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Increased Incidence of Life-Threatening Ventricular Arrhythmias in Implantable Defibrillator Patients After the World Trade Center Attack

Jonathan S. Steinberg, MD, FACC,*† Aysha Arshad, MBBS,* Marcin Kowalski, MD,* Atul Kukar, DO,* Valentin Suma, MD,* Margot Vloka, MD,*† Frederick Ehlert, MD,*† Bengt Herweg, MD,*† Jacqueline Donnelly, BA,* Julie Philip, PA-C,* George Reed, PHD,‡ Alan Rozanski, MD, FACC*

New York, New York; Ridgewood, New Jersey; and Worcester, Massachusetts

OBJECTIVES This study was designed to evaluate whether the destruction of the World Trade Center (WTC) on September 11, 2001 (9/11), led to an increased frequency of ventricular arrhythmias among patients fitted with an implantable cardioverter-defibrillator (ICD).

BACKGROUND The WTC attack induced psychological distress. Because ICDs store all serious arrhythmias for months, the attack provided a unique opportunity to compare pre- and post-9/11 frequencies of potentially lethal arrhythmias among ICD patients.

METHODS Two hundred consecutive ICD patients who presented for regularly scheduled follow-up to six affiliated clinics were recruited into this observational study. The electrograms stored in the ICDs for the three months before 9/11 and 13 months thereafter were scrutinized in a blinded manner (relative to date) for all ventricular tachyarrhythmias (tachycardia or fibrillation) triggering ICD therapy.

RESULTS The frequency of tachyarrhythmias increased significantly for the 30 days post-9/11 ($p = 0.004$) relative to all other months between May 2001 and October 2002. In the 30 days post-9/11, 16 patients (8%) demonstrated tachyarrhythmias, compared with only seven (3.5%) in the preceding 30 days, representing a 2.3-fold increase in risk (95% confidence interval 1.1 to 4.9; $p = 0.03$). The first arrhythmic event did not occur for three days following 9/11, with events accumulating in a progressive non-clustered pattern.

CONCLUSIONS Ventricular arrhythmias increased by more than twofold among ICD patients following the WTC attack. The delay in onset and the non-clustered pattern of these events differ sharply from effects following other disasters, suggesting that subacute stress may have served to promote this arrhythmogenesis. (J Am Coll Cardiol 2004;44:1261–4) © 2004 by the American College of Cardiology Foundation

On September 11, 2001 (9/11), New York City was the site of an unprecedented terrorist attack. An acute increase in mortality, noted after earthquakes (1–4) and missile attacks (5), was not reported post-9/11 (6). Nevertheless, in the weeks afterward, significant psychological distress was documented across the nation (7). This raises the issue of whether the World Trade Center (WTC) attack may have been associated with subacute health effects.

Patients with pre-existing heart disease are prone to adverse effects from acute mental stress, including arrhythmogenesis (8). Quantitative study of arrhythmias before and following a natural disaster has not heretofore been possible, but the implantable cardioverter-defibrillator (ICD), routinely used to prevent fatal arrhythmic events in high-risk cardiac patients, can also be used to study the precise incidence, nature, and timing of ventricular tachyarrhythmias both before and during acute disorders owing to its recall ability. Thus, the ICD is a potentially unique epidemiologic tool. Accordingly, we applied this technology to study the type and pattern of arrhythmic events following the WTC attack among ICD patients within the New York community.

METHODS

Patient selection. Our service operates six affiliated ICD clinics in Manhattan, Staten Island, the Bronx, northern New Jersey, and upstate New York. From this populace, the first 200 chronic ICD-fitted patients who had a regularly scheduled visit already planned beginning October 1, 2001, were recruited. Clinic visits were spaced three months apart, with appointments confirmed by phone reminder. No scheduled patient dropped out from routine follow-up. Non-routine visits were not included. Patients' demographic and clinical data were retrieved from clinic charts, and hospitalizations during the study period were recorded. Patients were queried regarding their location at the time of the WTC attack and television viewing habits before and after 9/11. All patients gave informed consent.

From the *Division of Cardiology, St. Luke's-Roosevelt Hospital Center and Columbia University College of Physicians and Surgeons, New York, New York; †Valley Hospital, Ridgewood, New Jersey; and the ‡Division of Preventive and Behavioral Medicine, University of Massachusetts Medical School, Worcester, Massachusetts.

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Abbreviations and Acronyms

CI = confidence interval
ICD = implantable cardioverter-defibrillator
9/11 = September 11, 2001
RR = relative risk
VT = ventricular tachycardia
VF = ventricular fibrillation
WTC = World Trade Center

ICD interrogation. Each patient underwent a comprehensive ICD interrogation at clinic visit. The date and time of each tachyarrhythmia that triggered ICD therapy, either shock or antitachycardia pacing, was recorded. The electrogram stored in the device for each arrhythmic event was carefully scrutinized, and only those meeting standard criteria for ventricular tachycardia (VT) or ventricular fibrillation (VF) were included (9). Each ICD event was analyzed in a blinded manner.

Study and statistical analyses. The primary end point of the study was development of VT or VF events that triggered ICD therapy. The 30-day period following 9/11 was compared with each of three monthly periods preceding 9/11 and 13 monthly periods afterward. The number of patients who experienced a primary event during the 30 days before and after the 9/11 attack were compared using McNemar's test and the relative risk (RR) estimated using a Mantel-Haenszel statistic that accounts for the paired data. Kaplan-Meier survival curves (time to first event) were derived and paired survival curves tested using Gehan's test for paired censored survival data. Rates of events per 100 person-days were computed using all events (multiple events per subject). Monthly and daily discharge rates over the follow-up period were estimated using a logit model and a generalized estimating equation approach to account for within-subject correlation. Lowess curves with a span of 0.1 were used to illustrate the estimated daily discharge rates over time. Days from index date (August 12, 2001 or 9/11) and distance from WTC were compared using a rank-sum test. Probability of a device discharge after 9/11 as a function of subject characteristics was calculated by using logistic regression analysis.

RESULTS

The study population (Table 1) included a predominance of elderly men with coronary disease and reduced left ventricular ejection fraction. No patient died, but seven were hospitalized for non-arrhythmic causes during the 30-day follow-up after 9/11. Only five patients were eyewitnesses to the WTC attack, with none at the immediate vicinity.

In the 30 days preceding 9/11, 7 of the 200 patients (3.5%) had at least one tachyarrhythmia treated by ICD versus 16 (8.0%) in the 30 days afterward. Paired analysis indicated that risk of tachyarrhythmia increased 2.3-fold (95% confidence interval [CI] 1.1 to 4.9, p = 0.03) after 9/11. Only three patients had events both before and after 9/11. Survival curve analysis (Fig. 1) and analysis of daily total arrhythmic events frequency (Fig. 2) indicated no cluster of events immediately post-9/11. Rather, events increased cumulatively, with the mean onset of tachyarrhythmia occurring 12.4 ± 7.8 days post-9/11. Cumulative frequency of individual arrhythmic events (those separated by >1 h) also increased from pre- to post-9/11: 27 versus 45

Table 1. Characteristics of the Study Population

Age, yrs	68.8 ± 11.6
Gender, %	
Male	74
Female	26
Race, %	
White	70
Black	14
Hispanic	13
Asian	3
LV ejection fraction, %	34.5 ± 16.8
Underlying heart disease, %	
Coronary artery disease	83
Other	17
Medications, %	
Beta-blockers	70
ACE inhibitors	63
Antiarrhythmics	19
Aspirin	44
ICD indication, %	
VT	59
Cardiac arrest	28
Syncope/inducible VT	7
Other	6
Distance from WTC site, miles (range)	22.8 ± 23.4 (1–118)
Television viewing, h/day (range)	4.1 ± 2.5 (0–12)
Increased television watching (%)	
Not at all	71/158 (45)
A little bit	25/158 (16)
A moderate amount	29/158 (18)
Quite a lot	33/158 (21)

Means are presented ± SD.
ACE = angiotensin-converting enzyme; ICD = implantable cardioverter-defibrillator; VT = ventricular tachycardia; WTC = World Trade Center.

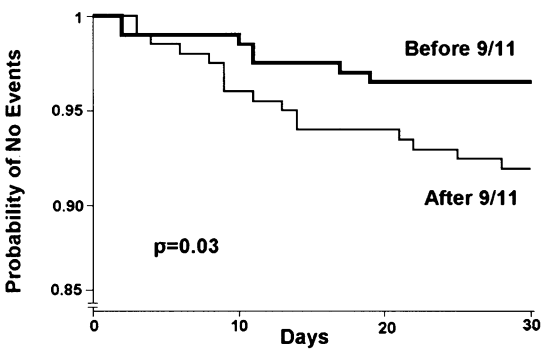

Figure 1. Kaplan-Meier survival curve comparing probability of implantable cardioverter-defibrillator (ICD) discharges for termination of ventricular tachycardia or ventricular fibrillation **(vertical axis)** for 30 days before and 30 days after September 11. A significantly greater proportion of patients experienced ICD discharges after the World Trade Center attack.

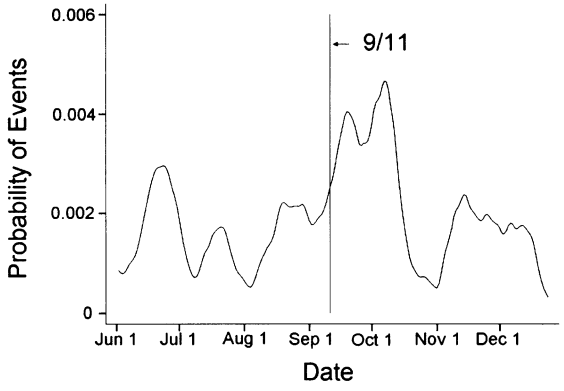

Figure 2. The day-to-day incidence of ventricular tachyarrhythmia triggering implantable cardioverter-defibrillator therapy during an eight-month observation period, with a substantial increase in event rate in the 30-day period after September 11, 2001, followed by a return to baseline.

instances for estimated rates of 0.45/100 and 0.75/100 person-days, respectively, and a RR = 1.67 (95% CI 1.03 to 2.68, p = 0.03). The first arrhythmic event post-9/11 did not occur until the third day post-attack (Fig. 1).

The incidence of tachyarrhythmia for the three monthly periods of May 11, 2001, to August 11, 2001, were 3.7%, 4.2%, and 3.2%, very similar to the formal 30-day control period. Following the increment in tachyarrhythmia incidence post-9/11, the incidence of tachyarrhythmias returned to baseline after approximately 30 days (Fig. 2), ranging between 2.1% and 5.4%. Compared with other months, the odds of ventricular arrhythmias for the 30 days post-9/11 was 2.9 (95% CI 1.6 to 5.3). An analysis combining all 30-day (monthly) periods indicated a significant effect of month (p = 0.045) and an estimated odds ratio of 2.6 (95% CI 1.4 to 4.9) comparing the 30-day period post-9/11 to the combined four 30-day periods before 9/11. An analysis of daily events revealed the same trend with a significant effect of month (p = 0.004) and an odds ratio of 2.5 (95% CI 1.5 to 4.3) comparing the 30-day period post-9/11 to the entire follow-up period. Principal characteristics of the ventricular arrhythmias occurring pre- and post-9/11 were similar (Table 2).

Univariate analysis of clinical and demographic data indicated that only tachyarrhythmia in the 30 days preceding 9/11 was a predictor of events post-9/11 (RR = 6.4, 95% CI 2.3 to 17.3, p = 0.01).

DISCUSSION

There was a significant increase in the frequency of life-threatening arrhythmias among our ICD patients in the 30-day period following the WTC attack. The incidence of VT and/or VF increased more than twofold, but in each instance, these arrhythmias were successfully terminated. Notably, there were no arrhythmic events for the first three days post-9/11, nor were the events clustered immediately thereafter. This stands in marked contrast to *immediate* increases in frequency of cardiac events reported with other disasters (1–5). The increased event rate returned to baseline levels after one month.

The only significant predictor of occurrence of ventricular arrhythmia following the WTC attack was the presence of a ventricular tachyarrhythmia before 9/11. Whereas seasonal variation in weather has been reported to influence the occurrence of ventricular arrhythmias (10), such effects were unlikely in our study because we noted no similar increase in arrhythmias from 9/11 to November 11, 2002. Further, potential effects of local pollution or seasonal variables are made less likely in light of a second study, evaluating ICD patients in Florida post-9/11, which observed findings very similar to our own (11).

The increase in ventricular tachyarrhythmias throughout our 30-day follow-up period raises a question as to the temporal duration of pathophysiologic abnormalities induced by acute disasters. Heretofore this has not been studied, except following the Hanshin-Awaji earthquake, where investigators had a unique opportunity to compare blood samples obtained pre-event to those post-event (4). A hypercoagulable state persisted for many weeks afterward. Another study found elevations of resting heart rates for two weeks following an Italian earthquake (12). In analogous fashion, it is possible that arrhythmogenic potential in our patient population may have been increased for weeks post-9/11. Acute mental stress can stimulate many factors that favor induction of cardiac events, including myocardial ischemia (13), coronary vasoconstriction (14), transient endothelial dysfunction (15), platelet activation (7), and proarrhythmic changes (16,17), but it is not clear whether any of these factors were an inciting mechanism here.

The delay in onset of arrhythmic events after 9/11 is more consistent with the presence of subacute stress in our patients. There are many potential factors that could have

Table 2. Characteristics of Ventricular Arrhythmias

Parameter	Pre-9/11	Post-9/11	p Value
Type of arrhythmia			
Ventricular tachycardia (%)	44/49 (90)	63/67 (94)	ns
Ventricular fibrillation (%)	5/49 (10)	4/67 (6)	ns
Termination (%)	42/49 (86) ATP	54/67 (80) ATP	ns
	7/49 (14) Shock	13/67 (20) Shock	
Cycle length (ms)	346.2 ± 10.2	315.6 ± 6.4	ns
Cycle length <280 ms (%)	9/49 (18)	15/67 (25)	ns

ATP = anti-tachycardia pacing; 9/11 = September 11, 2001; ns = not significant.

contributed to subacute stress, such as the pervasive media coverage, the prolonged and increased TV viewing in many of our patients post-9/11, the enormity of the losses and damage, and fear of additional attacks. Prospectively designed studies would be necessary to study such considerations further.

Study limitations. Because our study was conceived post-9/11, it suffered from limitations relative to prospectively designed studies. Because psychological stress was not measured, we are limited in assessing etiologic factors. Because our study was limited to an ICD population, we cannot readily extrapolate our findings to a broader spectrum of cardiac patients.

Conclusions. Following 9/11, there was an increased incidence of life-threatening arrhythmias among ICD patients. These findings should provide impetus for the medical community to develop uniform plans for coordinating future collection of all potentially relevant medical data in case of future catastrophic events. Were such efforts able to identify a cause for increased arrhythmogenicity or other medical morbidity, targeted prevention plans could be developed to protect relevant patient populations.

Reprint requests and correspondence: Dr. Jonathan S. Steinberg, Division of Cardiology, St. Luke's-Roosevelt Hospital Center, 1111 Amsterdam Avenue, New York, New York 10025. E-mail: jss7@columbia.edu.

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