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CLINICAL PAPER

Ventricular fibrillation in King County, Washington: A 30-year perspective☆

Linda Becker[a,*], Laura S. Gold[b], Mickey Eisenberg[a,c], Lindsay White[a], Thomas Hearne[a], Tom Rea[a,c]

[a] *Public Health Seattle and King County, Emergency Medical Services Division, 401 5th Avenue Suite 1200, Seattle, WA 98104 USA*
[b] *Department of Epidemiology, University of Washington, Seattle, WA 98195, USA*
[c] *Department of Medicine, University of Washington, Seattle, WA 98105 USA*

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Summary
Aim: We determined the effect of four major program changes over a 30-year period on survival from witnessed cardiac arrest (CA) with ventricular fibrillation (VF) as the rhythm causing collapse.
Methods: We conducted an investigation of emergency medical services (EMS)-treated CA occurring between 1978 and 2007. Data were obtained from a registry maintained by the King County Emergency Medical Services Division. Using Utstein style definitions, we measured changes in patient survival in light of four programs that were implemented during the span of the study: defibrillation by emergency medical technicians (EMTs), dispatcher-assisted cardiopulmonary resuscitation (CPR), public access defibrillation, and a CPR—defibrillation protocol that replaced delivery of three sequential shocks with administration of one shock followed by 2 min of CPR.
Results: Overall survival from witnessed VF during the study period was 34%. While demographic characteristics of patients in CA remained constant, we observed greater rates of survival in the years following the program changes, 1983—2006, compared to survival in the period before the changes, 1977—1982. The greatest increase in survival occurred following the CPR—defibrillation protocol change in 2005.
Conclusion: Despite adverse temporal trends, the four program changes appear to have contributed to increasing survival rates from out-of-hospital cardiac arrests in King County.

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* Corresponding author. Tel.: +1 206 263 8553; fax: +1 206 296 4866.
E-mail address: linda.becker@kingcounty.gov (L. Becker).

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Introduction

King County, Washington has maintained a registry of emergency medical services (EMS)-treated cardiac arrest (CA) since 1976. The registry includes both programmatic and demographic elements and has served as a useful tool to document performance and important trends, identify areas for improvement, and monitor the effect of new therapies and programs. Definitions of data elements have remained constant through the life of the registry. The present study examined survival from witnessed ventricular fibrillation (VF) for a 30-year period, 1978–2007, with emphasis on temporal changes and the effect of four programs intended to improve survival. These programs are defibrillation by emergency medical technicians (EMT-D),[1,2] dispatcher-assisted telephone cardiopulmonary resuscitation (TCPR),[3,4] public access defibrillation (PAD),[5,6] and a protocol change that altered the sequence of defibrillation and CPR.[7]

Materials and methods

Study design

This investigation was a retrospective cohort study of EMS-treated, non-traumatic out-of-hospital CA among persons over 18 years of age in King County, WA (excluding Seattle) between 1978 and 2007. In accordance with the Utstein style,[8] a case was defined as a patient whose CA occurred before arrival of EMS, was witnessed by bystanders, had ventricular fibrillation (VF) as the rhythm causing collapse and was due to cardiac causes. King County (excluding the city of Seattle) has an area of approximately 2000 square miles and includes urban, suburban, and rural areas. The population according to the 2000 census is approximately 1,200,000. The study was approved by the University of Washington Human Subjects Committee.

EMS system

King County is served by a two-tiered EMS system that is activated by calling 9-1-1 and speaking with an emergency medical dispatcher. The first tier consists of firefighter—EMTs who are trained in basic life support. The second tier consists of paramedics who are trained in advanced life support. Both tiers are dispatched simultaneously in the case of a suspected CA. First tier EMS providers arrive on scene an average of 5 min after dispatch and the paramedics arrive approximately 5 min later. The EMS system follows the American Heart Association guidelines for management of cardiac arrest.

Data collection

Though the registry began in 1976, some of the patients in the first 2 years were treated by EMTs without paramedics, due to a sequential phasing-in of paramedic services. Since not all of these early cases had the same level of care, we used data from 1978–2007 and eliminated any cases treated by EMTs only. The first and second tier personnel each complete medical incident reports following treatment. Patient demographics (age and sex), event circumstances (witnessed status, location, whether the arrest occurred before EMS arrival, response intervals and presenting rhythm), care provided (bystander CPR, shocks intubation and medications), and immediate outcome (whether the patient was admitted to hospital ICU or died at the scene or at the emergency department) were abstracted from these reports. Hospital records were used to determine survival to discharge. Dispatch tapes were reviewed for information on whether dispatcher-assisted CPR was offered and begun. Etiology was determined by all available sources of information including medical incident reports, hospital records, and death certificates.

Analysis

We analysed data according to implementation of the four program changes. We divided the 30 years into four-time periods based on the beginning dates of the programs. The first period was baseline, 1978 through 1982, before any of the changes. The second period, 1983–1998, included two of the program changes, EMT-D program, in which all EMTs were equipped with automated external defibrillators (AEDs), and the TCPR program. Both of these programs began in 1983, but were not fully implemented throughout the county for 12–24 months. Although a handful of cardiac arrests were treated with PAD before the beginning of the third time period in our study, 1999–2004, a countywide program sponsored and supported by the EMS Division of the Health Department with the goal of widespread diffusion of PAD in the community was fully implemented at

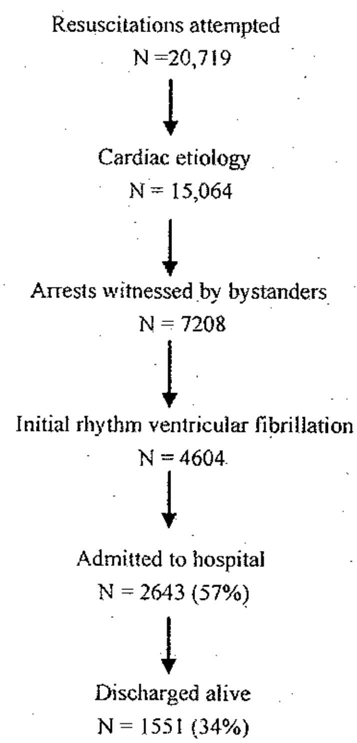

Figure 1 Survival from cardiac arrest with Utstein template, 1978–2007, King County, WA.

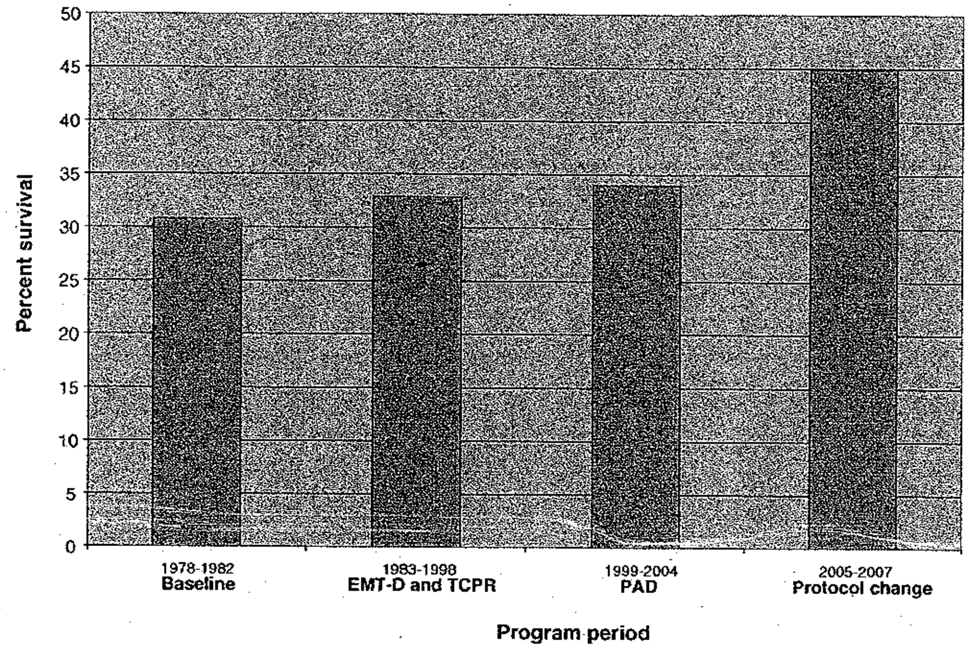

Figure 2 Percent survival by program period. Programs were sequentially implemented and were additions to previous programs.

this time. The fourth period, 2005—2007, marks the beginning of a CPR/defibrillation protocol change emphasizing the role of CPR. Before, the standard protocol was to check pulse, apply the AED, analyse rhythm and deliver three consecutive shocks if indicated, and then proceed with CPR. As of 2007, all personnel changed the order of events to check pulse, apply the AED, analyse rhythm, deliver one shock if indicated and then perform 2 min of CPR before another analysis. Electronic transmissions from the AEDs were examined for each case insure the new protocol had been followed. Each of these programs added to the previous ones, creating a cumulative effect on treatment of out-of-hospital cardiac arrest.

Descriptive statistics were used to assess various characteristics: patient age, gender, whether CPR was initiated by a bystander prior to arrival of EMS and whether the bystander received instructions, location of the arrest, BLS and ALS response times, and time to first defibrillation. We also compared the mean ages, times to treatment, and survival over the four time periods using analysis of variance. Linear-by-linear associations were examined to analyse trends in categorical variables over time. Multivariable logistic regression was used to determine which characteristics were independently associated with survival to hospital discharge. Analyses were performed using SPSS 11.5 (Chicago, IL).

Results

EMS treated 20,719 out-of-hospital cardiac arrests during the study period (Figure 1). There were 4604 persons whose arrests were witnessed and were in VF upon arrival of EMS, 34% of whom survived to hospital discharge. Figure 2 depicts survival by the program periods: baseline, EMT-D plus TCPR, PAD, and protocol change. Survival during the EMT-D and TCPR period increased slightly compared to the baseline, and survival increased slightly again during the PAD program. A large increase in survival occurred with the protocol change. While the upward trend was statistically significant ($p < 0.001$) there was no significant change between baseline and the EMT-D/TCPR period and between baseline and the PAD period.

Changes in demographic characteristics of this population over three decades are presented in Table 1. The mean age peaked at 65 years during the second time period and decreased in the third and fourth periods. The gender distribution remained constant over time, with about 20% of the cardiac arrests occurring in females. Following implementation of the TCPR program, about 25—30% of all cases were treated by bystanders who used dispatcher-assisted CPR. The proportion of events that occurred in public increased for unknown reasons, as did the proportion of events in which the first defibrillation was provided by EMTs. Both EMT and paramedic response intervals increased over time. The time to first defibrillation, however, decreased because as of the second period, the first shock was being provided by the faster-arriving EMTs. Survival also increased over the periods.

Odds ratios and 95% confidence intervals (95% CI) for survival for select variables are shown in Table 2. As expected, increases in age and in BLS, ALS, and defibrillation response intervals were associated with decreases in odds of survival. A bystander performing CPR and the arrest occurring in a public location were associated with increased odds of survival. Finally, use of PAD on scene was also associated with increased odds of survival.

Results of multivariate logistic regressions are shown in Table 3. Unadjusted logistic regression showed that patients whose cardiac arrests occurred in 2005—2006 had significantly greater odds of survival compared to those whose arrests occurred between 1977 and 1982, but survival was

Table 1 Demographic characteristics of cardiac arrests in King County, Washington from 1978 through 2007

Characteristic	Time period				
	1978–1982 Baseline (n = 870)	1983–1998 EMT-D and TCPR (n = 2555)	1999–2004 PAD (n = 798)	2005–2007 Protocol change (n = 381)	p-Value for trend over time periods
Age, years: mean (standard deviation)	63.1 (12.2)	65.3 (13.0)	64.3 (14.4)	62.5 (14.1)	<0.001
Female, % (n)	19.0 (165)	21.3 (543)	22.4 (179)	19.4 (74)	0.21
Bystander CPR, % (n)					
Bystander CPR without dispatcher assistance	44.1 (384)	38.0 (970)	42.0 (335)	39.6 (151)	
Bystander CPR with TCPR	0	28.6 (732)	25.1 (200)	29.9 (114)	
No CPR before EMS	55.9 (486)	33.4 (853)	33.0 (263)	30.4 (116)	<0.001
Location[a], % (n)					
Private residence	–	64.2 (1640)	57.0 (455)	52.8 (201)	
Public	–	30.4 (742)	36.6 (292)	45.1 (172)	
Nursing home	–	2.3 (58)	6.3 (50)	2.1 (8)	0.01
Public access defibrillator (PAD) used, % (n)	0	0.2 (6)	4.5 (36)	8.4 (32)	<0.001
Shock provided by EMT-D, % (n)	–	76 (1033)	79.0 (630)	90.0 (343)	<0.001
BLS response interval, minutes, mean (standard deviation)	4.2 (2.1)	5.0 (2.2)	5.5 (2.4)	5.3 (2.3)	<0.001
ALS response interval, minutes, mean (standard deviation)	8.8 (4.2)	9.9 (4.8)	9.4 (4.8)	9.9 (5.8)	<0.001
Collapse to defibrillation interval, minutes, mean (standard deviation)[b,c]	10.4 (5.1)	7.9 (2.9)	7.5 (3.2)	7.5 (2.6)	<0.001
Survival, % (n)	30.8 (268)	32.9 (841)	34.0 (271)	44.9 (171)	<0.001

[a] Location of arrest was not routinely collected until 1986.
[b] Excludes times to defibrillation by PAD.
[c] Time from collapse to defibrillation was estimated in the baseline period using time from collapse to paramedic arrival. In the subsequent time periods, it was estimated based upon time from collapse to delivery of a defibrillatory shock by EMTs.

Table 2 Univariate odds ratios of survival from 1978 through 2007

Characteristic	Time period odds ratio (95% CI)			
	1978–1982 baseline (n = 870)	1983–1998 EMT-D and TCPR (n = 2555)	1999–2004 PAD (n = 798)	2005–2007 protocol change (n = 381)
Age[a]	0.98 (0.96–0.99)	0.99 (0.98–0.99)	0.97 (0.96–0.99)	0.97 (0.95–0.98)
Female	0.90 (0.62–1.31)	1.10 (0.90–1.35)	1.34 (0.95–1.88)	0.99 (0.59–1.64)
Bystander CPR	1.29 (0.97–1.72)	1.44 (1.20–1.73)	1.30 (0.95–1.79)	1.59 (1.01–2.48)
PAD used on scene	—	—	2.01 (1.03–3.93)	4.12 (1.80–9.43)
Location[b], % (n)				
Private residence	—	1.00 (referent)	1.00 (referent)	1.00 (referent)
Public	—	2.20 (1.84–2.64)	1.90 (1.40–2.58)	2.54 (1.67–3.86)
Nursing home/ medical office	—	0.85 (0.46–1.56)	0.46 (0.21–1.00)	0.62 (0.12–3.17)
BLS response interval[c]	0.86 (0.79–0.93)	0.82 (0.78–0.85)	0.83 (0.76–0.90)	0.84 (0.76–0.93)
ALS response interval[c]	0.86 (0.81–0.91)	0.92 (0.90–0.94)	0.95 (0.92–0.99)	0.99 (0.95–1.03)
Defibrillation response interval[c,d]	0.86 (0.86–0.93)	0.83 (0.79–0.88)	0.77 (0.68–0.86)	0.85 (0.74–0.98)

[a] Odds ratio refers to a 1 year increase in age.
[b] Location of arrest was not routinely collected until 1986.
[c] Odds ratio refers to a 1 min increase in response interval.
[d] Time from collapse to defibrillation was estimated in the baseline period using time from collapse to paramedic arrival. In the subsequent time periods, it was estimated based upon time from collapse to delivery of a defibrillatory shock by EMTs.

not significantly increased in the 1983–1998 or 1999–2004 time periods. The same results were seen when the model was adjusted for age and gender (Model 1). However, when we adjusted for the increased response times of basic and advanced life support units (Model 2), we found that the odds of survival increased significantly in each of the time periods compared to the baseline.

Discussion

Survival during the EMT-D/TCPR period increased slightly compared to the baseline and survival increased slightly again during the PAD program. Neither of these increases was significant compared to survival in the first time period. However, a large increase in survival occurred with the protocol change and the upward trend in survival was statistically significant ($p < 0.0001$). We analysed several factors that may have affected survival rates, including demographic characteristics, EMT and paramedic response times, and programmatic changes. Logistic regression models that were adjusted for age and gender showed no changes in the odds of survival in the EMT-D plus TCPR and the PAD periods. However, when we adjusted for the increasing response times, we found that the odds of survival were significantly increased in each of the time periods, indicating that these programmatic changes may have been responsible for the increases in survival. It has already been documented in a previous study[7] that survival from 33% for the years 2002–2004 increased to 46% for years 2005–2006, due to the protocol change.

The fact that we saw increases in survival rates in each of the time periods in spite of longer response times (which were most likely due to growing congestion) indicates how important the development of innovative treatments and community programs are to improve survival from out-of-hospital cardiac arrest.

These programs may have improved survival by shortening the time from collapse to CPR and to defibrillation. TCPR allowed bystanders to immediately begin CPR while waiting for the arrival of EMS. The programs that allowed EMTs and, later, bystanders to perform defibrillation shortened the time to first shock. The CPR–defibrillation protocol shift improved survival by increasing the time that CPR was given between shocks.

A previous study[9] reported improvement in survival from CA in King County over a 25-year period. That study focused on demographic and service factors, and included all cases of CA. The present study examined survival in light of sequentially implemented programs and included cases of VF only, since the program changes we evaluated were designed to treat VF and were unlikely to improve survival in patients with other rhythms. Additionally, the PAD program has grown widely and the CPR–defibrillation protocol change has been implemented since that study was published in 2003.

A potential limitation of this study is that the EMT-D and TCPR programs were implemented over 12–24 months, making comparisons in survival rates in the pre- and post-program periods difficult. Similarly, the PAD program is continually expanding and thus would be expected to have had a greater effect of survival in later years than its

Table 3 Multivariate odds ratios of survival from 1978 through 2007

Characteristic	Time period odds ratio (95% CI)			
	1978—1982 baseline (n = 870)	1983—1998 EMT-D and TCPR (n = 2555)	1999—2004 PAD (n = 798)	2005—2007 protocol change (n = 381)
Survival, % (n)	30.8 (268)	32.9 (841)	34.0 (271)	44.9 (171)
Unadjusted	1.0 (referent)	1.10 (0.93—1.30)	1.16 (0.94—1.41)	1.83 (1.43—2.34)
Model 1	1.0 (referent)	1.14 (0.97—1.36)	1.17 (0.95—1.44)	1.82 (1.41—2.34)
Model 2	1.0 (referent)	1.35 (1.09—1.68)	1.42 (1.10—1.84)	2.27 (1.68—3.06)

Model 1: adjusted for age and sex, and Model 2: adjusted for Model 1 variables plus basic and advanced life support response times.

early years. In fact, during the PAD period, survival for patients receiving defibrillation by a PAD was 50% (18/36), and increased to 75% (24/32) during the protocol change period. Finally, we did not account for another therapy, in-hospital hypothermia, which may have had an influence on survival, because the data are not yet complete. However, we were able to assess the frequency of hypothermia among survivors from 2006 as a sample. Twenty-two of the 55 survivors received hypothermia.

Conclusion

Improved survival over time may be attributed to the cumulative effect of four program changes aimed at shortening times to CPR and defibrillation, and at optimizing interaction between CPR and defibrillation.

Conflict of interest statement

This study received no outside agency or company support or loan equipment.

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This study has not been previously published and the manuscript is not under consideration elsewhere.

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