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Who Should Receive a Wearable Defibrillator Vest at Hospital Discharge?

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Abstract

Purpose of Review To discuss the role of wearable cardioverter defibrillator (WCD) vests in preventing sudden cardiac death (SCD) in at-risk populations.

Recent Findings The impact of randomized-controlled trials with implantable cardioverter-defibrillators (ICD) therapy is well established in randomized clinical trials in ischemic cardiomyopathy. Although the benefits are not as clear in non-ischemic cardiomyopathy, meta-analyses show significant mortality benefits from immediate electrical cardioversion strategies. The role of WCDs in at-risk populations in whom ICD therapy is temporarily not indicated is not as well-established. Smaller cohort trials have shown efficacy in patients with newly-diagnosed cardiomyopathy, requiring temporary ICD explantation, and others with less common indications for WCD therapy.

Summary The Vest Prevention of Early Sudden Death Trial was a landmark randomized control study seeking to examine the benefits of WCD therapy in at-risk population, and although the primary endpoint of reducing arrhythmic death was not reached, the structure of the trial and significant differences in total mortality make a compelling case for continued use of WCD therapies in our healthcare systems.

Keywords Wearable cardioverter-defibrillator · Sudden cardiac death · Ventricular arrhythmias · Ischemic heart disease · Implantable cardioverter-defibrillator

Introduction

Sudden cardiac death (SCD) is defined as witnessed death within an hour of symptom onset, or unwitnessed death within 24 h of last being seen alive [1]. In 2015, approximately 566,000 people in the USA experienced out-of-hospital sudden cardiac arrest or inpatient cardiac arrest.. Mortality related to cardiac arrest results in 3.3 million person years of life lost, which is comparable to each of the most common causes of death [2]. Worldwide, the burden of SCD is approximately 4.25 million deaths per year [1].

This paper briefly summarizes evidence for the most widely used prophylactic therapy for SCD reduction, the implantable cardioverter-defibrillator (ICD), and also offers guidance regarding the use of its temporary replacement: the wearable cardioverter-defibrillator vest (WCD).

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Brief History of Implantable Cardioverter-Defibrillators

In their current form, ICDs are generally reliable medical devices that can add years of life when used in those at high risk for arrhythmic mortality. This success is the result of over 6 decades of development, from the initial proof-of-concept studies in dogs in the 1960s and 1970s, to the first ICD implantation in a human by Dr. Michel Mirowski and colleagues at Johns Hopkins in 1980 [3]. The US Food and Drug Administration (FDA) approved ICDs for clinical use in

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1985, and since then, electrical defibrillation using ICDs has become the mainstay of preventative therapy in patients at risk for SCD [4••]. Secondary prevention of SCD using ICDs, especially in the setting of known sustained ventricular arrhythmia, is well-established in both literature and guidelines [4••].

However, ICD use in primary prevention was initially considered controversial in comparison with medical therapy alone as a means to protect from arrhythmia-induced SCD. The Cardiac Arrhythmia Suppression Trial (CAST) as well as European and Canadian post-MI arrhythmia trials (EMIAT and CAMIAT) were pivotal in demonstrating the lack of efficacy of various medical therapies for modifying the risk of SCD, and helped spur interest in subsequent randomized, controlled trials of ICDs versus medical therapies [5•, 6, 7].

Primary Prevention in Ischemic Cardiomyopathy

The CAST study's demonstration of anti-arrhythmic drugs' adverse effects and the emergence of ICD therapy as an effective treatment for ventricular arrhythmia paved the way for the design of more trials evaluating the efficacy of ICDs [5•]. The Multicenter Automatic Defibrillator Implantation Trial (MADIT) compared ICD therapy with antiarrhythmic drug therapy (predominantly amiodarone) in a post-acute coronary syndrome (ACS) population with reduced left ventricular ejection fraction (EF) and inducible ventricular tachycardia/fibrillation (or ventricular arrhythmia [VA]) that was refractory to procainamide therapy. In the 196 MADIT patients, the 2-year risk of death was 13% in the ICD group and 32% in the control group [8]. The Multicenter Unsustained Tachycardia Trial (MUSTT) was a similar, but non-randomized, cohort study that offered implantation to a similar group of post-ACS patients with inducible VA with, EF ≤ 40% and medically refractory inducible VA. MUSTT showed a 58% relative risk reduction in mortality in the ICD cohort during 5 years of follow-up [9]. Together, these data made it clear that VA inducibility was a predictor of SCD in patients with ischemic heart disease and reduced EF, and that ICD implantation improved mortality in this population.

Given the results of early ICD trials, MADIT II was designed to test the hypothesis that ICDs can reduce SCD risk in patients with ischemic cardiomyopathy and EF ≤ 30% who were enrolled at least 1 month after their most recent MI [10•]. In that study, 2-year follow-up showed a modest but statistically significant benefit of 6% absolute mortality risk reduction. Subsequently, the Sudden Cardiac Death in Heart Failure Trial (SCD-HeFT) examined symptomatic heart failure patients with EF ≤ 35% regardless of etiology (ischemic or nonischemic), and used three separate arms: ICD therapy vs. amiodarone vs. control [11]. There was a 2-year absolute mortality benefit of 7% at 5 years in the ICD arm when compared with controls. The amiodarone arm showed no benefit. Several cost-effectiveness analyses have shown the financial benefits of ICD implantation, and combined with the outcomes in the above trials, have led to a Class I recommendations for ICD placement for SCD prevention in patients with stable left ventricular systolic dysfunction (Fig. 1) [4••, 12–17].

Contrary to the positive trials showing benefit to ICD implantation in patients with stable cardiomyopathy, the Defibrillator in Acute Myocardial Infarction Trial (DINAMIT) showed no overall survival benefit from implantation of ICDs in the immediate post-ACS period, despite showing reduced arrhythmic mortality [18]. Several years later, the Immediate Risk Stratification Improves Survival (IRIS) trial also found no mortality difference between ICD and medical therapy in a similar group of immediately post-MI patients with EF < 40% and tachycardia or NSVT [19]. The reasons for this lack of mortality improvement are unclear, but it may be related to complications from ICD implantation itself, morbidity/mortality of ICD shocks, or the reduction in arrhythmic risk related to the high rate of LVEF recovery following revascularization [20, 21].

Primary Prevention in NICM

Nonischemic cardiomyopathy also has been examined with respect to arrhythmic SCD and the protective effects of ICD implantation. Initial trials appeared to find no protective effect from ICD therapies in the NICM population. One of the first of these trials was the Cardiomyopathy Trial (CAT), which was stopped prematurely due to lower-than-expected rates of all-cause mortality in the control group [22] The Amiodarone versus Implantable Defibrillator (AMIOVIRT) trial examined ICD versus amiodarone in patients with asymptomatic non-sustained ventricular tachycardia (NSVT) and EF < 35%, and found no mortality difference between the two groups at 1 and 3 years [23]. The Defibrillators In Non-Ischemic Cardiomyopathy Treatment Evaluation (DEFINITE) study evaluated 458 individuals with EF < 35%, a history of NSVT or frequent premature ventricular contractions, and heart failure symptoms. A 2-year mortality rate of 7.9% was found in the ICD group, which was non-significantly lower than the 14.1% mortality seen with standard therapy ($p = 0.08$) [24]. A subgroup analysis, however, did show significant mortality improvement in individuals with prolonged QT and NYHA class III or higher heart failure symptoms.

A more recent randomized ICD trial, the Defibrillator Implantation in Patients with Nonischemic Systolic Heart failure (DANISH) study, found that in 1016 patients with symptomatic systolic heart failure (EF ≤ 35%) not caused by coronary artery disease, mortality rates at ~ 5 years were not significantly different in the ICD versus non-ICD group (21.6% vs 23.4%) [25].

Recommendations for Primary Prevention of SCD in Patients With Ischemic Heart Disease.		
Class	**Level of Evidence**	**Recommendation**
I	A	In patients with LVEF of 35% or less that is due to ICM who are at least 40 days post-MI and at least 90 days post-revascularization, with NYHA class II or III HF despite GDMT, an ICD is recommended if meaningful survival of >1 year is expected.
I	A	In patients with LVEF of 30% or less that is due to ICM who are at least 40 days post-MI and at least 90 days post-revascularization, with NYHA class I HF despite GDMT, an ICD is recommended if meaningful survival of >1 year is expected.
I	B-R	A transvenous ICD provides high value in the primary prevention of SCD, particularly when the patient's risk of death due to a VA is deemed high and the risk of non-arrhythmic death is deemed low based on the patient's comorbidities and functional status.
Value Statement	B-R	In patients with NSVT due to prior MI, LVEF of 40% or less, and inducible or sustained VT or VF during an EP study, an ICD is recommended if meaningful survival >1 year is expected.
IIa	B-NR	In nonhospitalized patients with NYHA Class IV symptoms who are candidates for cardiac transplantation or an LVAD, an ICD is reasonable if meaningful survival of >1 year is expected.
III: No benefit	C-EO	An ICD is not indicated for patients in NYHA Class IV with medication-refractory HF who are not also candidates for cardiac transplantation, an LVAD, or a CRT defibrillator that incorporates both pacing an defibrillation abilities.

CRT = cardiac resynchronization therapy; GDMT = guideline directed medical therapy; HF = heart failure; ICD = implantable cardioverter/defibrillator; ICM = ischemic cardiomyopathy; LVAD = left ventricular assist device; LVEF = left ventricular ejection fraction; MI = myocardial infarction; NSVT = non-sustained ventricular tachycardia; NYHA = New York Heart Association; SCD = sudden cardiac death; VA = ventricular arrhythmi; VF = ventricular fibrillation; VT = ventricular tachycardia

Fig. 1 Recommendations for primary prevention of SCD in patients with ischemic heart disease [4••]

However, other data do suggest a mortality benefit from ICDs in NICM. Bristow and colleagues evaluated resynchronization therapy (CRT) with or without an ICD, and found a 50% relative risk reduction in the risk of death and hospitalization with ICD compared with CRT alone [26]. In 2004, a meta-analysis of patients with cardiomyopathy (including 2146 individuals with NICM) suggested a 30% reduction in total mortality in those with ICD, even after adjustment for CRT [27]. Furthermore, in the DANISH study referenced above, rates of SCD in the ICD group were significantly lower (4.3% vs. 8.2%, $p = 0.005$), although this came at the expense of increased non-sudden causes of death [25].

Given the mix of outcomes in these studies, recent meta-analyses were performed to elucidate pooled effects of ICD therapy to help guide management in the NICM population. In a 2017 meta-analysis by Golwala and colleagues examining 2970 patients with NICM across 5 studies, ICD use resulted in a 23% risk reduction in all-cause mortality (HR 0.77; 95% CI 0.64–0.91) [28••].

As a result, societal guidelines give a Class I recommendation for ICD implantation for primary prevention of SCD in NICM patients with persistently (> 90 days) reduced ejection fraction despite maximal medical therapy, as long as at least 1 year of survival is anticipated (Fig. 2) [4••].

ICD Indications in Other Disorders

In some cases, scant data are available to guide therapy for patients with rare acquired, congenital, and inherited sudden death conditions. Current recommendations are largely based on registry and small cohort datasets combined with expert opinion. Data regarding hypertrophic cardiomyopathy, myocarditis, arrhythmogenic right ventricular dysplasia, and cardiac sarcoidosis suggest that ICD implantation is favorable for primary prevention if additional risk factors (such as reduced EF, presence of ventricular arrhythmias, or cardiogenic syncope) are present [4••]. For less common conditions, the decision on whether to implant an ICD is deferred to individual clinical decision-making [29, 30].

Wearable Vest Implementation

The wearable cardioverter-defibrillator (WCD) vest is an external cardiac monitoring and defibrillation device that was approved by the FDA in 2002 for use by individuals who are at risk for SCD but who are not candidates for, or who refuse, ICD implantation. The device (seen in Fig. 3) consists of 3 main parts: a wearable fabric frame supporting electrodes for monitoring and therapy delivery (along with conductive gel), the electrodes themselves, and a computational device (monitor) that processes rhythm data and delivers power for defibrillation. The vest comes with an audible alarm that signals impending defibrillation, and includes a patient-triggered switch that can disable energy delivery in cases of false alarms. This switch greatly reduces the incidence of inappropriate shocks.

The WCD was developed to be a rescue device for patients at risk for VA but who may not be able to receive immediate ICD implantation. This population has historically been composed of two main groups: the first comprises patients with recently detected elevated risk of arrhythmic SCD but for whom there may be optimism for clinical improvement (e.g.,

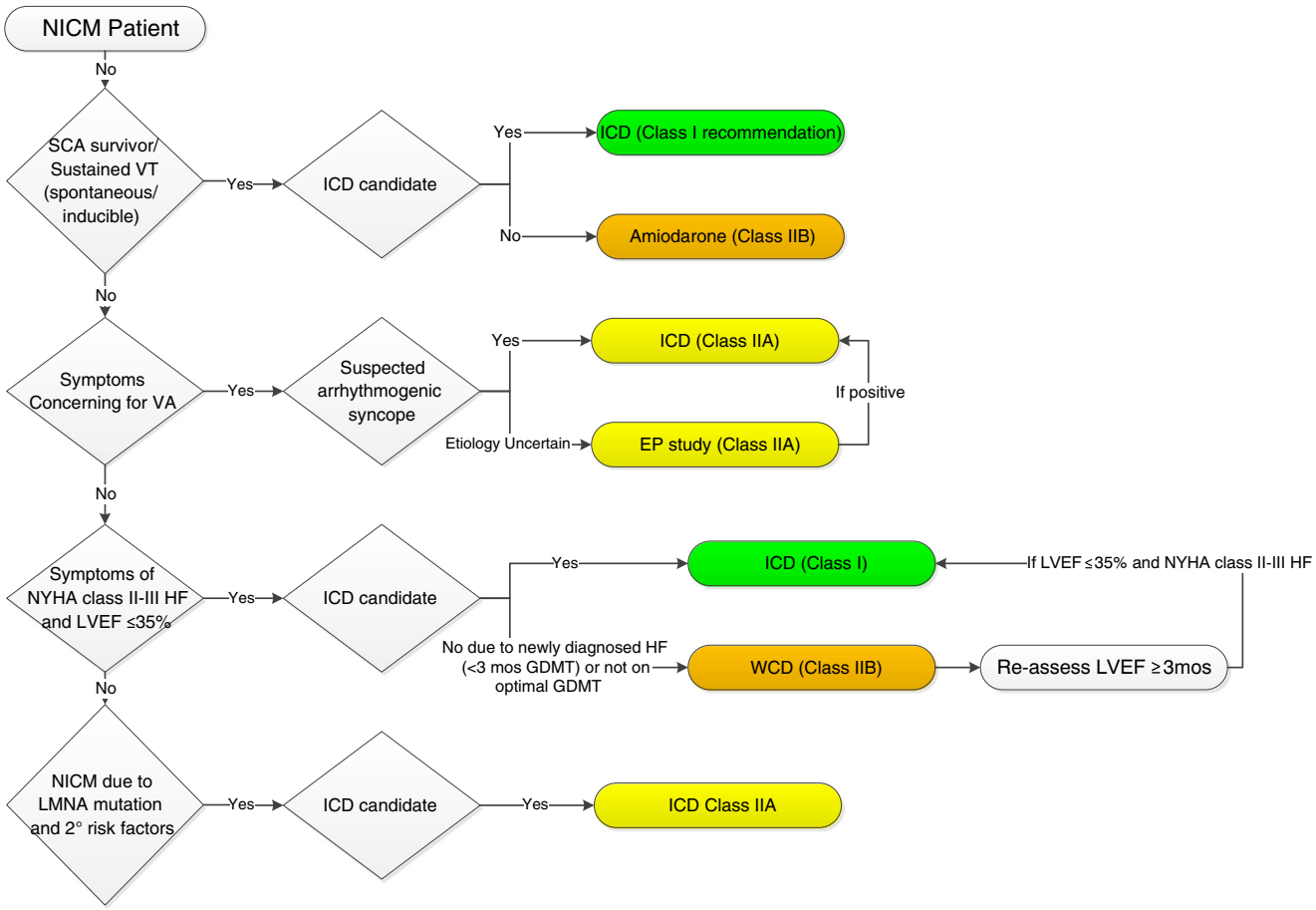

Fig. 2 Recommendations for primary prevention of SCD in patients with NICM [4••]

those undergoing medical management optimization prior to reevaluation for ICD candidacy), and the second group consists of individuals who have an indication for an ICD, but who also have a (perhaps temporary) contraindication to device implantation [31].

Until recently, data regarding effectiveness of the WCD have been available only through registry-based studies and smaller cohort analyses that have lacked mortality comparisons. The Wearable Defibrillator in Terminating Tachyarrhythmias in Patients at High Risk for Sudden Death (WEARIT/BIROAD) studies enrolled patients with NYHA class III-IV heart failure and EF < 30% who were not eligible for ICD (WEARIT), and those who were at high risk for SCD within 120 days of an MI or surgical revascularization (BIROAD) [32]. The efficacy data from these studies resembles subsequent registry data on efficacy of shocks and proportional survival. In various registries with a combined 12,350 patients, the incidence of appropriate shocks was ~ 1–2% and ~ 2% for inappropriate shocks, with an overall post-shock survival of ~ 95% [33–35].

Significant outliers from these statistics included a cohort with peripartum cardiomyopathy and/or NICM, and a cohort of 134 newly diagnosed and/or revascularized cardiomyopathy patients. In both cohorts, patients received a particularly low number of shocks. Saltzburg et al. conducted a retrospective review of women with peripartum and/or NICM who were prescribed a WCD. These women had a mortality rate of 15% that appeared to be unrelated to WCD shocks, especially in light of the very low 0.6% appropriate shock rate [36]. Similarly, Mitrani et al. prospectively studied a mixed group of patients (57:43 newly diagnosed NICM to recently-revascularized ICM) with EF < 35%. Though this study of uninsured patients was limited by high levels of attrition (35% over < 3 months) and relatively low levels of compliance (only 14 h/day wearing the WCD), no shocks or arrhythmias were observed [37]. In contrast, one of the highest reported rates of observed shocks was seen in a group of 119 relatively adherent patients (91% compliance) who had inherited arrhythmia syndromes but did not have an ICD in place (largely due to ICD explantation for infection, or continuing disease workup, or pregnancy). Among these patients, 2% received appropriate shocks over an average of approximately one month's WCD use, while 3% received inappropriate shocks [38].

Fig. 3 LifeVest 4000 (ZOLL) wearable cardioverter defibrillator. (With permission from ZOLL Medical Corporation; https://lifevest.zoll.com/news/imagery)

The available data suggest that WCDs provide life-saving intervention in individuals with heart failure and reduced EF when ICD is temporarily not indicated or contraindicated. This led to the formulation of a Class I recommendation from the International Society for Heart and Lung Transplantation (ISHLT) in support of WCD as a bridge to transplant. Likewise, a science advisory from the American Heart Association lists Class II indications for WCD in patients who qualify for an ICD but who have contraindications for implantation, or as a bridge to more definitive therapy, and/or while potentially reversible underlying risks for SCD are being treated [31].

The VEST Trial

Data from various studies conducted up to decades ago, not all of them examining primarily the outcome of SCD, suggest very high arrhythmic risk in the immediate post-MI period, and thus, high potential for WCD efficacy during that period. Specifically, in the Valsartan in Acute Myocardial Infarction Trial (VALIANT), those with EF ≤ 30% had a 4.4% cumulative incidence of sudden death in the 3 months following MI [39]. A subgroup analysis of the DEFINITE trial showed that patients who received an ICD within 90 days of a diagnosis of ischemic cardiomyopathy had a 48% reduction in SCD when compared with medical therapy alone, though statistical significance was borderline (9.2% vs. 17.7%; $P = 0.058$) [24]. Additionally, although the DINAMIT study found no significant difference in all-cause mortality, there was a lower risk of arrhythmic death (HR 0.42; $P = 0.009$) [18]. These data suggest that in at-risk individuals with reduced EF following MI, there is arrhythmic SCD that may be preventable with cardioversion/defibrillation, but the benefit may be eroded by risks associated with early device implantation.

The Vest Prevention of Early Sudden Death Trial (VEST) was designed to clarify the mortality benefit of WCD therapy when used in immediate post-MI patients with LVEF ≤ 35%. It randomized such patients in a 2:1 ratio to WCD with GDMT, versus GDMT alone [40••]. The VEST primary outcome was initially 60-day death from any cause, but after initial difficulties with enrollment, this was changed to 90-day incidence of SCD and VA-associated death. The trial examined patients hospitalized with an MI and EF ≤ 35% (with or without revascularization), and required enrollment within 7 days of hospital discharge. Exclusion criteria included the presence of a unipolar pacemaker, long-term hemodialysis, significant valvular disease, inability to fit a WCD, and planned discharge to a skilled nursing facility for > 7 days. Patients were followed at 1 and 3 months.

The VEST trial included 2302 randomly assigned patients, with no significant differences in baseline characteristics between the WCD and control groups. Death from any cause occurred in 3.1% of the participants in the device group and in 4.9% of controls (RR 0.64; nominal $p = 0.04$). Among these deaths, arrhythmia-induced mortality occurred in 1.6% of the WCD group, 33% lower than in the control group, though this did not meet statistical significance (RR 0.67; $p = 0.18$). Likewise, non-arrhythmic death was less frequent in the WCD group: 1.4%, compared with 2.2% in the control group (RR 0.63; $p = 0.15$). The appropriate shock rate was comparable with prior WCD studies at 1.3%, and there were very few inappropriate shocks (0.6%) [40••].

One controversy about these findings was associated with changes in the design of the study after its initiation. Due to the slow pace of early enrollment, the primary outcome was changed from all-cause mortality to arrhythmic mortality, and target enrollment was reduced from the originally planned 4506 patients to 2300 patients. Given data from ICD trials, the pre-test probability of achieving statistical significance regarding death from arrhythmia was thought to be higher than the chance of achieving a significant difference in all-cause mortality, due to the increased incidence of non-arrhythmic mortality in ICD groups. However, in the VEST trial, both non-arrhythmic mortality and arrhythmia-associated mortality were numerically lower in the WCD group, but neither of these specific endpoints met statistical significance by themselves. When arrhythmic death and nonarrhythmic death were combined to form the all-cause mortality endpoint, significance was reached.

In addition to finding significantly lower all-cause mortality in the WCD group, the VEST study affirmed the rates of

appropriate shock found in earlier retrospective studies and demonstrated a significant incidence of potentially fatal arrhythmias. Furthermore, the efficacy and safety of the WCD system was demonstrated by the presence of strong trends toward improvement in both arrhythmia-induced and non-arrhythmic mortality subgroups, with an overall low burden (0.6%) of inappropriate shocks.

The VEST trial may have been underpowered, and this may have been further complicated by between-group crossover in the form of suboptimal compliance with VEST use, as illustrated in the VEST manuscript's supplementary materials [40••]. One example of this challenge was the decreasing wear time over the course of the trial, from a mean of 80% at the beginning of the 3 months of follow-up to ~ 50% at the end of follow-up. Additionally, as many as a third of the patients randomized to receive the WCD did not wear the WCD at all, and some patients randomized not to receive the WCD had a WCD prescribed anyway. Despite these limitations, the overall trial showed that the WCD was able to improve outcomes. When optimally used, the WCD may be even more effective for mortality reduction (both arrhythmic and otherwise). The WCD is likely to be particularly effective in patients who are highly adherent to the prescribed treatment. Whether the WCD is cost-effective is another matter entirely, however. This subject is under active investigation.

Although not supportable by available evidence, use of the WCD may be particularly prudent in patients with risk factors for VA or other clinical features that suggest especially high risk. For example, long episodes of non-sustained ventricular tachycardia, or a history of syncope consistent with arrhythmia, may encourage clinicians to consider WCD use more strongly than when these features are not present.

WCD Indications Other than Post-MI

In patients with newly diagnosed NICM, during the 90 day period of GDMT optimization, ejection fraction recovery can take place in 35–40% of patients [41]. In this same group, the rate of VA is lower than in ICM, and varies directly with the amount of cardiac fibrosis [36, 42]. However, in the high-risk sub-group of such patients with detectible LV scar, the WCD may be particularly life-saving during the period of GDMT optimization. No randomized trial data exist to support this concept, however. Similarly, individuals already identified as being at high risk who must undergo ICD explantation (e.g., due to infection) should receive a WCD prior to discharge, and should continue wearing it until another ICD is implanted [31].

Conclusion

Based on the available evidence, current recommendations support WCD therapy for patients who qualify for ICD for either primary or secondary prevention (in the absence of reversible causes) as a bridge to permanent device implantation [4••]. Likewise, these devices can safely serve as an anti-SCD bridge for those in NYHA Class IV HF who are under consideration for advanced HF therapies, such as a left ventricular assist device or cardiac transplant, especially when they have a pre-VAD/pre-transplant estimated survival of greater than 1 year.

Given the non-trivial medical and financial costs associated with ICDs, together with the high chance of recovery from an initial diagnosis of heart failure with reduced EF following medical therapy and/or revascularization, delaying risk stratification before making decisions regarding ICD implantation makes sense. However, this delay results in a thirty-to-ninety day gap in protection from SCD for these individuals who have high risk of fatal VA [39]. The WCD was developed to protect patients during periods in which arrhythmic risk is high and yet permanent ICD implantation is not possible. It is unclear whether such a strategy is cost-effective, however.

Until the release of the VEST trial, the benefit of the WCD was unclear. It remains controversial. VEST validated the safety of WCDs and showed improved all-cause mortality (albeit as a secondary end-point) in patients immediately post-MI with reduced EF, but failed to meet its primary end-point of improvement in arrhythmic death. The WCD may be especially useful in highly motivated, compliant patients. Given the VEST data, it is reasonable to prescribe WCDs in this patient population, either at hospital discharge or on early outpatient follow-up.

In the NICM population, the VA burden has been shown to be lower, and the effectiveness of WCD therapy is still uncertain. However, given the demonstrated safety and efficacy of WCDs, the benefit for any individual who is at high risk of ventricular arrhythmia appears self-evident. Further study would be required to demonstrate efficacy and cost-effectiveness in the NICM population. It is reasonable to consider prescribing the WCD at hospital discharge for newly diagnosed nonischemic cardiomyopathy patients, in order to mitigate risk during the 90-day GDMT optimization period, or in patients with suspected inherited arrhythmia syndromes during the workup period.

Finally, the WCD is a device that must be in place (i.e., worn) in order to deliver the electrical cardioversion it was designed to deliver. Thus, compliance with the therapy is paramount. As the WCD is expected to be particularly effective among patients who wear the device as often as possible, this is a point that medical professionals who prescribe the WCD should stress strongly to their patients.

Compliance with Ethical Standards

Conflict of Interest Sergey Kachur has no disclosures.

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