Implantable Cardioverter-Defibrillators Have Reduced the Incidence of Resuscitation for Out-of-Hospital Cardiac Arrest Caused by Lethal Arrhythmias

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Background**—**Over the last decades, a gradual decrease in ventricular fibrillation (VF) as initial recorded rhythm during resuscitation for out-of-hospital cardiac arrest (OHCA) has been noted. We sought to establish the contribution of implantable cardioverter-defibrillator (ICD) therapy to this decline.

Methods and Results**—**Using a prospective database of all OHCA resuscitation in the province North Holland in the Netherlands (Amsterdam Resuscitation Studies [ARREST]), we collected data on all patients in whom resuscitation for OHCA was attempted in 2005–2008. VF OHCA incidence (per 100 000 inhabitants per year) was compared with VF OHCA incidence data during 1995–1997, collected in a similar way. We also collected ICD interrogations of all ICD patients from North Holland and identified all appropriate ICD shocks in 2005–2008; we calculated the number of prevented VF OHCA episodes, considering that only part of the appropriate shocks would result in avoided resuscitation. VF OHCA incidence decreased from 21.1/100 000 in 1995–1997 to 17.4/100 000 in 2005–2008 ($P<0.001$). Non-VF OHCA increased from 12.2/100 000 to 19.4/100 000 ($P<0.001$). VF as presenting rhythm declined from 63% to 47%. In 2005–2008, 1972 ICD patients received 977 shocks. Of these shocks, 339 were caused by a life-threatening arrhythmia. We estimate that these 339 shocks have prevented 81 (minimum, 39; maximum, 152) cases of VF OHCA, corresponding with 33% (minimum, 16%; maximum, 63%) of the observed decline in VF OHCA incidence.

Conclusions**—**The incidence of VF OHCA decreased over the last 10 years in North Holland. ICD therapy explained a decrease of 1.2/100 000 inhabitants per year, corresponding with 33% of the observed decline in VF OHCA. **(*Circulation*. 2012;126: 815-821.)**

Key Words: cardiopulmonary resuscitation ■ heart arrest ■ implantable cardioverter-defibrillator ■ incidence ■ ventricular fibrillation

Multiple studies from Europe and the United States noted a gradual decrease in the incidence of ventricular fibrillation (VF) during resuscitation for out-of-hospital cardiac arrest (OHCA) over the last decades. These studies showed that the proportion of OHCA with VF as initial rhythm during a resuscitation attempt (VF OHCA) declined on average from 54% to 38% over a 15-year period.[1–5] There is no clear 1-dimensional explanation for this widely observed decline in VF incidence. The introduction of the implantable cardioverter-defibrillator (ICD) has been linked to the decline in VF OHCA incidence.[1]

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The purpose of this investigation was to confirm whether the incidence of VF OHCA in the Netherlands has declined over the years and to calculate the extent to which this decline could be explained by ICD usage. We used a prospective database of all resuscitation efforts in the province of North Holland in the Netherlands. This Amsterdam Resuscitation Studies (ARREST) registry covers the period 1995–1997 and from 2005 onward.

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Importantly, although the first ICD implantation in the Netherlands was performed in 1984, ICD implantation remained rare until 1997.[6] Only after large randomized controlled trials, first published in 1997, demonstrated the efficacy of ICD usage did ICD implantations become common.[7–9] This allowed us to study changes in VF OHCA incidence between both periods and the extent to which these changes were associated with ICD usage.

Methods

We compared the incidence of VF OHCA in 2005–2008 with the VF OHCA incidence in 1995–1997 (VF OHCA incidence*).* Additionally, we calculated the number of prevented VF OHCA by ICD shocks in 2005–2008 (ICD therapy) and compared this with the observed decrease in VF OHCA incidence, assuming that ICD implantation was hardly performed before 1997 and that no VF OHCA was avoided by ICD shocks in the period 1995–1997. The Medical Ethics Review Board of the Academic Medical Center, Amsterdam, approved the study and gave a waiver for the requirement of (written) informed consent.

VF OHCA Incidence

The ARREST research group maintains a prospective database of all resuscitation efforts in North Holland, a province of the Netherlands, which includes Greater Amsterdam. This province has a population of ≈2.4 million people and covers 2671 km^2, including both urban and rural communities. The organization of the emergency medical services (EMS) and data collection in the study region has been described previously.[10] Only OHCA cases from presumed cardiac causes that were not witnessed by paramedics were included in this analysis. OHCA was defined as cardiac if the EMS rescuers or the physicians at the hospital could not identify an unequivocal noncardiac condition for OHCA.

Data were collected according to the Utstein recommendations.[11] Between July 4, 2005, and May 1, 2008, we prospectively collected data on all patients in whom EMS personnel attempted resuscitation during an OHCA. After each resuscitation attempt, ambulance personnel routinely sent the continuous ECG recording from their manual defibrillators to the study center by modem. These data were stored and analyzed with dedicated software (Code Stat Reviewer 7.0, Physio Control, Redmond, WA). Paramedics reported whether an automated external defibrillator (AED) had been used before ambulance arrival. Study personnel visited the site of the AED shortly after the cardiac arrest and collected the ECG recording from the AED. The initial rhythm retrieved from the AED or manual defibrillator was categorized as VF (including pulseless ventricular tachycardia) or non-VF (asystole, bradycardia, supraventricular tachycardia, or normal rhythm).

The reference data set for VF OHCA incidence consisted of the results from the ARREST study conducted in 1995–1997.[12] This prospective cohort study was performed in Amsterdam and surroundings (Greater Amsterdam, ≈1.3 million inhabitants, 1030 km^2) between June 1, 1995, and August 1, 1997, employing the same method of data collection as in 2005–2008.[12]

ICD Therapy

All ICD-implanting hospitals in North Holland and adjacent regions participated in this study. Patients who received an ICD or visited the ICD clinic in one of the participating hospitals between July 4, 2005, and May 1, 2008, and lived in North Holland were included in the analysis. Age, sex, ICD implantation dates, and stored electrogram data were obtained from the included patients. Only shocks from which the provoking rhythm was documented and electrograms were available were included in the analysis. ICD shocks that did not prevent OHCA were not included in the analysis.

The rhythm before and after the ICD shock was classified as VF, polymorphic ventricular tachycardia, monomorphic ventricular tachycardia (MVT), nonsustained ventricular tachycardia, supraventricular tachycardia, bradycardia, asystole, normal, or unknown rhythm. In 20 ICD shocks (2.0% of all ICD shocks), we were not able to differentiate MVT from polymorphic ventricular tachycardia because only a near-field (tip ring) ventricular electrogram was available. These VTs were classified as MVT in order not to overestimate the potential prevention of VF OHCA.

Cycle length of the provoking rhythm and programmed cycle length of the lower limit of VF zone were documented. An experienced electrophysiologist evaluated all electrograms.

Calculation of Number of Prevented VF OHCA by ICD Shocks

We calculated the number of VF OHCA cases that were prevented by ICD shocks by multiplying the number of life-threatening arrhythmias that were successfully terminated by ICD shocks by the probability that the life-threatening arrhythmia would have led to an EMS call and a subsequent OHCA attempt. We defined a life-threatening arrhythmia as VF or polymorphic ventricular tachycardia, regardless of cycle length, or MVT faster than the lower limit of the programmed VF zone.

We considered the probability that resuscitation for OHCA was attempted must be taken into account because not all OHCA patients without ICDs undergo resuscitation. First, some of these patients succumb before an EMS call is made. To estimate the probability of an EMS call after a collapse of a patient at risk of a lethal arrhythmia, we used results from Bardy et al.[13] From this study, we estimated that 62% of all OHCA instances led to an EMS call. Second, if the collapse had led to an EMS call, the patient could have died before EMS arrival, and EMS personnel would not have attempted OHCA. To estimate this probability, we determined the number of EMS dispatches for suspected OHCA in which no resuscitation was attempted from ARREST data collected in 2005–2008.

Correction for Multiple Successful ICD Shocks

Some ICD patients experienced multiple successful ICD shocks during the study period. Addition of all of these ICD shocks to calculate the number of OHCA episodes that were prevented by ICD therapy would lead to overestimation of this number because most patients without ICDs would not have survived the OHCA episode to have an opportunity to undergo a subsequent resuscitation for OHCA. To correct for this, we calculated a corrected total number of successful ICD shock instances per patient (NICDt). NICDt is a measure of the number of life-threatening arrhythmias that would have occurred without ICD usage, considering that only the first successful ICD shock per patient contributed fully to the calculated NICDt; the contribution of every following shock was corrected for the probability that the patient would survive the previous OHCA episode. This could be expressed as follows:

$$\mathrm{NICDt} = \sum_{i=1}^{N} Z^{i-1}$$

where NICDt=total number of successful ICD shock instances, N=total number of appropriate shocks on life-threatening arrhythmias per patient, and Z=average survival rate from VF OHCA of patients without ICD in ARREST in 2005–2008.

All calculated NICDts per patient were added to estimate the total number of life-threatening arrhythmias potentially leading to resuscitation for VF OHCA.

Statistical Analyses

OHCA incidence and baseline demographic and resuscitation characteristics were calculated for Greater Amsterdam in 1995–1997, for Greater Amsterdam in 2005–2008, and for North Holland in 2005–2008. No substantial differences existed between Greater Amsterdam and North Holland without Greater Amsterdam in 2005–2008 (data shown in the online-only Data Supplement). Therefore, in this analysis, we used the results of North Holland including Greater Amsterdam for the 2005–2008 time period. Comparisons of baseline demographic and resuscitation characteristics between VF OHCA in 1995–1997 and in

Table 1. Population and OHCA Incidence in Greater Amsterdam and North Holland

	1995–1997, Greater Amsterdam (n=1 273 382)	2005–2008, North Holland (n=2 373 302)	*P*
Duration of data collection, mo	26	34	
OHCA incidence*			
EMS dispatches	1685 (61.1)	3696 (55.0)	<0.001
OHCA	918 (33.3)	2478 (36.9)	0.007
VF OHCA	581 (21.1)	1173 (17.4)	<0.001
Non-VF OHCA	337 (12.2)	1305 (19.4)	<0.001

OHCA indicates out-of-hospital cardiac arrest; EMS, emergency medical services; and VF, ventricular fibrillation.

*Variables are denoted as cases (incidence per 100 000 person-years).

2005–2008 were analyzed by Student *t* test, χ^2 test, or Kolmogorov-Smirnoff test where appropriate. Continuous data were shown as mean±SD. All time intervals were expressed as median (25th to 75th percentile). All incidence rates were reported per 100 000 person-years. Incidences were modeled as intensities (λ) of a Poisson process. Changes with confidence intervals between 1995–1997 and 2005–2008 were tested with the assumption of independent λ values. For 2005–2008, we added the calculated number of prevented VF OHCA by ICD shocks to the observed incidence of VF OHCA and compared this with the observed VF OHCA incidence in 1995–1997.

We performed a sensitivity analysis for our calculated number of prevented VF OHCA to account for patients with missing ICD readout data and ICD shocks without an available electrogram, as well as our assumption that all MVT faster than the lower limit of the VF zone would have led to a VF OHCA. All statistical tests were 2-tailed, and a *P* value of <0.05 was considered statistically significant. Statistics were performed in SPSS 16.0 for Mac (Chicago, IL) and Excel 11.5 for Mac (Chicago, IL).

Results

OHCA Incidence and Resuscitation Characteristics

In Greater Amsterdam in 1995–1997, 581 persons experienced a VF OHCA in a period of 26 months, amounting to a yearly incidence of 21.1/100 000 (Table 1). In North Holland in 2005–2008, 1173 persons experienced a VF OHCA in 34 months, amounting to a reduced yearly incidence of 17.4/100 000. The VF OHCA incidence decreased in a statistically significant manner by 3.6/100 000 (95% confidence interval, 1.6–5.6) over time (*P*<0.001).The yearly non-VF OHCA incidence increased from 12.2/100 000 in 1995–1997 to 19.4/100 000 in 2005–2008. The non-VF OHCA incidence increased in a statistically significant manner by 7.2/100 000 (95% confidence interval, 5.5–8.9) over time (*P*<0.001). Thus, the proportion of patients with OHCA with VF as presenting rhythm declined from 63% to 47% (*P*<0.001). In 2005–2008, 3696 dispatches for OHCA occurred. Resuscitation was not attempted in 33% of these dispatches because the patient was considered dead on arrival.

Table 2 shows the baseline demographic and resuscitation characteristics of all OHCA cases of both periods. Median time of EMS call to initial rhythm assessment increased from 9.0 to 10.5 minutes. In 2005–2008, an AED was attached in 21% of all OHCA cases. The median time of EMS call to shock decreased from 11.0 to 10.7 minutes (Table 2).

Survival of all OHCA patients increased from 9% to 14% (*P*<0.001; not shown). Survival of patients with VF OHCA increased from 17% to 31% (*P*<0.001; not shown).

Prevented VF OHCA by ICD Shocks

In 2005–2008, 1972 patients living in North Holland had or received an ICD. Of the 1972 patients, 475 (24%) received the ICD before the study period, and 1497 patients (76%) received the ICD between July 4, 2005, and May 1, 2008.

Table 2. Demographic and Resuscitation Characteristics of All OHCA Cases in Greater Amsterdam and North Holland

Variable	1995–1997, Greater Amsterdam (n=918)	2005–2008, North Holland (n=2478)	*P*
Demographic characteristics			
Age, mean±SD, y*	64.1±14.4	64.8±16.2	0.276
Male gender†	712 (78)	1825 (74)	0.037
Resuscitation characteristics			
Witnessed collapse†	779 (85)	1888 (76)	<0.001
Bystander CPR†	497 (54)	1486 (60)	<0.001
Collapse at home†	564 (61)	1715 (69)	<0.001
Time from call to initial rhythm analysis, min‡	9.0 (8.0–12.0)	10.5 (8.1–13.1)	<0.001
Time from call to shock, min‡	11.0 (9.0–14.0)	10.7 (8.2–13.5)	<0.001
AED connected	…	527 (21)	…

OHCA indicates out-of-hospital cardiac arrest; CPR, cardiopulmonary resuscitation; and AED, automated external defibrillator.

*Group differences were tested with Student *t* test.

†Variables are denoted as cases (percentage); group differences were tested with χ^2 test.

‡Time intervals are presented as median (25th to 75th percentile); group differences were tested with Kolmogorov-Smirnoff test.

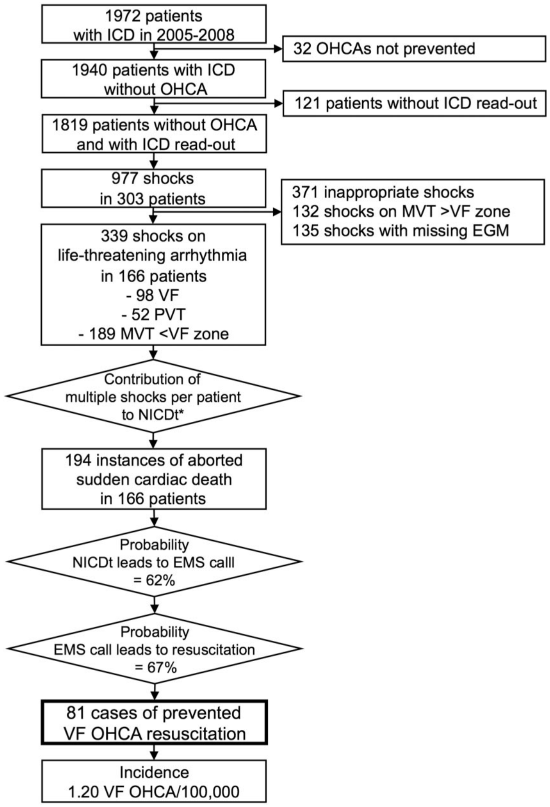

Figure 1. Data flow and calculation of estimated number of prevented ventricular fibrillation (VF) out-of-hospital cardiac arrests (OHCA) by successful implantable cardioverter-defibrillator (ICD) shocks. *Some patients experienced successful ICD shocks because of a life-threatening arrhythmia more than once. If the patient had not received an ICD, only a small percentage would have survived the initial episode of a life-threatening arrhythmia. Only the first successful ICD shock per patient contributed fully to the total number of successful shock instances (NICDt). The contribution of every following shock was corrected for a survival probability of 31% for VF OHCA patients experiencing a resuscitation effort. Hence, a second successful ICD shock per patient contributed to 0.31 instance of NICDt, a third successful ICD shock contributed to 0.096 instance of NICDt, etc. MVT indicates monomorphic ventricular tachycardia; EGM, electrogram; PVT, polymorphic ventricular tachycardia; and EMS, emergency medical services.

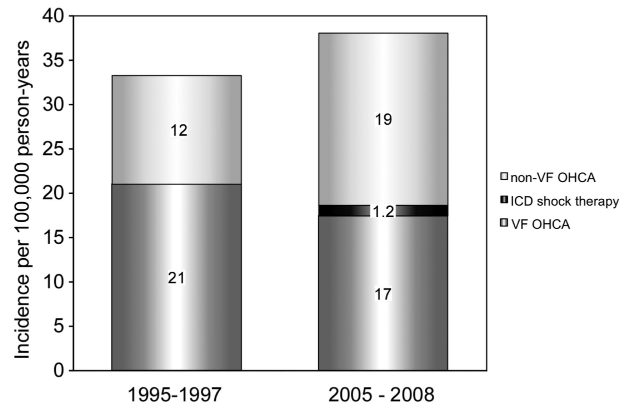

Figure 2. Incidence of ventricular fibrillation (VF) and non-VF cardiac arrest in 1995–1997 and 2005–2008 and estimated avoided episodes of out-of-hospital cardiac arrest (OHCA) from implantable cardioverter-defibrillator (ICD) use. In 2005–2008, the incidence of VF OHCA declined, whereas the incidence of non-VF OHCA increased. ICD shocks in 2005–2008 avoided 1.2/100 000 resuscitations for VF OHCA, which explains 33% of the decline in VF OHCA.

During the study period, the yearly ICD implantation rate increased from 11/100 000 in 2005 to 26/100 000 in 2008. The mean age of the ICD patients at entry in the cohort (either at July 4, 2005, or at implantation during the study period) was 62.2±12.6 years. Of the 1972 ICD patients, 1539 (78%) were male (not shown).

Figure 1 shows the calculation of the estimated number of prevented resuscitations for VF OHCA by ICD shocks. Thirty-two patients were resuscitated despite carrying an ICD; therefore, in these patients the ICD did not prevent an OHCA. These patients were excluded from the calculation of prevented VF OHCA. Furthermore, no ICD readouts were available for 121 patients. Because we could not establish whether OHCA was prevented by ICD shocks in these patients, we also excluded them from our calculation. The analysis cohort thus consisted of 1819 analyzable ICD patients. The duration of the ICD readout period for these patients varied between 1 and 1032 days, with a mean of 567±367 days (not shown). In total, 977 shocks were given to 303 patients. Of these shocks, 371 shocks were excluded from further analysis because they were inappropriate, mainly because of supraventricular tachycardia (272 shocks). We excluded another 132 ICD shocks because they were given for MVT with a cycle length outside the VF zone (which was, on average, set at 290±22 ms) and would not have led to a life-threatening arrhythmia either. We further ignored 135 ICD shocks because electromyograms were not available. As a result, we identified 339 ICD shocks given to 166 patients for a proven life-threatening arrhythmia. Of these 166 patients, 41 received 2 shocks, 21 received 3 shocks, 6 received 4 shocks, and 8 received 5, 6, 7, 8, 9, 10, 12, and 23 shocks, respectively. Because we found in ARREST that only 31% of patients without an ICD would have survived an episode of a life-threatening arrhythmia, and using the calculation for multiple successful ICD shocks (NICDt), we estimate that in this population 194 instances of life-threatening arrhythmia in 166 patients were successfully aborted by ICD shocks. Under the assumption that a life-threatening arrhythmia would have led to an EMS call in 62% and subsequently a resuscitation effort for VF OHCA in 67% of the cases, we estimate that appropriate ICD shocks have prevented 81 cases of presumed VF OHCA. This amounts to an incidence of 1.2/100 000 in North Holland in 2005–2008 (Figure 2). Because the VF OHCA incidence declined by 3.6/100 000 during 1995–1997 and 2005–2008, ICD usage thus accounted for 33% of the decline in VF OHCA.

Sensitivity Analysis

To account for the possible contribution of missing ICD data and the influence of our assumption that only MVT faster than the lower limit of the VF zone would have led to a VF OHCA, we performed a sensitivity analysis (Table 3). With the assumption that 121 patients with missing readout data, 135 ICD shocks without an available electrogram, and 132 patients with MVT rate below the VF zone would have

Table 3. Part of Decline of VF OHCA Explained by ICD Shocks: Sensitivity Analysis

Estimation	Calculated Prevented VF OHCA, n	Calculated Incidence of Prevented VF OHCA	Percentage of VF OHCA Decline Explained by ICD Shocks
Estimates as in Figure 1*	81	1.20	33
Maximal†	152	2.26	63
Minimal‡	39	0.60	16

VF indicates ventricular fibrillation; OHCA, out-of-hospital cardiac arrest; and ICD, implantable cardioverter-defibrillator.

*Assumptions as in Figure 1: excludes patients without follow-up; excludes shocks without electromyogram; only monomorphic ventricular tachycardia less than VF zone.

†Includes patients without follow-up and includes all shocks with missing electrogram. We assume that the clinical course of 121 patients without an ICD readout would have been the same as that of patients with an ICD readout. We further assume that the characteristics of the 135 shocks with missing electrogram would have been the same as the shocks if electrograms were available (Figure 1).

‡Assumptions are as in Figure 1 but also excludes all monomorphic ventricular tachycardia, regardless of cycle length.

contributed to the analysis with a clinical course and shock distribution as in Figure 1, a maximum of 152 cases of prevented VF OHCA episodes could be calculated. This would account for 63% of the decline in VF OHCA incidence. To calculate the minimal number of prevented VF OHCA, we also excluded, in addition to the patients and ICD shocks that we excluded in Figure 1, the 189 shocks for MVT within the VF zone, assuming that such fast MVT would not have resulted in VF OHCA in the absence of an ICD. With this calculation, only 39 cases of VF OHCA would have been prevented by ICD shocks. This corresponds to 16% of the decline in VF OHCA incidence.

Discussion

This study shows that VF OHCA incidence decreased by 3.6 per 100 000 person-years during the 10-year period during 1995–1997 and 2005–2008 in the province of North Holland in the Netherlands. We estimated that in 2005–2008, ICD shocks prevented 81 cases of resuscitation for VF OHCA (ie, 1.2 VF OHCA per 100 000 person-years). Hence, ≈33% of the decline in VF OHCA incidence could be explained with ICD shocks. The decline in VF OHCA is accompanied by a statistically significant increase in non-VF OHCA. As a consequence, there is a small increase in total OHCA incidence during 1995–1997 and 2005–2008. Both the lower numerator and higher denominator contribute to the observed decreased proportion of VF OHCA. The decline in VF OHCA incidence has been observed consistently in multiple other reports, albeit at different levels, but not the increase in overall OHCA incidence.[1–4,14,15]

In the only other study determining coexisting trends of ICD therapy and declining VF OHCA incidence, 3.5/100 000 potentially life-threatening arrhythmias were terminated by ICD shocks in Rochester, MN, with increasing ICD implantation rates up to 2002.[1] According to their calculation, ICD shocks had an impact of 10% to 33% on the reduced incidence of VF OHCA. However, the authors did not account for the correction of multiple successful shocks or for the <100% likelihood that a life-threatening arrhythmia leads to a resuscitation attempt.[15] Furthermore, some potentially life-threatening arrhythmias that triggered an appropriate shock may only have resulted in a short episode of syncope with spontaneous recovery if no ICD had been present. This may be the case in up to half of all appropriate shocks.[16] Thus, an appropriate ICD shock might not be a reliable surrogate for sudden cardiac death leading to a resuscitation effort. For all of these reasons, we believe that correction factors must be applied to appropriate ICD shocks to achieve the most reliable estimate of prevented resuscitation for VF OHCA.

Other Explanations for the Decline in VF OHCA

The reduced incidence of VF as first recorded rhythm may be explained by an intrinsically reduced incidence of VF as the cause of OHCA either from ICD use or other changing biological mechanisms in the population at risk for VF. However, in addition, an increased delay in the documentation of this first recorded rhythm or an increased speed of deterioration from VF to another rhythm, specifically asystole, might explain the reduced incidence of VF. Between 1995–1997 and 2005–2008, the total incidence and proportion of collapse in public locations and of witnessed collapse decreased (2 factors that may be related), resulting in a delay to call the dispatch center and in more deterioration of VF in asystole.[17] This is in agreement with recent observations of a lower proportion of VF OHCA at home, possibly because of differences in patient characteristics.[18] However, overall bystander cardiopulmonary resuscitation in 2005–2008 had increased, which might have prevented some cases of VF from deteriorating to asystole.[17] We also noted an increased median time from call to first rhythm analysis for all patients, which may have caused more VF to deteriorate to asystole. However, the median time to first shock decreased. This can be attributed to the group of patients who received an early shock from an AED.

The use of a β-blocker has also been associated with the reduced incidence of VF. In an animal model, duration of VF was significantly reduced with β-blocker use.[19] In a retrospective cohort study, it was shown that OHCA victims taking β-blockers were 5 times more likely to show non-VF than VF as first documented rhythm.[20] If β-blocker use would hasten VF deterioration without changing the initial incidence of VF, one would then expect to observe a still high VF OHCA incidence if time to initial rhythm recording is short, such as when an AED is used. Indeed, when on-site or dispatched AED use was compared with attachment of manual defibrillators by EMS personnel, a considerably higher percentage of shockable rhythms was noted (59% or 76% versus 24% or 47%, respectively).[21,22] In situations in which the response time is extremely short, such as in airports or casinos equipped with AEDs, VF is also the presenting rhythm in a high proportion of the cases.[23,24] These observations suggest that VF incidence might not have declined per se but rather that it possibly reflects faster deteriorating VF.

Increase in Non-VF OHCA

The overall increase in OHCA, which is larger than the decline in VF OHCA, indicates that more patients suffered an OHCA. The cause of this increase is not clear. We report on 100% of all known OHCA in both time periods with an unchanged system of case collection, which makes it less likely that we missed such a large number of non-VF OHCA cases in the period 1995–1997. Trends for cardiovascular and acute myocardial infarction hospital admissions and mortality have shown a decline between the 2 study periods. Mortality from competing illnesses such as malignancies has shown a (less pronounced) decline in the same time period and therefore cannot have caused an increased number of non-VF OHCA.

Limitations

The population of the study region of the period 2005–2008 was 43% larger than that of 1995–1997 but included the whole study region of 1995–1997 (Greater Amsterdam). Data shown in Table I in the online-only Data Supplement indicate that there was no statistically significant difference in VF and non-VF OHCA incidence in the area that contributed to both study periods compared with the area added in 2005–2008. Some covariates related to resuscitation were statistically significantly different (Table II in the online-only Data Supplement), probably related to the more rural characteristics of the added region. The prevented VF OHCA incidence in the Greater Amsterdam region only (1.21/100 000) was almost identical to the prevented incidence in the whole study region in 2005–2008 (1.20/100 000). The joint analysis therefore is not biased by the extension of the region in 2005–2008.

We did not consider antitachycardia pacing therapy to have prevented an OHCA in our analysis unless the antitachycardia pacing was unsuccessful and a (appropriate) shock followed. We also assumed that no VF OHCA was prevented by ICD shocks in 1995–1997. In that period, only a very limited number of patients had an ICD implanted, and therefore ICD therapy in this period was almost negligible. Furthermore, ICD-patient data from the time period 1995–1997 could not be retrieved.

In our model, we made a number of assumptions to estimate the contribution of multiple successful shock episodes in the study period in the same patient, the probability of an EMS call after collapse, and the probability of a resuscitation effort after EMS arrival. The sensitivity analysis indicates the limits of the potential impact of ICD use; our estimate of attributed reduction ranges from 16% to 63%. We did not account for the possibility that prevented VF could have deteriorated to asystole before the rhythm could be detected (ie, we assumed in our calculations that all life-threatening arrhythmias would be attended soon enough to identify VF as initial rhythm). It is possible that, despite our correction factors, we still overestimated the probability that a sudden cardiac death would have led to a resuscitation attempt.

Conclusions

The incidence of VF OHCA decreased in the province of North Holland in the Netherlands over the last decade. ICD therapy explained the decrease in 1.2/100 000 inhabitants per year, corresponding to ≈33% of this decline, with a range between 16% and 63%. There must be other factors that contribute at least equally to the reduced incidence of VF.

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Disclosures

None.

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CLINICAL PERSPECTIVE

The proportion and incidence of patients with out-of-hospital cardiac arrest (OHCA) that are found in ventricular fibrillation (VF) decreased over the last decades. It used to be well over 70% (incidence, 0.3–0.7/1000 inhabitants) and decreased to 25% to 50% (incidence, 0.1–0.3/1000 inhabitants) in a period of 15 to 20 years. The reason for this worldwide decline in VF is not clear. Possible explanations include a changing morbidity pattern from ischemic heart disease with more chronic heart failure, increased use of β-adrenergic receptor blocking drugs, and later arrival on scene by emergency medical services. We investigated the community impact of implantable cardioverter-defibrillators (ICDs) for primary and secondary prevention by comparing OHCA in the periods 1995–1997 when ICD therapy hardly existed to 2005–2008 in the Dutch province of North Holland. We took into consideration that if no ICD had been placed, resuscitation for OHCA would have occurred only in part of the patients who received an appropriate ICD shock. The incidence (per 100 000 inhabitants per year) of VF OHCA decreased from 21.1 to 17.4, and non-VF OHCA increased from 12.2 to 19.4, corresponding with a decline of VF OHCA from 63% to 47%. ICD shocks avoided 1.2 VF OHCA per 100 000 inhabitants per year. Thus, successful ICD shocks explained 33% of the decline in VF OHCA. In a sensitivity analysis, the explained decline ranged from 16% to 63%. Part of the decreased proportion of VF OHCA of all OHCA was explained by an even larger (and unexplained) increase in non-VF OHCA. Nevertheless, other factors must play at least an equal role in the explanation for the observed decline in VF OHCA.