Experience With the Wearable Cardioverter-Defibrillator in Patients at High Risk for Sudden Cardiac Death

BACKGROUND: This study evaluated the wearable cardioverter-defibrillator (WCD) for use and effectiveness in preventing sudden death caused by ventricular tachyarrhythmia or fibrillation.

METHODS: From April 2010 through October 2013, 6043 German WCD patients (median age, 57 years; male, 78.5%) were recruited from 404 German centers. Deidentified German patient data were used for a retrospective, nonrandomized analysis.

RESULTS: Ninety-four patients (1.6%) were treated by the WCD in response to ventricular tachyarrhythmia/fibrillation. The incidence rate was 8.4 (95% confidence interval, 6.8–10.2) per 100 patient-years. Patients with implantable cardioverter-defibrillator explantation had an incidence rate of 19.3 (95% confidence interval, 12.2–29.0) per 100 patient-years. In contrast, an incidence rate of 8.2 (95% confidence interval, 6.4–10.3) was observed in the remaining cardiac diagnosis groups, including dilated cardiomyopathy, myocarditis, and ischemic and nonischemic cardiomyopathies. Among 120 shocked patients, 112 (93%) survived 24 hours after treatment, whereas asystole was observed in 2 patients (0.03%) with 1 resulting death.

CONCLUSIONS: This large cohort represents the first nationwide evaluation of WCD use in patients outside the US healthcare system and confirms the overall value of the WCD in German treatment pathways.
Clinical Perspective

What Is New?

- The first large, nationwide study outside the United States extends wearable cardioverter-defibrillator (WCD) use to a healthcare system outside the United States in which patient treatment strategies vary such as the extensive use of myocarditis as a prescribing diagnosis in Germany.
- This is the first European analysis supporting the recently published recommendations of the German Cardiology Association and European Society of Cardiology for WCD use.

What Are the Clinical Implications?

- The study is initiating discussion to include using the WCD for patients with temporary high risk of sudden cardiac death and normal left ventricular function such as before establishing a treatment path for genetic sudden cardiac death syndromes and during optimization of antiarrhythmic drug therapy.
- Because implantable cardioverter-defibrillator implantation is frequent in Germany, use of the WCD provides time for patients and physicians to safely seek alternatives to implantation.
- The study confirms the overall value of the WCD in the detection and termination of ventricular tachyarrhythmia/ventricular fibrillation among outpatients independently of patient or bystander intervention.

Previous studies have established the safety and efficacy of the wearable cardioverter-defibrillator (WCD) as a noninvasive alternative for patients who are suspected of being at temporary risk for sudden cardiac death (SCD) caused by ventricular fibrillation (VF) or ventricular tachyarrhythmia (VT). As demonstrated by large landmark trials, patients with ischemic cardiomyopathy (ICM) or nonischemic cardiomyopathy (NICM) and left ventricular ejection fraction (LVEF) ≤35% are at high risk for SCD and benefit from implantable cardioverter-defibrillator (ICD) therapy. In ≥40% of patients, however, LVEF may recover. As a result, ICD implantation is not indicated during the first 40 days after acute myocardial infarction (MI) or <3 months after coronary artery bypass grafting. In contrast, the WCD has been used successfully in patients during the first 40 days after acute MI and during the first 90 days after revascularization. Additional WCD uses fall into other transitional SCD risk categories such as postponed ICD implantation or reimplantation, early after the initial diagnosis of NICM, myocarditis, and during optimization of heart failure medical treatment. Capable of VT/VF detection and termination, the fully automated WCD protects outpatients and enables survival in patients experiencing otherwise fatal arrhythmic events independently of patient or bystander intervention.

Despite extensive use of the WCD, evidence of its effectiveness when prescribed to patients outside the US healthcare system is lacking. To address this concern, the present nonrandomized, observational study investigated WCD use in a large cohort, including the types of cardiac patients currently receiving a WCD prescription, heart rhythm associated with delivery of electric shocks, conversion success, and survival outcome 24 hours after treatment.

METHODS

Informed Consent

All patients signed consent to use their data for research purposes and quality monitoring when they received the WCD. Deidentified German patient data were used for a retrospective, nonrandomized analysis.

Cohort

From April 2010 through October 2013, 6043 German WCD patients from all 16 German states were accrued. All patients were registered into the LifeVest Network, a registry maintained by the manufacturer of the WCD (ZOLL, Pittsburgh, PA). The German national database recorded demographics (eg, sex and age), cardiovascular indication leading to WCD prescription, defibrillation treatments, and daily wear times. Patient demographic data and the cardiac indication for WCD prescription were abstracted from physician medical orders.

Cardiac Indications

Patients were grouped into 8 cardiovascular indications reflecting diagnoses recorded for reimbursement billing purposes in Germany (Table 1), disease origin, and onset of symptoms leading to WCD prescription and wear. Patients were assigned to a single cardiovascular category with the use of the hierarchy and definitions below.

- ICD explantation: ICD explantation patients were those in whom a previously implanted ICD was removed but in whom reimplantation was delayed. The diagnosis leading to the original ICD implantation and the reason for reimplantation delay were unavailable for analysis.
- Congestive heart failure (CHF): Patients with CHF were under long-term heart failure medical therapy (>9 months) with a history of heart failure and otherwise met indications for an ICD but were not implanted because of comorbid conditions.
Heart transplantation: Heart transplantation patients were on the transplant waiting list. The underlying cardiac condition necessitating the transplantation was unavailable for analysis.

ICM: Patients with ICM had coronary artery disease and low LVEF. This group included both patients within 40 days after MI and patients within 90 days after revascularization.

Dilated cardiomyopathy (DCM): Patients with DCM had newly diagnosed heart failure (within 90 days of the start of heart failure therapy) and characteristic chamber enlargement.

NICM: Patients with NICM did not meet the characteristics of ICM or DCM and were <90 days from diagnosis.

Myocarditis: Patients with myocarditis had documented inflammation of the heart muscle, including viral infections, bacterial infections, and giant-cell myocarditis.

Genetic disease: Patients with genetic disease had evidence of familial SCD syndromes such as long- or short-QT syndrome or Brugada syndrome.

Adherence
Patient use data were obtained from the LifeVest Network database. Time of wear for individual days was recorded as seconds. Days of wear was defined as the sum of days in which the WCD was worn for >15 minutes. WCD daily use is reported as the ratio of the sum of hours and the sum of days minus 1. The 1-day adjustment is a correction for partial days available on the first and last days of prescribed wear.

Table 1. Baseline Patient Characteristics and Indication Leading to WCD Prescription

<table>
<thead>
<tr>
<th></th>
<th>Total* (n=6043, 100%)</th>
<th>Male (n=4740, 78.5%)</th>
<th>Female (n=1296, 21.5%)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic, median (IQR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>57 (48–68)</td>
<td>57 (48–68)</td>
<td>56 (44–67)</td>
<td>1.5×10⁻⁶</td>
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<tr>
<td>Primary cardiac indication, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCM</td>
<td>2,220 (36.7)</td>
<td>1681 (35.5)</td>
<td>533 (41.1)</td>
<td>2.0×10⁻⁴</td>
</tr>
<tr>
<td>ICM</td>
<td>1,625 (26.9)</td>
<td>1365 (28.8)</td>
<td>260 (20.1)</td>
<td>4.2×10⁻⁵</td>
</tr>
<tr>
<td>NICM</td>
<td>735 (12.2)</td>
<td>556 (11.7)</td>
<td>179 (13.8)</td>
<td>4.7×10⁻²</td>
</tr>
<tr>
<td>ICD explantation</td>
<td>717 (11.9)</td>
<td>592 (12.5)</td>
<td>124 (9.6)</td>
<td>4.6×10⁻³</td>
</tr>
<tr>
<td>Myocarditis</td>
<td>595 (9.8)</td>
<td>439 (9.3)</td>
<td>156 (12.0)</td>
<td>3.5×10⁻³</td>
</tr>
<tr>
<td>Genetic disease</td>
<td>86 (1.4)</td>
<td>51 (1.1)</td>
<td>35 (2.7)</td>
<td>2.2×10⁻⁵</td>
</tr>
<tr>
<td>HTX</td>
<td>40 (0.7)</td>
<td>33 (0.7)</td>
<td>7 (0.5)</td>
<td>0.67</td>
</tr>
<tr>
<td>CHF</td>
<td>25 (0.4)</td>
<td>23 (0.5)</td>
<td>2 (0.2)</td>
<td>0.16</td>
</tr>
</tbody>
</table>

CHF indicates congestive heart failure; DCM, new diagnosis for dilated cardiomyopathy; HTX, heart transplantation candidate; ICD, implantable cardioverter-defibrillator; ICM, ischemic cardiomyopathy; NICM, nonischemic cardiomyopathy; IQR, interquartile range; and WCD, wearable cardioverter-defibrillator.

*Sex was unavailable for 7 patients, including 6 patients with DCM and 1 ICD explantation patient.

ECG Records
ECG data from WCD-detected events were obtained from the LifeVest Network database as PDF files. Analysis was performed by physicians of the University Dresden Heart Center. The ECGs of all patients, both treated and nontreated recordings, were reviewed and analyzed.

Definitions
Appropriate treatments were defined as biphasic shocks delivered in response to an episode of VT with monomorphic or polymorphic characteristics or VF. Inappropriate treatments were WCD shocks delivered because of signal artifact or supraventricular tachycardia.

Asystole episodes were defined as periods of no discernable cardiac electric activity.

Interpretation of patient treatment data, including the review of ECG records, was performed by the authors.

Post-Treatment Follow-Up
Technical support representatives used by ZOLL investigated all WCD treatments and spoke directly with patients who received a WCD shock or with the physicians caring for those patients. Outcomes were categorized, with survival defined as alive 24 hours after receiving a WCD shock.

Statistical Analysis
Statistical analysis was performed by clinical statisticians from the University of Dresden who used the R statistical computing language.13 Analysis of categorical data was performed with the $\chi^2$ test. The frequency of cases is reported as 100 times the number of appropriately treated patients per total patients wearing the WCD. The mean incidence rate, in units
RESULTS

Patient Characteristics

From April 2010 through October 2013, a total of 6043 patients were prescribed and wore the WCD in Germany (Table 1). Complete case data consisting of age, sex, and cardiac diagnosis leading to WCD prescription were available for 6033 patients (99.8%). Patients were accrued from 404 German centers, with no single location contributing >4% of the patient population. Patients were recruited from each of the 16 German states, with the largest groups of patients residing in the most populous states such as North Rhine-Westphalia (1086, 18.0%) and Bavaria (742, 12.3%). Saarland had the fewest number of patients (26, 0.4%).

Patients were grouped into 8 cardiovascular indications (Table 1). The largest patient group was made up of those with newly diagnosed DCM (37%). ICM accounted for 27% of patients, including 43% who experienced MI within 40 days of WCD prescription, 44% who had received a percutaneous coronary intervention within 3 months, and 13% who had a coronary artery bypass graft within 3 months. In total, 12% of patients wore the WCD after ICD explantation. Patients with NICM accounted for an additional 12%. In 10% of patients, myocarditis was the reason for use. The remaining 2.5% of WCDs were prescribed for genetic disease (1.4%), heart transplantation listing (0.7%), or CHF (0.4%).

The German WCD population consisted of 78.5% male and 21.5% female patients with a median age of 57 years (interquartile range, 48–68 years; Table 1). The frequency distribution for reasons leading to WCD prescription differed between men and women, with the greatest difference occurring within ICM (28.8% of male prescriptions and 20.1% of female prescription). In contrast, female WCD users were more likely to be DCM and myocarditis patients.

Patient WCD Use Data

As summarized in Table 2, the median for the German national cohort was 23.1 hours (interquartile range, 21.0–23.7 hours) of daily use and 59 total days (interquartile range, 33–90 total days) of wear. Patients had similar hours of daily use regardless of sex, age, or reason for WCD prescription.

<table>
<thead>
<tr>
<th>Table 2. WCD Use by Sex, Age, and Reason for Prescription</th>
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<tbody>
<tr>
<td>WCD use</td>
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<tr>
<td>German National Cohort</td>
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<tr>
<td>WCD use by sex</td>
</tr>
<tr>
<td>Male</td>
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<tr>
<td>Female</td>
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<tr>
<td>WCD use by age quartile</td>
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<tr>
<td>≤48 y (quartile 1)</td>
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<tr>
<td>49–57 y (quartile 2)</td>
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<td>58–68 y (quartile 3)</td>
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<tr>
<td>&gt;68 y</td>
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<tr>
<td>WCD use by primary cardiac indication</td>
</tr>
<tr>
<td>DCM</td>
</tr>
<tr>
<td>ICM</td>
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<tr>
<td>NICM</td>
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<tr>
<td>ICD explantation</td>
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<tr>
<td>Myocarditis</td>
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<tr>
<td>Genetic disease</td>
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<tr>
<td>HTX</td>
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<td>CHF</td>
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</tbody>
</table>

Values are medians (interquartile ranges). CHF indicates congestive heart failure; DCM, new diagnosis for dilated cardiomyopathy; HTX, heart transplantation candidate; ICD, implantable cardioverter-defibrillator; ICM, ischemic cardiomyopathy; NICM, nonischemic cardiomyopathy; and WCD, wearable cardioverter-defibrillator.
In contrast, total days of prescribed WCD wear, although similar between the sexes, varied among patients by age (Table 2). For instance, when patients were grouped by age quartile, those patients ≤48 years of age (first age quartile) wore the WCD for a median of 66 days, whereas patients >68 years of age (fourth quartile) wore the WCD for a median of 49 days, a difference of 17 days of wear. Likewise, differences in total days of prescribed wear were observed in patients grouped by indication, in whom days ranged from a median of 40 days for patients with CHF to 73 days for patients with NICM, a difference equivalent to roughly 1 month. In fact, when examined by reason for WCD prescription, days of wear and age were highly correlated. Comparison between median days of wear by WCD indication and age indicated a Pearson correlation of 0.89 for the 6 indications of DCM, ICM, NICM, ICD explantation, myocarditis, and CHF, which combined for 98% of the patient population.

Comparison of patients in the first quartile of daily use (≤21.0 hours) with the upper 3 quartiles revealed younger median age (53 years [interquartile range, 43–61 years] versus 59 years [interquartile range, 49–69]; P<0.001). The median days of wear for patients in the first quartile differed by 12 days compared with the upper 3 quartiles (50 days [interquartile range, 24–83 days] versus 62 days [interquartile range, 37–92 days]; P<0.001). When grouped by primary cardiac indication, DCM occurred more frequently among the lower quartile of daily use, that is, 618 (41%) versus 1585 (35%; P<0.001). On the other hand, ICM and ICD explantation were observed less frequently among the patients in the lower quartile, occurring in 352 (23%) versus 1252 (28%; P<0.001) and 145 (10%) versus 561 (13%; P<0.01), respectively. The remaining indications were unchanged when the lowest and upper 3 quartile groups were compared.

The relationship between total days of wear and median daily use also was evaluated. Patients wearing the WCD for a greater number of days exhibited progressively increasing hours of daily use. For example, there were 179 patients (equivalent to 3% of the patient population) with ≤3 total days of WCD wear, and these patients exhibited a median hourly daily use of 17.6 hours (interquartile range, 12.1–23.4 hours). In contrast, 189 patients (3%) had 4 to 7 days of wear, and these patients exhibited median daily use of 22.1 hours (interquartile range, 16.1–23.6 hours; P<0.01). Among the 5692 patients (94%) wearing the WCD for >7 days, median daily use was 23.2 hours (interquartile range, 21.3–23.7 hours), ≈97% of the hours available in a day.

**Appropriate WCD Treatment**

In total, 120 patients were treated with 163 shocks ranging from 1 to 5 shocks per episode. Ninety-four patients were shocked in response to VT/VF during a cumulative wear time of 1124 patient years, corresponding to an appropriate treatment frequency of 1.6 (95% confidence interval [CI], 1.3–1.9) per 100 patients and incidence rate of 8.4 (95% CI, 6.8–10.2) per 100 years of wear (Table 3). Seventy percent of appropriate treatments occurred within the first 40 days of WCD use, and 89% of all treatments occurred within 90 days of the first day of wear. Appropriate treatments resulted from detection of VT in 62% and VF in 38% of cases. Episodes of VT included 4 instances of monomorphic VT that degenerated into VF after treatment, resulting in additional treatments from the WCD. In total 11% of episodes required >1 shock to terminate. Examination of the remaining ECG records revealed that the device detected 242 episodes of VT occurring in 70 patients during which patients responded by pressing the response buttons. These episodes were self-terminating VT, and as a result of patient interaction, shock treatment was safely withheld.

Evaluation of treated patients by sex illustrated that the appropriate shock incidence rate was 8.5% (95% CI, 6.7–10.7) for men and 7.9 (95% CI, 4.8–12.3) for women (Table 3). Evaluation of treated patients by age or by primary cardiac indication leading to WCD prescription revealed that, except for patients within the fourth quartile of age (>68 years) and ICD explantation patients, patient subgroups were statistically similar with regard to the incidence rate of appropriate treatment. For example, with the χ² test, the number of treated patients in the >68-year age group versus all other patients had a value of P<0.05 and an odds ratio of 1.7 (95% CI, 1.1–2.6). Evaluation of treated patients among the ICD explantation subgroup versus all other patients resulted in a value of P<0.001 and an odds ratio of 2.5 (95% CI, 1.5–4.0).

**Treatment Outcome**

Overall, 88 patients (94%) were converted successfully into a slower heart rhythm such as normal sinus rhythm. Survival 24 hours after shock was achieved by 87 treated patients (93%). Of 6043 patients, there were 7 deaths within 24 hours after defibrillation of treatable arrhythmia, 4 as a result of unresponsive monomorphic VT and 3 caused by VF. There was 1 additional death after sustained asystole. When all patient deaths were examined by sex, there were 7 male patients and 1 female patient. Half of the deaths occurred among ICD explantation patients, with the remaining distributed among the DCM, post-MI, and recent percutaneous coronary intervention groups (Table 4).

**Inappropriate Shock Treatments**

Shock treatment for reasons other than treatable VT/VF arrhythmia occurred in 26 patients (0.4%), an incidence rate of 2.3 (95% CI, 1.5–3.4) per 100 patient-years, and was primarily the combined result of signal artifact, fast
Supraventricular tachycardia, and patient decision not to interrupt the treatment sequence by pressing the WCD response buttons. Supraventricular tachycardia was the reason for inappropriate treatment in 10 instances. Inappropriate detection by the WCD and failure to press the response buttons by the patient occurred in 13 instances of inappropriate treatments, with signal artifact, multicounting on normal ECG signal, and ECG signal loss accounting for 8 instances, 4 instances, and 1 instance, respectively. In 1 case of inappropriate treatment preceded by the device alarm, the patient did not press the response buttons. Additionally, as a consequence of asystole, 2 treatment episodes occurred, presumably resulting from the ECG baseline being interpreted as fine VF, with 1 associated patient death that was attributed to asystole by medical staff with direct knowledge of the case. No deaths were linked to the delivery of inappropriate shocks if asystole was not already present.

### Table 3. WCD Appropriate Treatment by Sex and Reason for Prescription

<table>
<thead>
<tr>
<th>Indication</th>
<th>Treated Patients, n</th>
<th>Population, n</th>
<th>Wear, d</th>
<th>Frequency ×100 (95% CI)</th>
<th>Incidence per 100 Patient-Years (95% CI)</th>
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</thead>
<tbody>
<tr>
<td>WCD treatment</td>
<td></td>
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<tr>
<td>German national cohort</td>
<td>94</td>
<td>6043</td>
<td>410185</td>
<td>1.6 (1.3–1.9)</td>
<td>8.4 (6.8–10.2)</td>
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<tr>
<td>WCD treatment by sex</td>
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<tr>
<td>Male</td>
<td>74</td>
<td>4740</td>
<td>318211</td>
<td>1.6 (1.2–2.0)</td>
<td>8.5 (6.7–10.7)</td>
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<tr>
<td>Female</td>
<td>20</td>
<td>1296</td>
<td>91904</td>
<td>1.5 (0.9–2.4)</td>
<td>7.9 (4.8–12.3)</td>
</tr>
<tr>
<td>WCD use by age quartile</td>
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<tr>
<td>≤48 y (quartile 1)</td>
<td>24</td>
<td>1628</td>
<td>128044</td>
<td>1.5 (0.9–2.2)</td>
<td>6.8 (4.4–10.2)</td>
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<tr>
<td>49–57 y (quartile 2)</td>
<td>19</td>
<td>1486</td>
<td>103107</td>
<td>1.3 (0.8–2.0)</td>
<td>6.7 (4.0–10.5)</td>
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<td>58–68 y (quartile 3)</td>
<td>19</td>
<td>1508</td>
<td>97632</td>
<td>1.3 (0.8–2.0)</td>
<td>7.1 (4.3–11.1)</td>
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<td>&gt;68 y</td>
<td>32</td>
<td>1421</td>
<td>80623</td>
<td>2.3 (1.5–3.2)</td>
<td>14.5 (9.9–20.5)</td>
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<td>WCD treatment by primary cardiac indication</td>
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<tr>
<td>DCM</td>
<td>29</td>
<td>2220</td>
<td>109057</td>
<td>1.3 (0.9–1.9)</td>
<td>9.7 (6.5–13.9)</td>
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<td>ICM</td>
<td>23</td>
<td>1625</td>
<td>99113</td>
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<td>8.5 (5.4–12.7)</td>
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<td>NICM</td>
<td>7</td>
<td>735</td>
<td>55570</td>
<td>1.0 (0.4–2.0)</td>
<td>4.6 (1.8–9.5)</td>
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<td>ICD explantation</td>
<td>23</td>
<td>717</td>
<td>43426</td>
<td>3.2 (2.0–4.8)</td>
<td>19.3 (12.2–29.0)</td>
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<td>Myocarditis</td>
<td>8</td>
<td>595</td>
<td>44508</td>
<td>1.3 (0.6–2.6)</td>
<td>6.6 (2.8–12.9)</td>
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<td>Genetic disease</td>
<td>2</td>
<td>86</td>
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<td>2.3 (0.9–8.1)</td>
<td>14.0 (1.7–50.7)</td>
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<td>HTX</td>
<td>1</td>
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<td>12.7 (0.3–71.0)</td>
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<td>CHF</td>
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<td>25</td>
<td>1467</td>
<td>4.0 (0.1–20.4)</td>
<td>24.9 (0.6–138.6)</td>
</tr>
</tbody>
</table>

CHF indicates congestive heart failure; DCM, new diagnosis for dilated cardiomyopathy; HTX, heart transplantation candidate; ICD, implantable cardioverter-defibrillator; ICM, ischemic cardiomyopathy; NICM, nonischemic cardiomyopathy; and WCD, wearable cardioverter-defibrillator.

### Table 4. Patient Deaths by Indication

<table>
<thead>
<tr>
<th>Primary Cardiac Indication</th>
<th>Total Deaths by Indication, n</th>
<th>Death Caused by VF, n</th>
<th>Death Caused by VT, n</th>
<th>Death Caused by Asystole, n</th>
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</thead>
<tbody>
<tr>
<td>ICD explantation</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
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<tr>
<td>DCM</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>...</td>
</tr>
<tr>
<td>ICM</td>
<td></td>
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<td></td>
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<tr>
<td>After MI</td>
<td>1</td>
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<td>...</td>
<td>...</td>
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<tr>
<td>Recent PCI</td>
<td>1</td>
<td>...</td>
<td>1</td>
<td>...</td>
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<tr>
<td>Totals</td>
<td>8</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

DCM indicates new diagnosis for dilated cardiomyopathy; ICD, implantable cardioverter-defibrillator; ICM, ischemic cardiomyopathy; MI, myocardial infarction; PCI, percutaneous coronary intervention; VF, ventricular fibrillation; and VT, ventricular tachyarrhythmia.
DISCUSSION

The salient findings of the present study confirm the previously published conclusion that the WCD can save lives in vulnerable patients. This study also extends the description of the usefulness of the device to a healthcare system outside the United States where patient treatment strategies vary such as the extensive use of myocarditis as a diagnosis in Germany, and the accrued 6043 patients make up the second largest study cohort to date investigating WCD use among patients at risk for sudden cardiac arrest.

Previously published studies have shown that the WCD successfully identifies and terminates VT/VF. For example, in a study involving 3569 patients, 59 patients (1.7%) were shocked in response to 80 episodes of sustained VT or VF, with first shock success reported in 76 of 76 patients (100%) with unconscious VT/VF and 79 of 80 patients (99%) with any VT or VF. The effectiveness of the WCD was reproduced in a study of 8453 patients in which 133 patients (1.6%) received shock for VT/VF and 91% were resuscitated.

This analysis evaluated German experience with the WCD from 2010 to 2013. The data confirm good compliance of patients with wearing the device. An examination of daily use in the cohort indicated that the majority of patients (97%) wear the device during most activities of daily living. Patients are encouraged to remove the WCD only during bathing, and the overall hours of wear suggest that for the majority of patients this is indeed the case.

A comparison of days of wear with hours of daily use indicated that patients with more days of cumulative wear had increased hours of daily use, and this is consistent with previous evaluations of WCD patients. Of the 97% of German patients who wore the WCD for at least 4 days, the median daily use exceeded 22.1 hours, corresponding to at least 92% of the maximum hours available. Similarly, when days of wear exceeded 1 week, corresponding to 94% of patients, the median daily use reached 23.2 hours (97%), an increase of 1.1 h/d. This result is consistent with that reported for 3569 US patients in whom the median daily use was 21.7 hours. The correlation between days of wear and increasing daily use is suggestive of increased adherence to other therapies for these patients such as medication use, compliance with follow-up appointments, and lifestyle choices.

None of the previous large studies evaluated differences in total days of wear with respect to indication leading to WCD prescription. This analysis presents a difference of ≈1 month, ranging from a median of 40 days for patients with CHF and 48 days for patients with ICD explantation to 73 days for patients with NICM. These differences are arguably the result of variable diagnostic pathways and therapy strategies. For example, although WCD use among ICD explantation patients serves as a bridge to reimplantation and the observed time delay likely reflects the waiting time to reimplantation after ICD device removal owing to infection, the longer days of use recorded from the NICM patient group are likely related to longer time periods encountered before full evaluation of the patient’s chances for recovery.

In the national cohort overall, 1.6% of patients received shock treatment for VT/VF, which is comparable to the 1.7% and 1.6% reported by other investigations. Sudden cardiac arrest occurred among patients with different types of cardiomyopathy, suggesting that all patient groups benefit from the WCD.

Of the 94 patients who received treatment for VT/VF, 88 (94%) successfully converted into a slower heart rhythm. The rates of conversion and acute survival were similar to those reported in previous WCD patient studies. Of treated patients, 89% required 1 treatment shock by the WCD to terminate VT/VF, so shock efficacy among this cohort is similar to that reported in ICD studies (up to 80%–90%) and previous WCD studies (75%–99%). In contrast to large ICD trials, the examination of patients by sex revealed similar appropriate shock rates for men and women. However, 8 deaths occurred during the study. Analysis of these patients failed to indicate a correlation between death and patient subgroup characteristics.

ICD trials have reported that reductions in shock treatment correlate with reductions in all-cause mortality. The German cohort analysis uncovered 242 sustained but self-terminated episodes of VT among WCD patients that were not treated safely because conscious patients held the response buttons. Some of the self-terminated VT episodes were >8 minutes in duration without loss of consciousness by the WCD user.

The 3.6-fold difference in appropriate and inappropriate shocks exceeded that reported in previously published WCD studies. In the German cohort, 26 patients (0.4%) were shocked inappropriately, whereas in previous studies, 1.9% and 1.2% of patients were reported as having received inappropriate shocks.

By presenting data obtained from patients recruited from 404 different cardiology centers located throughout Germany, this study suggests that the recruited patients represent the German national experience. Furthermore, this study demonstrates that the usefulness of the WCD in clinical practice extends to a variety of cardiovascular indications and that guideline recommendations for WCD use should be expanded.

Limitations

The definitions and hierarchy used to assign patients to a single cardiac diagnosis likely resulted in overlap among disease types. Inherent to the study design of a retrospective, nonrandomized, observational analysis is
the possibility of selection bias. Follow-up data on death beyond 24 hours after treatment were lacking, as were data on cardiac comorbidities and LVEF, precluding analysis of these factors. During the patient accrual period, there were no guidelines in Germany to identify patients who might best benefit from WCD prescription instead of immediate ICD implantation. In fact, the WCD has been prescribed for a wide range of patients in whom the physician determined an elevated risk of SCD. Therefore, prescribing physicians may have influenced patient selection in ways undeterminable with the data available.

Conclusions
The German Cardiology Association and the European Society of Cardiology have recently published recommendations for use of the WCD. In agreement with the experience gained from the German national cohort that the WCD can save lives in vulnerable patients, WCD use was recommended for patients with poor left ventricular function who are at risk of SCD but are not candidates for ICD therapy. WCD use was given a Class Ila-C recommendation for use directly after an ICD explantation when reimplantation of an ICD is not possible, as a bridge to transplantation for patients on the waiting list for cardiac transplantation without an ICD, and for use during the acute phase of myocarditis until full recovery or ICD implantation. WCD use was given a Class IIb-C recommendation for continued use among myocarditis patients expected to achieve improved left ventricular function and for individual selection of patients early after revascularization by percutaneous coronary intervention or coronary artery bypass graft, recent acute MI patients, and patients with DCM and NICM when there is an expectation of improvement in LVEF. In the German national cohort, non–ICD explantation patients made up 85% of WCD use, and they experienced sudden cardiac arrest at rates equivalent to those in the United States. These sudden cardiac arrest rates were both nontrivial and comparable among the diagnostic groups. Moreover, it is unclear how to predict reliably which patients will see improvement in their LVEF. The German national experience with the WCD supports the German Cardiology Association and the European Society of Cardiology recommendations for use in patients who are at high risk of SCD.

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FOOTNOTES
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Experience With the Wearable Cardioverter-Defibrillator in Patients at High Risk for Sudden Cardiac Death
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Welcome to "Circulation on the Run", your weekly podcast summary and backstage pass to the journal and its editors. I'm Doctor Carolyn Lam, Associate Editor from the National Heart Center and Duke National University of Singapore. In just a moment, we will be discussing the very topical subject of wearable cardioverter defibrillators in patients at high risk of sudden cardiac death. Yes, this is the topic of our feature paper which really builds on prior US data using these devices and extends it, now, to a healthcare system outside the United States. First, here's the summary of this week's journal.

The first paper describes a novel class of mediators that may revolutionize the nonsurgical treatment of limb ischemia. This paper from first author Doctor Jung from University of Louisville School of Medicine and corresponding author Doctor Spite from Harvard Institute of Medicine and colleagues looked at resolvents. Resolvents are a family of lipid mediators synthesized from Omega-3 polyunsaturated fatty acids that promote the resolution of inflammation and have been shown to regulate the transition from inflammation to repair. Now, this is very relevant to limb ischemia because most other mediators that promote revascularization also exacerbate inflammation, thus potentially limiting their therapeutic use in chronic inflammatory diseases such as diabetes.

To assess the role of resolvents in revascularization and resolution of inflammation, the authors using a Murine model of hindlimb ischemia coupled with Laser Doppler perfusion imaging, micro-computed tomography and targeted mass spectrometry. They identified that resolvent D2 is produced in the skeletal muscles of their Murine model of limb ischemia as well as in skeletal muscle biopsies of patients with peripheral artery disease. They showed that resolvent D2 increases tissue perfusion by promoting arterial genesis that is collateral artery growth and, importantly, that it rescues defective revascularization in diabetic mice. These findings are important because they could inform the development of novel strategies for the clinical management of limb ischemia.

The next paper addresses food fortification with folic acid, which we all know prevents neural tube defects but may now even prevent congenital heart defects. This paper is from Doctor [Mule 00:02:53] and colleagues from The Center for Chronic Disease Prevention, Public Health Agency of Canada who studied approximately six million Canadian births from 1990 to 2011 and compared the prevalence rates and temporal trends in congenital heart disease sub-types before and after 1998 when folic acid fortification was mandated in Canada. They quantified the effects of folic acid fortification on the birth prevalence of specific non-chromosomal congenital heart disease sub-types, after controlling for concomitant changes in maternal age, pre-pregnancy diabetes, preterm pre-eclampsia, multiple birth and pregnancy termination. They found that there was an eleven percent reduction in non-chromosomal congenital heart defects following folic acid fortification. Specifically, folic acid fortification was associated with a twenty-seven percent reduction in conotruncal defects, a twenty-three percent reduction in coarctation of the aorta, a fifteen percent reduction in ventricular septal defects and an eighteen percent reduction in atrial septal defects. This large ecological study, therefore, provides
evidence of a modest protective effect of folic acid fortification on congenital heart defects.

The last study suggests that in patients with ischemic cardiomyopathy and right ventricular systolic dysfunction, we should perhaps be taking a look at the mitral valve. This is work from first author Doctor Seib from the Beth Israel Deaconess Hospital and Harvard Medical School, corresponding author Doctor Kwon from the Heart and Vascular Institute of Cleveland Clinic Foundation and colleagues, who looked at over five hundred and fifty patients with ischemic cardiomyopathy, all of whom underwent cardiac MRI. They found that mitral regurgitation, as measured by effective orifice area, was a significant independent predictor of right ventricular ejection fraction. They further found that the relationship between right ventricular ejection fraction and mortality may be affected by mitral valve surgery in that a reduction in right ventricular ejection fraction was associated with increased mortality in non-repaired patients but not in patients who had undergone mitral valve repair.

The clinical take-home messages are that right ventricular function should be carefully assessed in patients with ischemic cardiomyopathy and if systolic dysfunction is found, patients should be assessed carefully for significant mitral regurgitation as well as other known risk factors such as right bundle branch block, right ventricular scar or a decreased left ventricular ejection fraction. The study suggests that mitral valve surgery may mitigate the relationship between right ventricular rejection fraction and mortality, however further studies are clearly needed.

Those were the summaries. Now, for our feature paper discussion.

I am thrilled to be joined by three guests today to discuss the feature paper on wearable cardio defibrillators in patients at high risk of sudden cardiac death. This is a real world experience all the way from Germany. Joining us today we have two authors of the paper, the first and corresponding author Doctor Nadine Visnic as well as author Doctor Ruth Strasser, both from the University of Dresden and Heart Center Dresden in Germany. Welcome, ladies.

Ruth: Hello, how are you?

Carolyn: Very good, thank you.

We have Doctor Mark Link, Associate Editor from UT Southwestern. Thank you for joining us, Mark.

Mark: You're very welcome.

Carolyn: Mark, let's start with a behind the scenes look. We have data from the United States describing the wearable cardio defibrillator. We have ample data on the implantable
cardio defibrillators. What made the editorial board decide that this particular paper from Germany was so important?

Mark: There are a number of aspects that we looked at for this paper. This is exciting new technology that is beginning to impact the daily lives of all the physicians in the states, the wearable defibrillator. This is a very nice prospective study from Germany that looked at a very large group of patients with this wearable defibrillator, gave us real world experience and it also fits in with the circulation mission of becoming a world wide cardiac journal, not just United States journal. We were very interested in the topic. We're very interested in the international collaboration and we're very excited to publish this paper.

Carolyn: I love that. Practicing in a non US system, as well, I found this particularly special about this paper.

Nadine, we're all wondering, could you describe the patient population, just so we know the kind of patients that your results are applicable to.

Nadine: The patients included in the register were regular patients we meet in clinic in every day life. No specific selection was made. For legal reason, of course, to analyze the data, they signed informed consent for the register. From April 2010 through October 2013, in total six thousand forty-three patients were using the wearable cardioverter defibrillator in Germany. All of these patients were registered into the life vest network, the registry to record demographic such as gender and age. Also, the cardiovascular indications and defibrillation treatments and daily wear time. The German population consisted of seventy-eight male and twenty-two female patients with median age of fifty-seven years.

Carolyn: Great. What were the indications for the wearable defibrillators?

Nadine: Most of the patients had to reduce the ejection faction by below thirty-five percent or even had experienced ventricular tachycardia as an indication. The largest group we had in our analysis was thirty-seven percent where those with newly diagnosed dilatative cardiomyopathy and ischemic cardiomyopathy accounted for twenty-seven of patients, especially forty days after myocardial infarction or after a high risk PCI or cabbage. Also, in total, we had twelve percent of patients that had an ICD explantation mostly due to infection situation. What is very special on that paper is that ten percent of all our patients had myocardidas as a diagnosis and was reason to use the WCD.

Carolyn: Wow. That does sound very representative of the real world patients that we would put wearable defibrillators on, as well.

Ruth, could you tell us, what were the main results? Were there any differences by sub-groups?
Ruth: Perhaps, we should first go on the compliance because this is very important to the daily wear time. This was more than twenty-two hours in ninety-four percent of the patients. Many patients who complained about the inconvenience but understanding that this life vest is a potentially life saving and only temporary treatment strategy made it acceptable to ninety-eight percent of the patients. As to the [inaudible 10:52] there is a difference, the younger patients, patients younger than forty-eight years of age or younger, they wear the life vest longer, sixty-six days. While the older patients, older than sixty-eight patients, this was statistically significant, wore it only forty-nine days. This difference was not used to compliance, because you do the description based on the cardiac diagnosis.

We also observed that the longer the cumulative wear of the life vest was, the longer day hours the patient had the life vest on. They were somewhat accustomed to it. One thing which is very, very important is, that in more than twenty-five percent of the patients, we could save the implantation of a permanent ICD due to the recovery of the ejection fraction. This was especially important for those patients who had the life vest, for example after myocardias or after myocardial infarction, which is a very large population.

Also, which is important is that [full 12:06] shock treatment for reasons other then VT occurred only in point four percent, of less than one percent. Whereas those patients were successfully treated, this was one point six percent. They were treated in response to VT and VF. This means the incidence rate was eight point four per hundred patient years. This was even higher in those patients who had the life vest for the explantation. The life vest is very effective. It's a very effective strategy for general patient population with above indications. It can save the implantation, as I said already, in more than twenty-five percent in the population in Dresden itself. We could observe even a reduction of the need of implantation of permanent ICD more than thirty-five percent due to the recovery of the ejection. This is a very important treatment, especially for those patients who have an acute illness.

The German cohort is the first large cohort outside the US healthcare system. It confirms the overall value of the life vest and treatment pathways in Germany. Also, the cohorts analysis uncovered over two hundred forty-two sustained but self-terminated episodes of VT among seventy life vest patients, so that you have safely not treated because they were still conscious and could still press the response button. We found out that some of the self terminated VT episodes were even longer than eight minutes in duration time. All in all, we could see that the life vest is a device which is safe and which can prohibit shocks, as well.

Carolyn: Thanks, Nadine. [Ruth 14:12]

Mark, though, for the readers, I'm sure we need to put in perspective, as well, because there are still patients where perhaps an implantable cardio defibrillator is still more important. Could you share some thoughts about that?

Mark: Yeah. I think this is a very interesting, important study, for a number of regards.
One, is that there was a very high rate of compliance with using the life vest. To leave it on for twenty-three hours a day, for a mean of sixty days, is really quite impressive patient compliance. The data showed that it did recognize and treat VF in a small percentage, but in an important percentage, of people. This data does need to be put in perspective and the randomized trial is currently ongoing. The vest trial, which will randomize people, probably similar population to what the German study did, and look at the life vest performs in that population.

We look forward to further data from the vest trial and from other trials, that are looking at what the place of the wearable defibrillator will be in the future.

Carolyn: Thank you, Mark and that's perfect take home message for all us out there.

Thank you, once again, Nadine, Ruth, Mark. It has been wonderful chatting with you.

To all of you out there, you've been listening to Circulation on the Run.

Thank you for joining to us.