Increasing survival rate from commotio cordis

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BACKGROUND Commotio cordis events due to precordial blows triggering ventricular fibrillation are a cause of sudden death (SD) during sports and also daily activities. Despite the absence of structural cardiac abnormalities, these events have been considered predominantly fatal with low survival rates.

OBJECTIVE To determine whether expected mortality rates for commotio cordis have changed over time, associated with greater public visibility.

METHODS US Commotio Cordis Registry was accessed to tabulate frequency of reported SD or resuscitated cardiac arrest over 4 decades.

RESULTS At their commotio cordis event, 216 study patients were 0.2–51 years old (mean age 15 ± 9 years); 95% were males. Death occurred in 156 individuals (72%), while the other 60 (28%) survived. Proportion of survivors increased steadily with concomitant decrease in fatal events. For the initial years (1970–1993), 6 of 59 cases survived (10%), while during 1994–2012, 54 of 157 (34%) survived ($P = .001$). The most recent 6 years, survival from commotio cordis was 31 of 53 (58%), with survivor and nonsurvivor curves ultimately crossing. Higher survival rates were associated with more prompt resuscitation (40% <3 minutes vs 5% >3 minutes; $P < .001$) and participation in competitive sports (39%; $P < .001$), but with lower rates in African Americans (1 of 24; 4%) than in whites (54 of 166; 33%; $P = .004$). Independent predictors of mortality were black race ($P = .045$) and participation in noncompetitive sports ($P = .002$), with an on-site automated external defibrillator use protective against SD ($P = .01$).

CONCLUSIONS Survival from commotio cordis has increased, likely owing to more rapid response times and access to defibrillation, as well as greater public awareness of this condition.

KEYWORDS Sudden death; Defibrillation; Trauma; Commotio cordis; Ventricular fibrillation

ABBREVIATIONS AED = automated external defibrillator; **SD** = sudden death

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Introduction

Commotio cordis is a newly recognized cause of sudden death (SD) in which relatively innocent appearing, blunt, and nonpenetrating chest blows trigger ventricular fibrillation without structural damage to the ribs, sternum, or heart itself.[1–5] Among the cardiovascular causes of SD in athletes, commotio cordis is second in frequency only to hypertrophic cardiomyopathy.[6,7]

A series of experimental studies have provided insights into the mechanism responsible for ventricular fibrillation and commotio cordis.[8–12] Initial reports suggested that these events were associated with very low survival rates in the range of 10%–15% despite the presence of a structurally normal heart.[1,4] More recently, we considered the possibility that the epidemiology of commotio cordis may have evolved with a change in expected mortality. Consequently, we have taken this opportunity to reassess the outcome of these events over time in our registry population.

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Methods

The 216 cases consecutively entered into the US Commotio Cordis Registry (Minneapolis, MN) as of July 2012 constitute the present series.[1,2,4–6] Commotio cordis events were identified prospectively and retrospectively from news media accounts, Internet searches, or other public records using the LexisNexis database, US Consumer Product Safety Commission reports, or direct submission to the registry by medical examiners or other interested parties. Each case fulfilled the following inclusion criteria: (1) a witnessed blunt, nonpenetrating blow to the chest immediately preceding cardiovascular collapse; (2) event circumstances documented in detail; (3) no evidence of structural damage to the sternum, ribs, and heart itself; and (4) absence of underlying cardiovascular abnormalities.

Statistical analysis

Continuous (means, standard deviations, medians, ranges, and percentiles) and categorical (counts and percentages) variables were reported for each clinical variable. Continuous variables were compared by using the unpaired Student's

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Table 1 Multivariate predictors of survival from commotio cordis

Effect	Coefficient (SE)	Odds ratio (95% CI)	P
Intercept	−0.513 (0.214)	--	.017
African American race*	−2.143 (1.067)	0.117 (0.014–0.950)	.045
AED on-site	1.529 (0.598)	4.614 (1.430–14.881)	.010
Noncompetitive sports†	−1.112 (0.361)	0.329 (0.162–0.667)	.002

AED = automated external defibrillators; CI = confidence interval; SE = standard error.

*Caucasian race is reference group.

†Noncompetitive activity is reference group (combination of recreational sports and day-to-day activities group).

t test, and categorical variables were assessed by using the χ^2 test. Frequency of survivors and nonsurvivors over time was compared by a test for trend. Univariate analyses were performed to assess associations between individual predictors and survival.

Variables with $P < .05$ for univariate associations were entered into the stepwise multivariable logistic regression model. The multivariate model is summarized in Table 1 for variables with $P < .1$. The logistic regression model developed was assessed for model fit by using the Hosmer-Lemeshow test and for predictive ability by using the *c* statistic. Analyses were performed with Stata Version 12 (StataCorp, College Station, TX).

Results

Demographics

Ages of the 216 commotio cordis victims ranged from 0.2 to 51 years (mean age 15 ± 9 years); 161 (75%) were <18 years; 205 (95%) were males. One hundred sixty-six were whites (77%); 24 (11%) were African Americans; and 20 (9%) were of other races, most commonly Hispanics (6 are unknown). At the time of their event, victims were engaged in organized competitive sports (n = 115; 53%), recreational sporting activities (n = 52; 24%), or routine daily activities (n = 49; 23%). Chest blows were delivered by projectiles (eg, baseballs, hockey pucks; n = 134; 62%), or blunt bodily contact (n = 82; 38%). Of the 115 participants in competitive sports activities, 42 (37%) were wearing standard, commercially available chest barriers or padding to protect against direct blows to the chest wall (eg, chest protectors for baseball catchers or lacrosse goalies).[13]

Outcome

Of the 216 commotio cordis victims, 156 (72%) died as a consequence of the chest blow and 60 (28%) survived. Over the acquisition period for the registry, the proportion of commotio cordis survivors increased steadily and significantly with time. This enhanced survival was associated with a concomitant decrease in fatal events by 58% ($P < .001$, χ^2 test for trend) over the study period (Figure 1). For the initial years of the registry (1970–1993), fatal events greatly predominated with only 6 of 59 (10%) victims surviving. In comparison, over the most recent years (1994–2012), survivors predominated (54 of 157; 34%; $P < .001$). Furthermore, over the most contemporary period (2006–2012), the survival rate was 58% (31 of 53), and ultimately the survivor and nonsurvivor curves crossed (Figure 1).

Comparisons of survivors and nonsurvivors

Survivors were more commonly engaged in organized competitive sports (vs recreational activity or normal daily activities; $P < .001$) (Table 2). Cardiopulmonary resuscitation was known to have been performed in 171 individuals

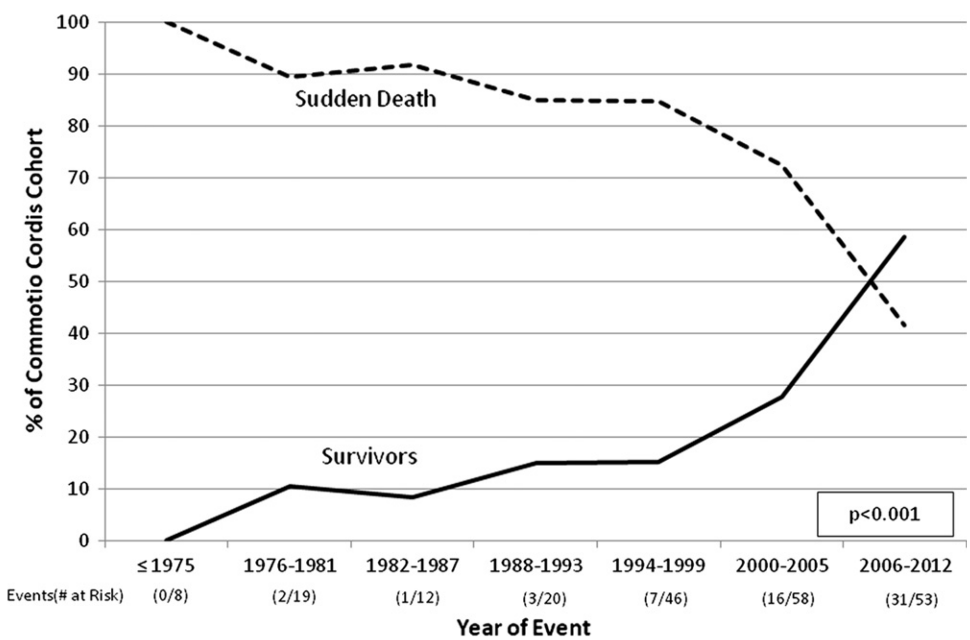

Figure 1 Commotio cordis-related survival and mortality over time in the US Commotio Cordis Registry.

and included defibrillation (by emergency medical technicians on-site or in the emergency room) in 87, initially by bystanders with an on-site automated external defibrillator (AED) in 14, or with both in 2. Of the 16 cases in which AEDs were known to be used, 11 survived.

Of the 163 events in which time from collapse to initiation of resuscitation could be estimated, this interval was <3 minutes in 121, of whom 48 survived (40%). In contrast, of the other 42 cases in which resuscitation was judged to be substantially delayed (estimated >3 minutes), there were only 2 survivors (5%; $P < .001$). Defibrillation was employed more frequently during the most recent 12 years of the registry (2000–2012) than before year 2000, including use of AEDs on-site, or defibrillation either by medical

Table 2 Comparison of 216 commotio cordis survivors and nonsurvivors

Variable	Survivors	Nonsurvivors	*P*
No of events	60	156	–
Age (y) (mean, range)	16 (1.5–51)	14 (0.2–50)	.16
Sex: Man, n (%)	57 (95)	148 (95)	.97
Race, n (%)			
African American	1 (2)	23 (15)	
White	54 (90)	112 (72)	.023
Other	4 (7)*	16 (10)†	
Unknown	1 (2)	5 (3)	
Circumstance, n (%)			
Competitive sports	45 (75)	70 (45)	
Recreational sports	9 (15)	43 (28)	<.001
Day-to-day activities	6 (10)	43 (28)	
Recreational and competitive sports, n (%)			
Baseball	29 (54)	55 (49)	
Football	4 (7)	14 (12)	
Hockey	4 (7)	9 (8)	
Karate	0	2 (2)	.81
Lacrosse	6 (11)	7 (6)	
Soccer	2 (4)	4 (4)	
Softball	4 (7)	14 (12)	
Other	5 (9)‡	8 (7)§	
Chest blow, n (%)			
Projectile/implement	40 (67)	94 (60)	
Bodily contact	20 (33)	62 (40)	.39
Chest padding, competitive sports, n (%)			
Yes	14 (31)	28 (40)	
No	30 (67)	41 (59)	.61
Unknown	1 (2)	1 (1)	
AED used on-site, n (%)			
Yes	11 (18)	5 (3)	
No	49 (82)	151 (97)	<.001
On-site defibrillation: EMT, AED, or both, n (%)			
Yes	37 (62)	66 (42)	
No	23 (38)	90 (58)	.014
Time to resuscitation, n (%)			
<3 min	48 (96)	73 (65)	
>3 min	2 (4)	40 (35)	<.001
Projectiles/implements, n (%)			
Baseball	23 (58)	57 (61)	
Baseball bat	2 (5)	3 (3)	
Hockey puck	4 (10)	6 (6)	.66
Lacrosse ball	5 (13)	6 (6)	
Softball	3 (8)	13 (14)	
Other	3 (8)‖	9 (10)¶	
Nature of projectile, n (%)			
Air-filled	2 (5)	2 (2)	.58
Solid	38 (95)	92 (98)	

AED = automated external defibrillator; EMT = emergency medical technicians.

*Hispanic (n = 3); Asian (n = 1).

†Hispanic (n = 9); Asian (n = 3); Pacific Islander (n = 2); Pakistani (n = 1); Native American (n = 1).

‡1 each with basketball, cycling, equestrian, skiing, and T-ball.

§1 each with basketball, boxing, cheerleading, cliff diving, cricket, kickball, hunting, and tennis.

‖1 each with lacrosse stick, soccer ball, and tennis ball.

¶1 each with lacrosse stick, cricket ball, football, kickball, rifle, rock, sled saucer, snowball, and tennis ball.

technicians or in the emergency room (61; 55% vs 43; 41%; $P = .04$).

Survivors and nonsurvivors did not differ with respect to a number of demographic variables, including age, sex, chest blow by projectile vs bodily contact, specific sports involved, or presence of chest barriers (Table 2).

Impact of race

Survival rate from commotio cordis proved to be significantly lower in African Americans than in whites (1 of 24; 4% vs 54 of 166; 33%; $P = .003$). In this regard, delayed resuscitation (>3 minutes) was also more common in African Americans (8 of 18; 44%) than in whites (27 of 125; 22%; $P = .035$). While AEDs were used 2-fold more commonly in white victims (14 of 166; 8%) than in African Americans (1 of 24; 4%), this difference did not achieve statistical significance ($P = .47$).

Multivariate analysis

Univariate predictors of survival were race, activity type, on-site use of AEDs, external defibrillation at any time during the event, and time from collapse to resuscitation of <3 minutes. The final multivariate model, determined by stepwise regression, indicated risk factors for commotio cordis mortality were African American race ($P = .045$) and involvement in noncompetitive (recreational) sports ($P = .002$), while the on-site use of AEDs was protective against SD ($P = .01$). The *c* statistic from the final multivariate model was 0.72. The HL χ^2 statistic was 0.12, with 2 degrees of freedom, corresponding to a *P* value of .94, indicating good fit to the data. Logistic coefficients and odds ratios from the model appear in Table 1.

Discussion

As a cause of arrhythmic SD in the young, commotio cordis is relatively new to the physician and general community. Previous reports from our large registry cohort initially conveyed the distinctly unfavorable impression that commotio cordis-related ventricular fibrillation was rarely reversible by cardiopulmonary resuscitation and life support (with a reported survival rate of only about 10%–15%).[1,2,4] Also, one case report documented the failure to resuscitate a commotio cordis victim even with particularly prompt use of an AED.[14] However, this high mortality rate was counterintuitive, given that commotio cordis occurs (by definition) in the absence of structural cardiac disease.[1,2]

Interrogation of cases submitted to our unique registry over a substantial period of time updates this issue. We found a progressive 5-fold increase in survival from commotio cordis, that is, from 10%–15% before year 2000 to >50% in the most recent 5-year period. Furthermore, our analysis defines certain factors that have likely potentiated survival and explain the decreasing mortality rate in the registry from these events.

In survivors, estimated response time from collapse to resuscitation was more prompt, defibrillation and on-site AEDs were more common, with AED use an independent predictor of survival by multivariate analysis. The latter is perhaps not an entirely unexpected finding, given the known effectiveness of public access defibrillation in restoring normal rhythm following out-of-hospital cardiac arrest,[15–18] as well as the increasing availability of AEDs over the last several years. Indeed, defibrillation and prompt response to resuscitation were more common in the most recent 12 years of the registry. Our data, therefore, support the principle of greater dissemination and availability of AEDs in the community, including sporting events involving young children.[19]

An additional independent predictor of survival was the location of commotio cordis events on the athletic field during competitive sports activities. Such public sites are highly sensitive to the possibility of SD in young people, including the potentially lethal consequences of chest blows.[19] Response times would be expected to be more rapid, and AEDs more likely available for bystander use, compared to more remote circumstances.

The race of commotio cordis victims proved to be an independent determinant of survival. Specifically, African Americans were 8-fold less likely to survive following collapse than white victims. Indeed, <5% of African Americans were successfully resuscitated following a chest blow, with potential determinants the longer response times to resuscitation and less frequent use of AEDs on-site. This apparent racial disparity in commotio cordis survival was unexpected and its antecedents unresolved.

Finally, it is possible (although uncertain) that the availability of particular resuscitative strategies at different times in the >40-year period of this study could have influenced our data. For example, it is possible that search methods available in the early years (ie, 1970–1993), largely limited to newspapers, were more likely to have reported deaths than successful resuscitations. However, it is also likely that commotio cordis events in the earlier era would have been fatal largely because of the absence of AEDs and contemporary emergency resuscitative measures.

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