REVIEW

THE AMERICAN JOURNAL of MEDICINE®

Advances in Sudden Death Prevention: The Emerging Role of a Fully Subcutaneous Defibrillator

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ABSTRACT

Randomized clinical trials support the use of implantable defibrillators for mortality reduction in specific populations at high risk for sudden cardiac death. Conventional transvenous defibrillator systems are limited by implantation-associated complications, infection, and lead failure, which may lead to delivery of inappropriate shocks and diminish survival. The development of a fully subcutaneous defibrillator may represent a valuable addition to therapies targeted at sudden death prevention. The PubMed database was searched to identify all clinical reports of the subcutaneous defibrillator from 2000 to the present. We reviewed all case series, cohort analyses, and randomized trials evaluating the safety and efficacy of subcutaneous defibrillators. The subcutaneous defibrillator is a feasible development in sudden cardiac death therapy and may be useful particularly to extend defibrillator therapy to patients with complicated anatomy, limited vascular access, and congenital disease. The subcutaneous defibrillator should not be considered in patients with an indication for cardiac pacing or who have ventricular tachycardia responsive to antitachycardia pacing. Further investigation is needed to compare long-term, head-to-head performance of subcutaneous defibrillators and conventional transvenous defibrillator systems.

Published by Elsevier Inc. • The American Journal of Medicine (2014) 127, 188-194

KEYWORDS: Defibrillator; Implantable cardioverter defibrillator; Subcutaneous defibrillator; Sudden cardiac death

Sudden cardiac death is the most common cause of cardiovascular mortality worldwide.[1] Multiple large clinical trials have demonstrated that implantable cardioverter defibrillator systems improve survival in select populations with excess risk of sudden cardiac death.[2-7] However, recent data suggest that implantable cardioverter defibrillator shocks and conventional implantable cardioverter defibrillator programming may adversely affect mortality.[6] Furthermore, the clinical consequences of transvenous lead failure rates are yet to be fully realized and have recently garnered much attention in the public arena.[7-18] These shortcomings led to the development of an entirely subcutaneous implantable cardioverter defibrillator, which received approval from the Food and Drug Administration in September 2012. In this review, we will summarize the available evidence supporting the use of implantable cardioverter defibrillators, and that supporting the emerging role of an entirely subcutaneous implantable cardioverter defibrillator.[19-23]

UTILITY OF TRANSVENOUS IMPLANTABLE CARDIOVERTER DEFIBRILLATOR FOR SUDDEN CARDIAC DEATH PREVENTION

Sudden cardiac death accounts for more than 50% of all cardiovascular deaths, with more than 60% of such deaths occurring out of the hospital.[1,24] Cardiovascular conditions associated with sudden death are numerous but are frequently structural or primary electrophysiologic conditions.[1] Sudden cardiac death is largely driven by malignant arrhythmias, and ventricular fibrillation is the most common underlying mechanism of arrhythmic death. For such patients, survival declines at a rate of 10% per minute.[1] Antiarrhythmic medications to suppress ventricular arrhythmias, although appealing in mechanism, fail to confer a mortality benefit to patients and may even be harmful.[25-27] In contrast, several large clinical trials have demonstrated that defibrillator implantation in select patient populations

Funding: None.

Conflict of Interest: None.

Authorship: All authors had access to the data and played a role in writing this manuscript.

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0002-9343/$ -see front matter Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.amjmed.2013.10.018

with excess risk for sudden death improves mortality when compared with medical therapy alone.[28]

The use of implantable cardioverter defibrillators to prevent sudden death in patients who have undergone cardiac arrest or experienced sustained ventricular tachycardia is supported by 3 large secondary prevention trials.[3,29-31] Subsequent studies demonstrated the clinical benefits of implantable cardioverter defibrillators as a primary prevention strategy in patients post-myocardial infarction with left ventricular dysfunction, as well as in patients with heart failure with both ischemic and nonischemic cardiomyopathy.[2-4,32] Such studies have been transformative in the care of heart failure and patients post-myocardial infarction with compromised ventricular function.

CLINICAL SIGNIFICANCE

- Studies suggest excellent arrhythmia detection, discrimination, and termination of malignant arrhythmias with subcutaneous defibrillators.
- Subcutaneous defibrillators overcome transvenous lead issues and may be considered in patients with infection risk, limited vascular access, and complex anatomy, as well as younger patients requiring lifelong sudden death protection.
- Subcutaneous defibrillators should not be considered in patients with indications for pacing or ventricular tachycardia responsive to antitachycardia pacing.

LIMITATIONS OF TRANSVENOUS DEFIBRILLATOR SYSTEMS

Despite providing life-saving therapy to a wide population of patients, the use of current implantable cardioverter defibrillator systems is at times complicated by the implantation procedure and device malfunction. Such complications include delivery of inappropriate therapy and lead failure over time (Table 1). The absolute incidence of implantable cardioverter defibrillator—related complications is not well characterized because of inconsistent reporting, but studies suggest that freedom from major and minor adverse events at 1 year is 51%.[33] Complications necessitating extraction of the device or leads occur in approximately 2% of cases.[34]

The majority of procedural complications result from the introduction of intracardiac leads. Introducing a greater number or leads, as is required with dual-chamber and biventricular devices, increases perioperative risk.[35] Severe bleeding requiring transfusion occurs in only 2% of patients.[36] Other potentially life-threatening complications, including pneumothorax or cardiac perforation, are rare.[36] Infection rates with implantable cardioverter defibrillators are higher than with other cardiac implantable devices and occur in approximately 2% of patients within 5 years.[37,38] Incision site hematoma formation, number of leads, and device type are associated with infection risk. The need for device revision or replacement also has been correlated to increased rate of infection.[17]

Conventional transvenous leads are prone to failure over time. Lead extraction procedures are complex, have variable success, and can be associated with significant complications, including death.[18,39,40] Implantable cardioverter defibrillator lead survival rates have been reported to vary from 91% to 99% at 2 years, 85% to 98% at 5 years, and 60% to 72% at 8 years[8-10-12,14,41] (Table 1). In one large series of 1317 patients with defibrillators implanted from 1993 to 2004, insulation defects, oversensing, and lead fractures accounted for the majority of lead malfunctions. In the study, lead malfunction led to delivery of inappropriate implantable cardioverter defibrillator therapies in 76% of cases.[9] Recent high-profile cases questioning defibrillator lead integrity have surrounded the St Jude Medical Riata lead (St Jude Medical, Saint Paul, Minn) and the Medtronic Sprint Fidelis lead (Medtronic Inc, Minneapolis, Minn). In 2007, the Medtronic Fidelis lead was suspended from distribution after reporting a 5-year lead fracture rate of as high as 17%.[42] In 2011, the St Jude Medical Riata lead was recalled after an advisory warned physicians of an insulation defect resulting in externalization of an internal conductor. Unfortunately, lead failure is often unrecognized until a patient has

Table 1 Summary of Clinical Studies Describing Rates of Lead Failure and Inappropriate Therapy Over Study Follow-up Periods

Author (Date)	No. of Patients (n)	Mean Follow-up (y)	Lead Survival Rate (% Over Time)	Rate of Inappropriate Shocks with Lead Failure (%)
Eckstein et al[9] (2008)	1317	6.4	97.5% 5-y survival	76%
Kleemann et al[41] (2007)	990	2.6	85% 5-y survival, 60% 8-y survival	33%
Kitamura et al[12] (2006)	241	2.6	98% 2.6-y survival	80%
Ellenbogen et al[10] (2003)	74	5.7	63% 5.7-y survival	29%
Dorwarth et al[8] (2003)	261	4	98% 4-y survival, 62% 8-y survival	61%
Luria et al[14] (2001)	369	1.6	82% 4-y survival	39%