICDs are effective in preventing sudden cardiac death and the device is recommended as an alternative to transvenous ICDs in patients who are indicated for defibrillation but not pacing support, cardiac resynchronization therapy, or antitachycardia pacing (Class IIa, Level C). Moreover, the S-ICD was considered to be a useful alternative for patients in whom venous access was difficult or for patients who had a transvenous system explanted because of an infection or for young patients expected to need long-term ICD therapy [41].

9.2 Pre-implant testing

Those considered for S-ICD therapy should be screened with a modified version of the three-channel surface electrocardiogram (ECG) set up to represent the sensing vectors of the S-ICD. With the patient both standing and supine, the ratio of R-wave to T-wave should be established and signal quality evaluated. If any of the three vectors does not result in satisfactory sensing, the S-ICD should not be implanted. Once the actual device is implanted in the patient, the system automatically selects the optimal sensing vector [11].

9.3 Programming

The S-ICD may be programmed to detect arrhythmias using a single- or dual-zone configuration. In the dual-zone configuration, a lower cutoff rate defines what might be called a "conditional shock zone" to which a discrimination algorithm is applied so that therapy is withheld if the rhythm might be deemed supraventricular in origin or non-arrhythmic oversensing. This discrimination zone relies on a form of template matching. Above that rate, a cutoff establishes the "shock zone" which delivers a shock based on the rate criterion alone. When the capacitors charge in anticipation of shock delivery, a confirmation algorithm assures the persistence of the arrhythmia prior to sending the shock. Shocks are delivered at the nonprogrammable 80 joules of energy [11].

10. Future directions

The evolution of the S-ICD adds an important new device into the armamentarium for rescuing patients from sudden cardiac death. To further improve S-ICD technology, size reduction, increased battery longevity, and improved T-wave rejection will be needed. In the near future, improvement in sensing function might eliminate the need for a separate screening ECG prior to implant, which could optimize clinical workflow.

Improved battery technology is particularly important as the S-ICD is often used in patients with a relatively long life expectancy. Leadless pacemaker systems that

might work together with an S-ICD are in development which would allow for bradycardia pacing support, antitachycardia pacing and a subcutaneous defibrillator without transvenous leads [32]. The development of a leadless epicardial pacemaker might allow for left-atrial and left-ventricular pacing function to be integrated to the S-ICD. Taken altogether, these improvements could make the S-ICD the preferred device in the vast majority of cases for rescue from sudden cardiac death.

11. Conclusion

The subcutaneous implantable cardioverter defibrillator (S-ICD) offers an alternative to transvenous ICDs but the two systems should not be considered interchangeable. The S-ICD is appropriate for patients who require only rescue defibrillation (primary or secondary prevention) but does not offer bradycardia pacing, antitachycardia pacing, overdrive pacing, or cardiac resynchronization therapy. S-ICD devices may be appropriate in patients who have occluded vasculature or device infection with a transvenous system. Effectiveness, rate of infections, and survival rates are similar for both devices although, in general, S-ICDs may be implanted in patients with more serious underlying conditions such as end-stage renal disease or advanced diabetes. Infections with S-ICDs are more likely to be effectively treated with a conservative course of antibiotic therapy and no device extraction. Inappropriate shocks occur at similar rates with both systems but are more likely caused by oversensing in the S-ICD. A main advantage of S-ICDs over transvenous systems is the elimination of the transvenous defibrillation lead which may be considered the Achilles heel of the transvenous system, having a 10-year complication rate of 25%. It is likely that considerable advances in ICD therapy will occur in the next decade as the S-ICD systems are further refined.

Conflict of interest

The authors have no conflicts of interest to declare.

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