Outcome of CPR in a Large Metropolitan Area — Where are the Survivors?

Lance B Becker, MD*
May Pat Ostrander, RN, MPH†
John Barrett, MD‡
George T Kondos, MD§
CPR Chicago
Chicago, Illinois

From the Section of Emergency Medicine, Department of Medicine, University of Chicago Hospitals and Clinics;* American Heart Association of Metropolitan Chicago;† Chicago Fire Department;‡ and Section of Cardiology, Department of Medicine, University of Illinois Medical Center,§ Chicago.

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Address for reprints: Lance Becker, MD, CPR Chicago, American Heart Association of Metropolitan Chicago, 20 North Wacker Drive, Room 1240, Chicago, Illinois 60606.

Study objectives: *Survival from out-of-hospital cardiac arrest in cities with populations of more than 1 million has not been studied adequately. This study was undertaken to determine the overall survival rate for Chicago and the effect of previously reported variables on survival, and to compare the observed survival rates with those previously reported.*
Design: *Consecutive prehospital arrest patients were studied prospectively during 1987.*
Setting: *The study area was the city of Chicago, which has more than 3 million inhabitants in 228 square miles. The emergency medical services system, with 55 around-the-clock ambulances and 550 paramedics, is single-tiered and responds to more than 200,000 emergencies per year.*
Type of participants: *We studied 3,221 victims of out-of-hospital cardiac arrest on whom paramedics attempted resuscitation.*
Measurements and main results: *Ninety-one percent of patients were pronounced dead in emergency departments, 7% died in hospitals, and 2% survived to hospital discharge. Survival was significantly greater with bystander-witnessed arrest, bystander-initiated CPR, paramedic-witnessed arrest, initial rhythm of ventricular fibrillation, and shorter treatment intervals.*
Conclusions: *The overall survival rates were significantly lower than those reported in most previous studies, all based on smaller communities; they were consistent with the rates reported in the one comparable study of a large city. The single factor that most likely contributed to the poor overall survival was the relatively long interval between collapse and defibrillation. Logistical, demographic, and other special characteristics of large cities may have affected the rates. To improve treatment of cardiac arrest in large cities and maximize the use of community resources, we recommend further study of comparable metropolitan areas using standardized terms and methodology. Detailed analysis of each component of the emergency medical services systems will aid in making improvements to maximize survival of out-of-hospital cardiac arrest. [Becker LB, Ostrander MP, Barrett J, Kondos GT, CPR Chicago: Outcome of CPR in a large metropolitan area — Where are the survivors? Ann Emerg Med April 1991;20:355-361.]*

INTRODUCTION

Survival from out-of-hospital cardiac arrest in cities with populations of more than 1 million has not been studied adequately. Most reports originate from midsized cities (population, approximately 500,000). Survival rates in these studies range from less than 1% to 33%.[1] Among the studies that document more than 200 arrests per year and include patients with all initial rhythms, survival rates also vary considerably — from less than 1% to 18% (Table 1).[2-14] The only published study that represents the overall experience of a large city reported a survival rate of 1%.[12] Bachman et al (northeastern Minnesota) and Stults et al (Iowa) demonstrated lower survival rates among rural and small city emergency medical services (EMS) systems.[2,15] Similarly, survival rates in large cities warrant description and evaluation for special characteristics that significantly affect survival rates.

The CPR Chicago project was created to answer questions about survival from cardiac arrest in the Chicago metropolitan area. The primary goals of the project were to establish a citywide data base of all Chicago Fire Department (CFD) cardiac arrests 1) to determine prospectively the overall survival rate for the city of Chicago, 2) to assess the effect of previously reported variables on survival, and 3) to compare the observed survival rates with those previously reported.

METHODS

System Description

The study area comprised the city of Chicago, which has approximately 3 million inhabitants in 228 square miles.[16] The Chicago EMS system is activated by dialing 911. All calls to 911 are answered by a Chicago Police Department dispatcher. The dispatcher refers calls for medical assistance to the CFD Fire Alarm Office, which receives more than 300,000 medical aid requests and dispatches more than 200,000 ambulance responses per year. Patients who are transported go to one of 46 designated CFD receiving hospitals. Only cardiac arrest victims not called in to 911 are excluded from this data base.

In the Chicago EMS system, two-person crews trained in advanced life support (ALS) staff 55 ambulances on a 24-hour-a-day basis. Training follows the National Department of Transportation curriculum used in most cities and covers intubation, defibrillation, IV line access, and pharmacotherapy. The curriculum requires a minimum of 390 hours of training plus 40 hours of continuing education per year. All 550 CFD paramedics were re-examined and recertified by uniform testing on cardiac disease during January 1987, the first month of the study.

Ambulance equipment is standard and meets the Illinois Department of Public Health requirements. Protocols to treat cardiac arrest, recommended by the American Heart Association, emphasize the importance of early defibrillation.[17] Medical control, education, and training are coordinated by five project medical directors.

Paramedics communicate with physicians at any of eight telemetry stations throughout the city. On receipt of a 911 call, a dispatcher notes the time and dispatches a paramedic unit. If a paramedic unit is not immediately available or is more than 18 blocks from the address, an ambulance assist unit staffed by firefighters trained in CPR is dispatched first, with paramedics following as soon as possible. This occurred in 10% of our cases. An ambulance assist unit is also dispatched if dispatchers recognize a cardiac arrest or paramedics call for backup at the scene of a cardiac arrest.

TABLE 1. *Survival rates for different locations*

Location/Year/Reference	No. of Cases Reported	Duration of Study	Cases per Year	Survival Rate N	Survival Rate %
Arrowhead/1986[2]	513	24	257	71	3
Auckland/1986[3]	405	12	405	72	18
Brighton/1973[4]	216	12	216	1	0
Chicago/1990	3,221	12	3,221	54	2
Israel/1988[5]	2,995	24	1,498	198	7
King County/1985[6]	2,043	89	275	373	18
Los Angeles/1983[7]	300	12	300	30	10
Lucas, Kent Counties, Michigan/1985[8]	3,849	84	550	274	7
Milwaukee/1989[9]	1,660	27	738	138	8
Pittsburgh/1984[10]	187	6	374	18	10
Seattle/1988[11]	1,287	25	618	155	12
Stockholm/1989[12]	548	12	548	4	1
Vancouver/1983[13]	358	10	430	34	9
Winnipeg/1980[14]	849	18	566	33	4

All studies listed reported an average of more than 200 arrests per year and all rhythms. When more than one report was available for a given city, we cited the larger series. Cases of obvious noncardiac cause, if included in the report, have been omitted.

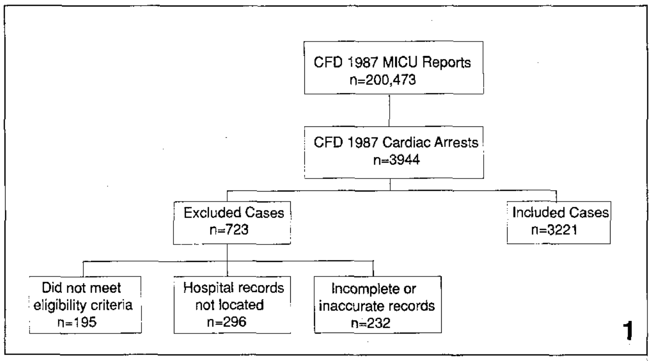
Sources of Information

The data were derived from four sources: 1) the dispatcher records for time of call to 911, 2) the mobile intensive care unit (MICU) reports completed by CFD paramedics during or after each ambulance call, 3) questionnaires completed by paramedics, and 4) hospital records. Emergency department and inpatient records of each cardiac arrest victim were abstracted by trained nurses and paramedics on the CPR Chicago staff. All 200,473 MICU reports filed with the CFD during 1987 were reviewed. In addition, each CFD district identified cardiac arrest records on a daily basis for the study.

The final data base for this project contained the patient's age, race, sex, and address; ambulance field times recorded by the CFD dispatchers (dispatch, arrival at scene, departure from scene, and arrival at hospital); patient's vital signs and cardiac rhythms as assessed by paramedics with the times each was observed; record of CPR, defibrillation, intubation, and drug therapy performed in the field with the times they were initiated; location of the arrest; problems encountered in gaining access to the patient; witnesses to the arrest; estimated time from collapse until paramedic arrival (preparamedic interval); number of rescuers; presence or absence of bystander CPR; patient's vital signs, cardiac rhythm, and primary diagnosis as assessed in the ED; resuscitative measures in the ED; medical history; dates and times of hospital admission; and hospital discharge or death of patient.

Case Definition

The study included all victims of nontraumatic cardiac arrest on whom CFD paramedics attempted resuscitation. Chicago EMS system policy dictates that only patients with decapitation, rigor mortis, or signs of physical decomposition are to be excluded from resuscitative attempts. Patients less than 18 years old, with physician-reported "terminal cancer," and in whom the cardiac arrest was secondary to an obvious noncardiac process were excluded. Obvious noncardiac processes identified in the ED chart included drug overdose, trauma, carbon monoxide poisoning, smoke inhalation, drowning, electrocution, gastrointestinal bleeding, airway obstruction, and ruptured abdominal aortic aneurysm. No ED or hospital record was located for 296 cases. The 232 cases with



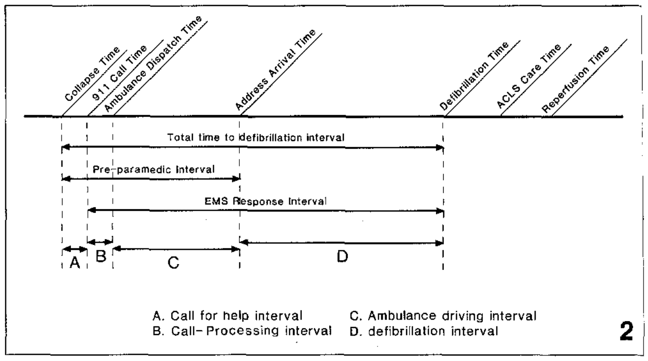


FIGURE 1. *CPR Chicago cases.*

FIGURE 2. *Times and intervals during emergency cardiac care.*

conflicting or missing data were excluded from analysis. The analysis of overall survival was performed on the remaining 3,221 cases (Figure 1).

Definition of Terms

"Survival" was defined as survival to hospital discharge. "Bystander-witnessed arrests" were arrests seen or heard by a witness before paramedic arrival. "Paramedic-witnessed arrests" were arrests occurring after the arrival of paramedics. Paramedic-witnessed arrests were excluded from analysis of bystander-witnessed arrests, bystander CPR, and response time. "Initial rhythm" was the first rhythm documented by paramedics. Rhythm data were not verified independently.

Time intervals from collapse until the initiation of CPR and definitive care crucially affected survival from cardiac arrest but were difficult to measure precisely in the prehospital setting.[18] We attempted to obtain the best estimates possible for times and intervals from patient collapse until arrival at the ED (Figure 2). A "time" referred to a single point, whereas an "interval" referred to the period elapsed between two time points. "Collapse time" was the moment the patient collapsed as estimated by witnesses. The "911 call time" was the time the call was received by the CFD dispatcher. "Ambulance dispatch time" was the time the central dispatcher instructed an ambulance to respond. "Address arrival time" was the time paramedics radio that they had arrived at the address. No data were available for the time of paramedic's arrival at the side of the patient. "Defibrillation time" was the time the first defibrillation was administered as estimated by paramedics. Times and intervals were defined schematically (Figure 2).

The mean call-processing interval (Figure 2) of one minute was determined from two sources: 1) a CFD EMS Oversight Committee Report from 1987 that documented a mean interval of one minute, and 2) a random survey of 100 records of cardiac arrest showing a median interval of one minute.

Statistical Analyses

All analyses were performed using Statistical Analysis System (SAS) software (SAS Institute, Cary, North Carolina). For continuous data, the t statistic was calculated to test the null hypothesis of no difference between the means of the two outcome groups (survivors and nonsurvivors). Results are given as mean ± SD.

The χ^2 statistic was calculated to test the assumption of no difference between the outcome groups for the discrete variables. A two-tailed $P < .05$ was considered significant. A multivariate analysis to determine which variables were most predictive of survival could not be performed because of the low numbers of survivors in the population.

RESULTS

The study population comprised 1,812 (56%) men and 1,409 (44%) women. In all, 1,689 (52%) were white, 1,390 (43%) were black, and 142 (4%) were Hispanic, Asian, or of unknown race. The mean age of the group was 67 ± 16 years. Women were on average five years older (70 ± 16) than men (65 ± 11 years). The incidence of out-of-hospital cardiac arrest as defined in the study was 107 of 100,000 in the population.

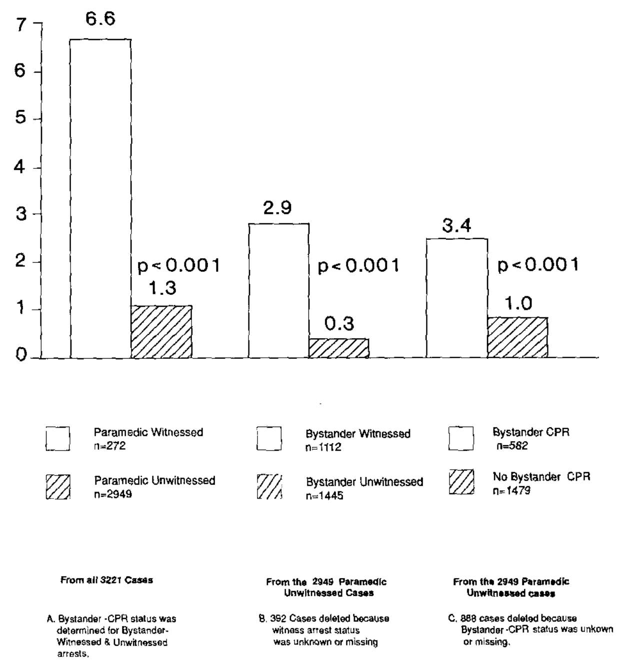
Most (77%) of the cardiac arrests occurred in private residences. In 29% (923 of 3,221) of cases, the paramedics reported a specific problem in gaining access to the patient. Problems most frequently cited were confined space of cardiac arrest environment (437 of 923; 47%), broken elevators (135 of 923; 15%), heavy patients (46 of 923; 5%), bad weather (40 of 923; 4%), hostile bystanders (26 of 923; 3%), and miscellaneous problems, including barking dogs, wrong addresses, difficult extrications, and locked doors (239 of 923; 26%).

Survival was determined for all 3,221 cardiac arrest cases. In all, 2,925 (91%) patients were pronounced dead in the ED, and an additional 241 (7%) were admitted to the hospital but subsequently died. There were 55 survivors; the survival rate for all 3,221 was 2%. Survival was significantly greater among patients with bystander-witnessed cardiac arrest, bystander-initiated CPR, or paramedic-witnessed cardiac arrest (Figure 3).

Survival among patients with an initial rhythm of ventricular fibrillation or ventricular tachycardia was significantly greater than among those with an initial rhythm of asystole or pulseless idioventricular rhythm ($P < .001$). Of the 2,949 arrests not witnessed by paramedics, survival in patients with an initial rhythm of ventricular fibrillation was 3% (17 of 664), ventricular tachycardia was 13% (two of 15), asystole was less than 1% (six of 1,780), and pulseless idioventricular rhythm was 0% (none of 248).

Survival also improved with shorter treatment intervals (Table 2). The mean preparamedic interval was 8 ± 7 minutes. There were significant differences in preparamedic intervals among survivors (3 ± 3 minutes) and nonsurvivors (8 ± 7 minutes) ($P < .05$). The mean defi-

FIGURE 3. *Survival rates among paramedic and bystander-witnessed arrests and arrests with bystander CPR.*



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brillation interval (address arrival until defibrillation) for patients with initial rhythms of ventricular fibrillation and ventricular tachycardia was 8 ± 5 minutes. The combined preparamedic interval and defibrillation interval (from collapse until defibrillation) totaled a mean of 16 minutes.

Among patients with combined favorable variables of bystander-witnessed arrest, bystander-initiated CPR, and initial rhythm of ventricular fibrillation or ventricular tachycardia, the survival rate was 10% (Figure 4). Among patients whose arrests were paramedic-witnessed and whose initial rhythm was ventricular fibrillation or ventricular tachycardia, the survival rate was 13%.

TABLE 2. *Interval durations*

Interval	Symbol	N	Time (Mean ± SD min)
Call for help*	A	692	2
Activation†‡	B	1	. . .
Ambulance driving†	C	3,221	5 ± 2
Defibrillation§	D	473	8 ± 5
Preparamedic*	. . .	711	8 ± 7
Total time to defibrillation*§	. . .	473	16

*Reported in 711 (72%) of 994 bystander-witnessed arrests.
†Centrally monitored and recorded.
‡Estimated one-minute constant interval (see "Methods").
§Estimated by paramedics for patients in ventricular fibrillation and ventricular tachycardia.

DISCUSSION

This study of cardiac arrest in a large urban population found significantly lower survival rates than those predicted by previous studies, which predominately originate from midsized cities with populations approximating 500,000. This suggests that special problems in Chicago (and perhaps in other large cities as well) may adversely affect outcome for patients in cardiac arrest.

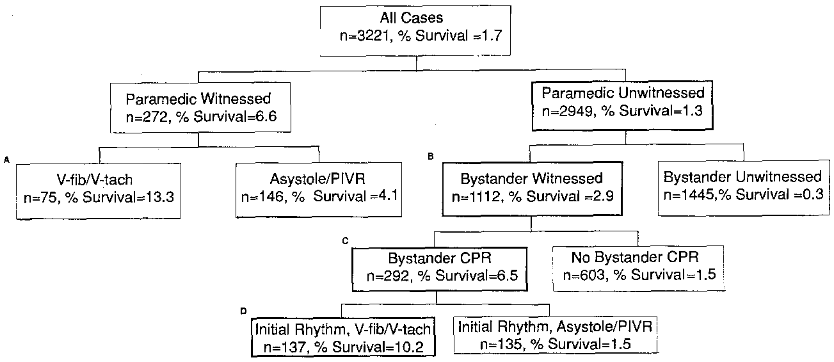
In our review of the literature, we examined all articles published in peer-reviewed journals from 1970 to 1989 that reported survival for out-of-hospital nontraumatic cardiac arrest patients, included all rhythms, and had a study population of more than 200 patients per year (Table 1). The only published data on large cities, based on this review, are from Stockholm (population, 1.6 million) and Los Angeles (population, 3 million). A year-long study of early defibrillation in Stockholm reported four survivors among 548 victims of cardiac arrest (less than 1%).[12] By design, the study reported only the subgroup of cardiac arrest patients treated with automatic external defibrillators. Nevertheless, this finding of a survival rate of less than 1% was our best source of published data about the experience in a large city.

In contrast, investigators from Los Angeles reported a survival rate of 10%. However, this study, again by design, combined suburban and metropolitan data and drew on a small overall number of patients relative to the total population.[7] Therefore, no published studies of survival from out-of-hospital cardiac arrest provide data on cities with more than 1 million inhabitants, include all patients within city boundaries, and include patients with all rhythms.

Emergency Cardiac Care System in Chicago

High survival rates from out-of-hospital cardiac arrest depend on all phases of the emergency cardiac care system to work efficiently. Like a weak link in a chain, a single deficiency in the system can lower overall survival rates. The major components of an effective emergency cardiac care system include a trained citizenry that is able to call rapidly for help and initiate bystander CPR, a rapid EMS response, and prompt defibrillation.

We analyzed these components in the Chicago system and highlighted areas that may be particularly problematic in large cities. Differences among studies in terminology, reporting practices, and methods of calculating time and incidence make it difficult to compare findings directly. This complicates the attempt to distinguish real problems of large cities (eg, EMS systems, demographics) from differences produced by re-



A. 51 cases among paramedic witnessed arrests had other rhythms as their initial rhythm.
B. 392 cases deleted because Bystander-witnessed status missing or unknown.
C. 217 cases deleted because Bystander-CPR status missing or unknown.
D. 20 cases excluded because initial rhythm classified as other; ie., not VF, VT, AS, ID.

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FIGURE 4. *Percent survival of most favorable subsets.*

search design and terminology.[19]

Citizen Response

We could not accurately determine the level of citizen training in CPR. However, the rate of bystander CPR (28%) was comparable to that in midsized cities with better survival rates.[1] The quality of performance of bystander CPR, rarely reported in the literature, is not reported here.[20,21]

EMS Response

The mean ambulance driving interval of five minutes was comparable to reports from midsized cities, but communities with shorter EMS response time intervals invariably show significantly better survival rates.[6,7,9-11] Large-city traffic, high-rise buildings, and other city access problems may significantly delay the optimal EMS response. Paramedics reported difficulties gaining access to patients in 29% of the cases. The precise time the paramedics arrived at the patient's side was not in our data base and was not reported in other studies. The time interval between the address arrival time and the paramedics' arrival at the patient's side may be critical in large cities and requires further investigation.

Unlike many cities studied, Chicago has a one-tiered rather than a two-tiered EMS system. A two-tiered system includes a first-response unit trained in basic life support (BLS) and, in many cases, defibrillation, followed when necessary by paramedics trained in ALS. In the Chicago one-tiered system, ALS paramedics respond to all requests for aid. An ambulance assist (BLS) unit may be dispatched for the reasons noted previously. However, in the majority of cardiac arrest cases, the ambulance assist unit is not present when the paramedics arrive and even when present, does not have defibrillation capability. Eisenberg et al, in analyzing 29 different EMS systems, reported the highest survival in systems that are two-tiered with the first responder capable of defibrillation.[1]

Interval to Defibrillation

Prompt defibrillation is an important factor in surviving cardiac arrest. We found a mean total interval of 16 minutes from collapse until defibrillation and an interval of eight minutes from paramedic arrival at the address until defibrillation. For comparison, the Milwaukee report stated that the "average EMT response time" is two minutes, and the King County report stated that the "average time interval from call until EMT arrival" is four minutes.[9,6] However, Los Angeles and Pittsburgh reported an average ambulance driving interval of five and six minutes, respectively, almost identical to our intervals.[7,10] None of these studies estimated a specific time point for the initiation of defibrillation and thus did not directly report the defibrillation interval. If Chicago data were presented only as the ambulance driving interval (five minutes on average), the time interval data would blend in with previous reports and neglect a potentially important interval in the treatment of cardiac arrest in large cities.

This lengthy interval until defibrillation is probably the one most important factor in Chicago's low survival rates. Accordingly, efforts directed at shortening this interval are our most promising approach to improving outcome.

An additional concern was the finding of 13% survival for patients who had paramedic-witnessed cardiac arrest, a figure lower than that reported by others.[22] One possibility is that these patients may have had different underlying diseases. A second possibility is that the interval between paramedic witness of the arrest and the actual initiation of defibrillation was longer than it needs to be, again raising the question of excessive time until defibrillation. Unfortunately, no data on these factors were available in Chicago, nor do most earlier studies provide data for comparison. The study of survival from paramedic-witnessed cardiac arrest warrants further study.

For Chicago, potential improvements in the emergency cardiac care system include educating the patient community, enhancing the ability of dispatch personnel to recognize cardiac arrest, improving traffic management for emergency vehicles, implementing a two-tiered response with the first responders using automatic defibrillators, creating additional first responders by training and equipping police and other nontraditional health care providers, and re-emphasizing the priority of rapid defibrillation.

Demographics of Large Cities

The demographics of large cities may influence outcome. Differences in socioeconomic characteristics and comorbid illnesses may be responsible for some differences between our results and those from midsized cities. The mean age of 67 ± 16 years seen in our study population is comparable to the mean ages reported by other cities, but other demographic differences exist.[1] According to 1980 census data, the population of Chicago is 48% white, 38% black, and 14% Hispanic and other minorities. Approximately 20% of the population has a family income at or below the proverty level.[16] In comparison, none of the cities listed (Table 1) reported such diversity. The effect of these demographic factors on survival rates requires further study.

Time Estimates

As suggested (Figure 2), the entire time sequence associated with the treatment of cardiac arrest is complex. As in most studies, data on times of events or treatments in the field are frequently estimated and recorded by paramedics after the arrest.

We based our time of collapse on bystander estimates of the preparamedic interval. On the surface, the average estimated preparamedic interval of eight minutes seemed plausible, considering that mean ambulance driving time was five minutes. As we examined our data, however, we became aware of conflicting time information. For example, in every arrest that occurs before 911 is called, the preparamedic interval (A + B + C in Figure 2) should always be greater than the sum of the call-processing and ambulance driving intervals (B + C). But we found discrepancies in 39% of our cases. These cases might lead us to conclude that 911 was called before the patient collapsed; however, we know from the narrative record that the patient's collapse came first.

We conclude that witnesses' estimates of the preparamedic interval were simply not reliable. Likewise, the defibrillation interval was not objectively recorded but instead was taken from the paramedic report completed after the event. Furthermore, there was no synchronization among dispatch times, ED times, and paramedics' watches.

Given the vital importance of these times in the field, future studies must find methods to document them more accurately. Potential solutions may lie in the use of computer-aided dispatch, synchronized paramedic watches, audio recorders with integral time channel recorders, audio recorders in defibrillation equipment, and other recording devices.

Implications for Change

As these results indicate, any change that shortens the interval until defibrillation may improve survival. Chicago is now developing a two-tiered response system that will involve the training of more than 3,000 firefighter first-responders to be capable of carrying out defibrillation. Additional paramedic units have been added. Ambulance dispatchers are now emergency medical technician certified. Funding has been provided to improve the 911 system and upgrade radio communications.

The system's effectiveness will be re-examined in a future study. At the same time, comprehensive data from other large cities are urgently needed to help determine precisely which factors most influence survival rates in large urban settings.

CONCLUSION

We prospectively studied out-of-hospital cardiac arrests during a one-year period in Chicago, a city of more than 3 million people. We found a disappointing 2% survival rate, significantly lower than that predicted by research from midsized cities but consistent with results from Stockholm, the only other large metropolitan area that has been comparably studied in the literature. These findings suggest that we have much to learn about out-of-hospital cardiac arrest in large cities.

In the United States, eight cities have populations of more than 1 million (New York, Los Angeles, Chicago, Houston, Philadelphia, Detroit, San Diego, and Dallas). With a combined population of more than 20 million, we can predict that in these cities, approximately 20,000 cardiac arrests will occur each year. Based on the most optimistic predictions from midsized cities, of these 20,000, as many as 3,600 people (18%) could survive out-of-hospital cardiac arrest. However, if predictions based on Chicago and Stockholm are applicable, only 200 to 400 people (1% to 2%) will survive. If we are to improve the survival rate in large metropolitan areas, we urgently need 1) further study of comparable metropolitan sites, 2) further study of each component of the EMS system, and 3) rigorous efforts among researchers to standardize terms and validate measurements.

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See related editorial, p 433.