Treatment of Ventricular Fibrillation

Emergency Medical Technician Defibrillation and Paramedic Services

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• **We compared the effect of rapid defibrillation by emergency medical technicians (EMTs) combined with paramedic care with that of standard EMT and paramedic care on survival from 540 witnessed episodes of out-of-hospital cardiac arrest caused by ventricular fibrillation. More than 400 EMTs were trained in the recognition of ventricular fibrillation and operation of a defibrillator. For a portion of the three-year study, emergency care for 179 cases was randomized between the two types of services. For randomized cases, when the time interval between EMT and paramedic arrival was greater than four minutes there was significantly improved survival with EMT defibrillation and paramedic care (42%) compared with basic EMT and paramedic care (19%). Similar findings occurred when all cases were considered (38% *v* 18%). Defibrillation by EMTs combined with paramedic services can enhance survival from ventricular fibrillation, compared with basic EMT and paramedic care.**

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THE SUCCESS of paramedic services in providing definitive treatment for out-of-hospital cardiac arrest has been documented in several large case series.[1-5] Discharge rates as high as 33% have been reported for patients with cardiac arrest caused by ventricular fibrillation.[5] In many communities, emergency personnel are effectively utilized in a tiered-response system. The first arriving tier consists of emergency medical technicians (EMTs) trained to provide cardiopulmonary resuscitation (CPR). Emergency medical technicians receive a standard 81-hour course in emergency care and often provide care as part of existing fire-fighting services. The second tier, arriving several minutes later, consists of paramedics able to deliver advanced cardiac life support (defibrillation, medications, and endotracheal intubation). Paramedic services are expensive because of extensive training (up to 1,500 hours) and dedicated personnel. In 1982, in King County, Washington, the annual cost of a paramedic program serving 100,000 people was $415,000. The success of a tiered-response system is related to the rapidity with which CPR is initiated and also to the brevity of the interval between collapse and the initiation of advanced cardiac life support.[6]

A community study in South King County, Washington, in 1978, demonstrated that EMTs trained to provide defibrillation improved survival from cardiac arrest compared with basic EMT care. This study used only a single-tier emergency system (paramedics were not available); 26% of patients in ventricular fibrillation were discharged when treated by EMTs trained in defibrillation compared with 7% of patients treated by basic EMTs.[7] We reasoned that EMTs trained in defibrillation could enhance survival from cardiac arrest in a tiered-response system. Furthermore, we hypothesized that the benefit of EMT defibrillation and paramedic care compared with basic EMT and paramedics would be greatest for cardiac arrests with long intervals between EMT and paramedic arrival. We report herein the results of a three-year study comparing EMT defibrillation and paramedic care with basic EMT and paramedic care.

METHODS

The study community was suburban King County, adjacent to Seattle. The entire area (600 sq miles, 598,000 population) consists of suburban and semirural areas with several small (10,000 population) towns and one medium-sized (72,000 population) incorporated city.

A case was defined as a person with heart disease who experienced out-of-hospital cardiac arrest caused by ventricular fibrillation and who received CPR. Only patients whose collapse was directly witnessed or heard were included in the study. A surveillance system identified all patients with out-of-hospital cardiac arrest.[6] There were 595 cases meeting the case definition. Excluded from the analysis were 26 patients whose collapse occurred after the arrival of paramedics and 29 cases with missing time values. Thirteen cases of arrest after EMT arrival but before paramedic arrival are included in the analysis. Thus, data are presented

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on 540 cases. Analysis was confined to witnessed episodes of ventricular fibrillation occurring before paramedic arrival to demonstrate the benefit, if any, of early EMT defibrillation. Patients not in ventricular fibrillation or those whose arrests are not witnessed are unlikely to benefit from defibrillation. Furthermore, we could not estimate resuscitation time intervals for unwitnessed cardiac arrest.

The period of study was June 1, 1979, through June 30, 1982. Emergency care was provided by EMTs and paramedics. There were approximately 1,200 volunteer and full-time EMTs employed by 38 fire departments. A total of 121 EMT rescue vehicles operated in the study area. Paramedics staffed a total of eight vehicles and operated under fire department, hospital district, and county health department auspices. During the study period, 406 EMTs received training in recognition of ventricular fibrillation and operation of a defibrillator. There were 42 EMT vehicles equipped with portable defibrillators modified with a two-channel cassette recorder to take continuous ECG and voice recordings.

Participation in EMT defibrillation was voluntary on the part of the fire department and the EMTs. Training consisted of a ten-hour course during three evenings provided in fire stations and taught by physicians (M.C., M.E.). The course curriculum included CPR review, arrhythmia recognition with emphasis on ventricular fibrillation, and the use of a defibrillator. Students were evaluated with a written test, and training manikins were used to assess the ability to recognize and manage ventricular fibrillation satisfactorily. Fifty EMTs did not complete the course either through withdrawal (45) or unsatisfactory performance (five).

Standing orders authorized the defibrillator-trained EMTs to deliver up to three 320-joule shocks for ventricular fibrillation. No medications, tracheal intubation, or use of esophageal obturator airways were authorized.[8] Training costs were negligible because instructor time was contributed and EMTs volunteered for the training without pay. Classes in 1979 used a dog laboratory (total cost, $2,000) that was dropped in subsequent classes.

For a portion of the study, June 1, 1979, through March 16, 1981, EMT defibrillation was provided in a random fashion within the 23 busiest fire departments. A limited number of defibrillators and monitors precluded participation of all the departments. There were 42 emergency vehicles within the 23 departments. Half of the emergency vehicles were equipped with ECG monitors and defibrillators and the other half with ECG monitors without defibrillators. Every 75 days the defibrillators were switched. In other words, at any given moment during the period of randomization, only half the participating EMT units could defibrillate. The period of randomization coincided with a grant-funded study protocol. On March 17, 1983, alternation of the defibrillators ended and, in accordance with the program plans of the King County Emergency Medical Services Division, EMT defibrillators were available if the fire department chose to provide EMT defibrillation services. Eleven additional departments chose to participate, and data collection continued on all cases through June 30, 1982. Data are presented from the randomized period as well as from the entire study period pooling randomized and nonrandomized cases.

Outcomes were determined for all patients. Patients admitted to hospital were followed up until death or discharge. Data routinely collected on all patients included time intervals relating to the provision of emergency care, whether the collapse was witnessed (seen directly or heard), and the identity of the person initiating CPR. Emergency vehicle response times were determined from incident reports. The time from collapse to initiation of CPR was estimated based on telephone interviews with emergency personnel and with bystanders. When cardiac arrest occurred after arrival of EMT personnel, the time from collapse to start of CPR was arbitrarily given as 0.5 minutes. Paper ECG tracings and cassette recordings of both ECGs and voices of emergency personnel for each case of cardiac arrest were reviewed to determine presence of ventricular fibrillation, occurrences of defibrillatory shocks, response to shocks, and time interval until arrival of paramedics.

The basis for cardiac arrest was determined from available sources of information, including autopsy, medical history (including medications) from family members, emergency agency run reports, and death certificates.

Data analysis was based on univariate techniques, primarily χ^2 analysis and a χ^2 test for linear trends in proportions. A multivariate analysis of outcome involved a multiple logistic regression model.[9]

Table 1.—Characteristics of Witnessed Cases of Cardiac Arrest in Ventricular Fibrillation Treated by Basic EMT and Paramedics* and EMT Defibrillation and Paramedics

	Randomized Cases		All Cases	
	Basic EMT and Paramedics	EMT Defibrillation and Paramedics	Basic EMT and Paramedics	EMT Defibrillation and Paramedics
No. of cases	79	75	366	174
Mean age (SD)	61.7 (±11.1)	62.9 (±13.3)	63.4 (±11.8)	63.2 (±12.8)
% male	86	85	79	87
% of cases with bystander CPR†	42	37	38	40
Mean time from collapse to CPR, min (SD)	3.0 (±1.9)	3.5 (±2.6)	3.6 (±2.8)	3.4 (±2.6)
Mean response time of EMT unit, min (SD)	3.6 (±1.5)	3.8 (±1.7)	4.3 (±2.0)	3.9 (±2.1)
Mean response time of paramedic unit, min (SD)	8.5 (±4.0)	9.6 (±4.3)	8.2 (±3.7)	10.0 (±4.6)
No. (%) of cases discharged	29 (37)	29 (39)	113 (31)	63 (36)

*The emergency medical technicians (EMTs) were trained in defibrillation but were only provided with monitors and could not provide defibrillatory shocks.
†CPR indicates cardiopulmonary resuscitation.

Table 2.—Witnessed Cases of Ventricular Fibrillation Discharged After Basic EMT* and Paramedic Care or EMT Defibrillation and Paramedic Care

Interval Between Arrival of EMTs and Paramedics, min	Randomized Cases					All Cases				
	EMT and Paramedic		EMT Defibrillation and Paramedic			EMT and Paramedic		EMT Defibrillation and Paramedic		
	N	Discharges, No. (%)	N	Discharges, No. (%)	P	N	Discharges, No. (%)	N	Discharges, No. (%)	P
0-4	43	22 (51)	32	11 (34)	NS	229	88 (38)	70	24 (34)	NS
>4	36	7 (19)	43	18 (42)	<.05	137	25 (18)	104	39 (38)	<.001

*EMT indicates emergency medical technician.

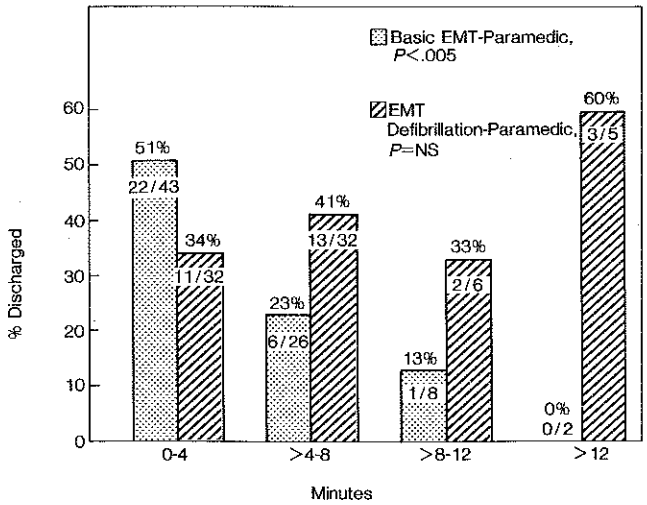

Fig 1.—Witnessed cases of ventricular fibrillation discharged after basic emergency medical technician (EMT) and paramedic care and EMT defibrillation and paramedic care for various time intervals between arrival of EMTs and paramedics—randomized cases. *P* value denotes test of trends; NS indicates not significant.

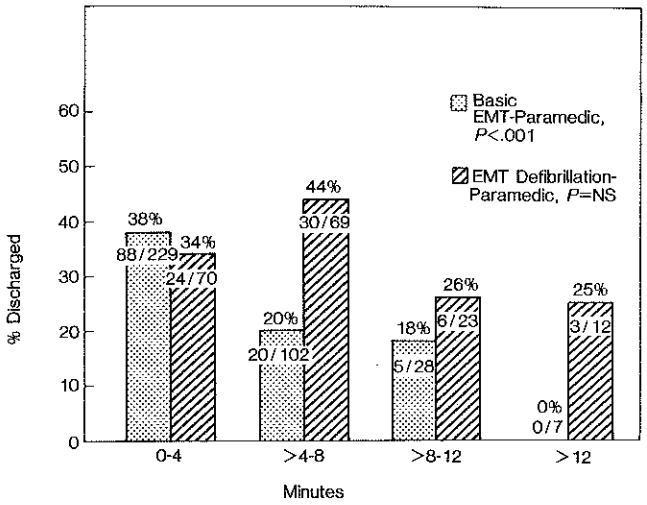

Fig 2.—Witnessed cases of ventricular fibrillation discharged after basic emergency medical technician (EMT) and paramedic care and EMT defibrillation and paramedic care for various time intervals between arrival of EMTs and paramedics—all cases. *P* value denotes test of trends; NS indicates not significant.

RESULTS

There were no significant differences in age, sex, bystander involvement, or response times between patients (EMT defibrillation *v* basic EMT) during randomized period or during the overall study (Table 1). During the randomized period, 79 patients received basic EMT and paramedic care and 75 received EMT defibrillation and paramedic care. The percentage of patients discharged with 37% and 39%, respectively. During the overall study period there were 540 cases.

Basic EMT and paramedic care was provided in 366 cases and 174 received EMT defibrillation and paramedic care. Patients treated by EMT defibrillation and paramedics fared slightly better, 36% discharged, than those receiving basic EMT care, 31% discharged. The difference was not significant ($P=.22$).

The percentage of patients discharged in relation to the time interval between arrival of EMTs and arrival of paramedics shows significant differences for the two types of services. When the interval between EMTs and paramedics was four minutes or less, there was no statistically significant difference in survival between cases receiving EMT and paramedic care and those receiving EMT defibrillation and paramedic care (51% and 34%, respectively, for randomized cases and 38% and 34%, respectively, for all cases). When the interval was greater than four minutes, 19% of randomized cases treated with basic EMT and paramedic care were discharged compared with 42% of patients treated with EMT defibrillation and paramedic care ($P=.05$). For all cases with an interval greater than four minutes, survival among patients treated by basic EMTs was 18% compared with 38% for those treated by EMT defibrillation ($P<.001$) (Table 2).

The relationship of patients discharged to various time intervals between EMT and paramedic arrival for the two types of services is shown in Fig 1 for those patients whose care was randomized and in Fig 2 for all patients. Both figures show a dramatic decrease in survival for cases treated by basic EMTs and paramedics as the interval between EMT and paramedic care increases. When this interval was longer than 12 minutes, there were no discharged patients (test of trends, $P<.001$ for all cases and $P<.005$ for randomized cases). On the other hand, for patients receiving EMT defibrillation and paramedic care, there was no apparent decrease in survival (test of trends for all cases and randomized cases were not significant).

Only 43% of patients in ventricular fibrillation received EMT defibrillatory shocks in the zero- to four-minute time interval compared with 77% when the interval was greater than four minutes. (Based on tape recordings of resuscitations, it seemed to take two to four minutes for EMT defibrillation personnel to initiate CPR, attach electrodes, and interpret the rhythm.)

The observed difference in outcome (EMT defibrillation *v* basic EMT) was not associated with any single factor, eg, age, sex, response time, or bystander involvement. A multivariate analysis was performed to determine whether the observed differences in outcome could be explained by a combination of variables. Adding the type of service (basic EMT and paramedic *v* EMT defibrillation and paramedic) to the best multivariate fit obtained from the other variables, including the interval between the arrival of EMTs and paramedics, improved the regression significantly ($P<.01$). Thus, EMT defibrillation services had a significant positive impact after controlling for other variables.

We detected no instances in which defibrillatory shocks were inappropriately delivered. There were, however, 36 instances in which defibrillatory shocks were not given by EMT defibrillation personnel because of insufficient time to attach the electrodes and assess the cardiac rhythm before arrival of paramedics. There were two instances of failure because of improper maintenance of the defibrillator and eight instances in which EMTs failed to diagnose ventricular fibrillation and, thus, did not deliver

possibly beneficial defibrillatory shocks.

COMMENT

Defibrillation by EMTs is a relatively new concept. The first demonstration of benefit occurred in 1978 in communities without paramedic care.[7] In this study, we determined whether a tiered-response EMT system utilizing EMT defibrillation combined with paramedic care was better than basic EMT and paramedic care. Overall, survival was only slightly improved with EMT defibrillation and paramedic care. However, when the cases were stratified by time intervals between EMT and paramedic care, a definite benefit emerged. When the interval exceeded four minutes, survival was lower with basic EMT care. When more than 12 minutes elapsed between arrival of basic EMTs and arrival of defibrillator-equipped paramedics, none of seven patients survived. However, three of 12 patients survived when defibrillation was instituted by EMTs, even though more than 12 minutes elapsed before arrival of paramedics (all three survivals occurred during the randomized period, a finding perhaps explained by the small number of cases in the longest time interval).

Not readily explainable is the higher survival in the zero- to four-minute time interval when treatment was provided by basic EMTs (Fig 1). The difference is not significant (P=.14) and it does not appear to the same degree when all cases are considered (Fig 2), but it is potentially important. A possible explanation is that the EMT defibrillation personnel delayed CPR while assessing the cardiac rhythm. Although we could not measure inappropriate delays, EMT defibrillation training following the randomized period stressed the need to minimize delays in CPR. In fact, there was no difference in survival in the zero- to four-minute time interval in 66 of 186 *v* 13 of 38 cases for the much larger series of cases that occurred after the randomized period.

The selection of cases was purposeful in order to demonstrate the possible benefit of rapid defibrillation by EMTs. Patients with unwitnessed cardiac arrest even if found to be in ventricular fibrillation have a poor prognosis.[6,7] Furthermore, it is not possible to measure time intervals for unwitnessed cardiac arrest cases.

Unmeasured interventions could, in part, explain the improved survival rate. For example, as part of the special defibrillation training, each EMT received a three-hour review and test in basic CPR. Hence, patients treated by EMT defibrillation may have received better CPR, which could account for part of the improved outcome. We doubt this played a large role, if any, as the possible benefit of better CPR was controlled for in the randomized cases. Furthermore, improved survival with EMT defibrillation care was not evident in all cases but only for those with longer intervals before paramedic arrival.

This study did not compare EMT defibrillation services with paramedic services but merely assessed the additive benefit of one service to the other. Clearly, paramedics are trained to handle a variety of emergency conditions and can administer intravenous solutions, medications, and provide advanced airway support—skills EMT defibrillation personnel cannot perform. A definitive, comparative study would require randomization of paramedic and EMT defibrillation services.

Defibrillation by EMTs combined with paramedic services can enhance survival from ventricular fibrillation compared with basic EMT and paramedic care. This benefit is most evident when the time interval between EMT and paramedic arrival is greater than four minutes.

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