

Paramedic Programs and Out-of-Hospital Cardiac Arrest: I. Factors Associated with Successful Resuscitation

MICKEY EISENBERG, MD, MPH, LAWRENCE BERGNER, MD, MPH, AND ALFRED HALLSTROM, PhD

Abstract: As part of an evaluation of whether the addition of paramedic services can reduce mortality from out-of-hospital cardiac arrest compared to previously existing emergency medical technician (EMT) services, factors associated with successful resuscitation were studied. A surveillance system was established to identify cardiac arrest patients receiving emergency care and to collect pertinent information associated with the resuscitation. Outcomes (death, admission, and discharge) were compared in two areas with different types of prehospital emergency care (basic emergency medical technician services vs. paramedic services).

During the period April 1976 through August 1977, 604 patients with out-of-hospital cardiac arrest received emergency resuscitation. Eighty-one per cent

of these episodes were attributed to primary heart disease. Considered separately, four factors were found to have a significant association with higher admission and discharge rates: 1) paramedic service, 2) rapid time to initiation of cardiopulmonary resuscitation (CPR), 3) rapid time to definitive care, and 4) bystander-initiated CPR. Using multivariate analysis, rapid time to initiation of CPR and rapid time to definitive care were most predictive of admission and discharge. Age was also weakly predictive of discharge. These findings suggest that if reduction in mortality is to be maximized, cardiac arrest patients must have CPR initiated within four minutes and definitive care provided within ten minutes. (Am. J. Public Health 69:30-38, 1979.)

Introduction

The goal of paramedic programs* is to reduce mortality from medical emergencies. Few studies have attempted to evaluate the attainment of this goal. Rather than studying the outcome, namely a reduction in mortality, most studies have focused on structure or process.¹⁻⁴ The few studies considering outcome have been uncontrolled case series⁵⁻⁸ or uncontrolled community studies.^{9, 10} While it is indisputable that paramedics can save lives, particularly patients in cardiac arrest due to ventricular fibrillation, the quantitation of this on a community basis has not been demonstrated. Fur-

thermore, the identification of factors associated with successful resuscitation has not been well documented.

The purpose of this paper is to identify factors associated with successful resuscitation from out-of-hospital cardiac arrest. The results are from the initial period of a three-year outcome evaluation of paramedic services in King County, Washington.

Methodology

The overall study, known locally as Product Restart and reported in detail elsewhere¹¹ is designed to evaluate whether the addition of a paramedic program can reduce mortality from sudden cardiac arrest when compared to the previously existing emergency medical technician (EMT) services. The study, located in suburban King County, Washington, began in April 1976. King County is the largest metropolitan community in the state of Washington and includes the city of Seattle. The study area (1976 population 598,000) is comprised of the more densely populated suburban ring surrounding Seattle. It does not include Seattle, which has paramedic services provided by the Seattle Fire Department. During the initial period of the study, part of the area received EMT services and the remainder received paramedic services (see Figure 1). The two areas are very similar in demographic characteristics such as proportion of population over age 65 and male to female ratio. The population is over 98 per cent Caucasian. Both areas are predominately middle to upper middle class with the paramedic area having slightly higher socioeconomic characteristics. Information was obtained on every cardiac arrest incident meeting the

From the Robert Wood Johnson Clinical Scholars Program, University of Washington, King County Department of Public Health, and the Department of Biostatistics, University of Washington. Address reprint requests to Dr. Mickey Eisenberg, Emergency Medical Services Division, King County Department of Public Health, 5th Floor, Smith Tower, Seattle, WA 98104. This paper, submitted to the Journal February 8, 1978, was revised and accepted for publication June 24, 1978.

*A paramedic program is defined as an emergency service whereby individuals trained in advanced life support (defibrillation, intubation, cardiac medications) can respond to out-of-hospital emergencies. Paramedics receive up to 1,500 hours of training. In many communities paramedic programs offer a variety of emergency services but most are characterized by treatment of patients with suspected myocardial infarction and cardiac arrest. The terminology for these programs is not uniform. They are also known as mobile intensive care, mobile coronary care, or advanced emergency medical technician programs. In contrast to paramedics, emergency medical technicians (EMTs) receive only 80 hours of training and are able to provide only basic life support such as cardiopulmonary resuscitation (CPR).

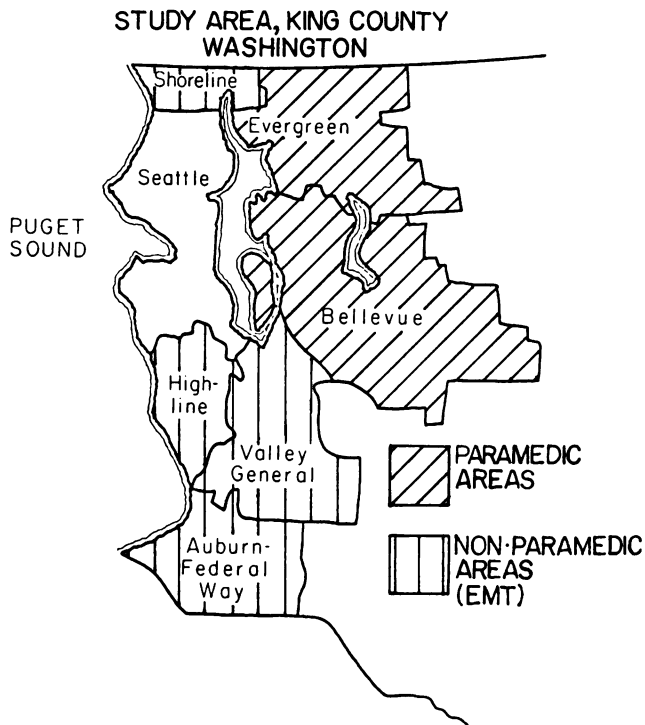


FIGURE 1—Paramedic and EMT Study Areas in King County, Washington*

case definition which occurred in the study area in suburban King County. ** Only out-of-hospital events were considered and all ages were included. Trauma (accidents, gunshot wounds, etc.) was specifically excluded because of previous unsuccessful efforts to define and demonstrate adequately a valid tool to assess emergency intervention.¹²

A questionnaire was completed by all 34 emergency agencies (27 fire departments, two paramedic programs, four ambulance companies, and King County Police) in the two study areas following each cardiac arrest in which CPR was performed. In addition, back-up surveillance systems (review of hospital logs and County Division of Emergency Medical Service Incident Report forms) were maintained to identify incidents not directly reported. Approximately 5 per cent of the cases were identified by the back-up surveillance systems. For each cardiac arrest the following information was obtained:

- 1) Patient identifying information
- 2) Type of prehospital care (EMT or paramedic)
- 3) Time from collapse to initiation of CPR
- 4) Time from collapse to definitive care (defined as advanced emergency procedures such as defibrillation, intubation, and emergency medications)

- 5) Duration of CPR
- 6) Response time of the emergency agency
- 7) The person or agency initiating CPR
- 8) Whether the collapse was witnessed
- 9) Weight of the patient
- 10) ECG rhythm (the busiest EMT departments were provided with lightweight portable ECG machines to record the cardiac rhythm. We obtained ECG rhythm strips in 25 per cent of EMT cases and a tracing or a report of the rhythm in virtually 100 per cent of those treated by paramedics)
- 11) Outcome: Death or admission to an intensive care or coronary care unit was used as a measurable outcome rather than "admission" to the emergency room, since frequently CPR is continued after arrival in the emergency room, thus making it difficult to decide where death occurs for unsuccessful resuscitation.

Times were determined through fire department or ambulance company dispatch logs, run reports, and phone interviews with bystanders. Times were rounded to the closest half-minute. Times were considered unknown in those instances (22 per cent) when a time of collapse could not be determined, for example in unwitnessed cardiac arrest. In addition, each incident was classified by etiology. Clinical information was obtained from the hospital, and autopsy and death certificate information was reviewed. Primary heart disease was defined as death certificate or hospital discharge diagnosis of acute or chronic ischemic heart disease (ICDA codes 410-414).[†] Admitted patients were followed to determine if discharge occurred and were followed after discharge to determine long-term survival.

Statistical Analysis

Associations between individual variables and resulting outcomes were computed using Chi Square. In order to determine which variables were the best predictors of outcome, logistic regression analysis was used. Logistic regression analysis is an attempt to regress a discrete outcome variable, in this case death, admission, or discharge against both discrete (for example, sex) and continuous (such as response time) variables. Maximum likelihood techniques applied to the logistic model were used to relate the probability of a favorable outcome for an individual to his/her values on a number of variables such as age, sex, time to initiation of CPR, time to definitive care, type of service, etc.

Results

During the period of April 1976, through August 1977, 604 incidents of out-of-hospital cardiac arrest in which CPR was initiated occurred in the study area. The annual incidence (7.1/10,000) was similar in paramedic and EMT areas. The vast majority, 487 (81 per cent), of these events were ascribed to a primary heart disease etiology. Other conditions associated with cardiac arrest in the community were

*Seattle, not included in this study, has paramedic services provided by the Seattle Fire Department.

**A case was defined as a patient with cardiac arrest with a pulseless condition (confirmed by an EMT or paramedic) for whom CPR was initiated.

[†]Acute and chronic heart disease were not separated in analysis because we do not believe local physicians adequately distinguish between them on death certificates.

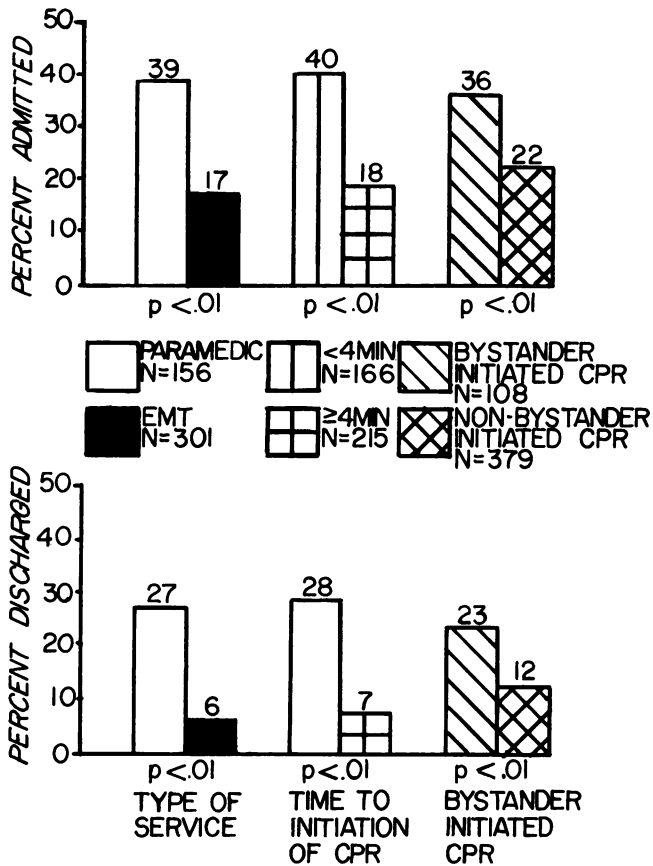


FIGURE 2—Type of Service, Time to Initiation of CPR, Bystander-Initiated CPR and Outcome of Cardiac Arrests Due to Primary Heart Disease, April 1976-August 1977, King County, Washington

cancer (4 per cent), neurologic disease (3 per cent), respiratory disease (3 per cent), drowning (2 per cent), sudden infant death (2 per cent), suicide and non-suicide drug overdoses (2 per cent); all other etiologies comprised 3 per cent. Although the study did not collect information on CPR performed on trauma patients, through empirical observation and from information provided by the King County Medical Examiner such cases represented less than 5 per cent of the total CPR incidents in the community.

Type of service (paramedic), a short time to initiation of CPR, bystander initiated CPR, and a short time to definitive care were each significantly associated with successful outcome (Figures 2 and 3).^{‡‡} A striking association was found between the type of service and outcome. For primary heart disease patients experiencing cardiac arrest in paramedic areas, 39 per cent were admitted to hospital, compared to 17 per cent in non-paramedic areas ($p < .01$). In paramedic areas 27 per cent were discharged alive compared to 6 per cent in non-paramedic areas ($p < .01$). If CPR was initiated within four minutes of collapse, 40 per cent of patients were admitted and if CPR took four or more minutes to initiate, 18

^{‡‡}In considering this and all subsequent relationships, only the 487 CPR incidents due to primary heart disease are considered.

per cent were admitted ($p < .01$); 28 per cent and 7 per cent respectively were discharged ($p < .01$).^{*} If a citizen-bystander initiated CPR, 36 per cent of patients were admitted compared to 22 per cent for emergency personnel-initiated CPR ($p < .01$). For discharge these rates were 23 per cent and 12 per cent respectively ($p < .01$) (Figure 2).

As seen in Figure 3, an approximately linear relationship existed between time from collapse to definitive care and outcome. If, for example, time to definitive care was less than six minutes, 67 per cent of patients were admitted and 52 per cent discharged. On the other hand if time to definitive care was greater than 12 minutes, 16 per cent were admitted and 6 per cent discharged. The average time to definitive care in the paramedic area was nine minutes and in the EMT area it was 28 minutes.

The above relationships between outcome and certain variables pertain to all patients with cardiac arrest due to primary heart disease regardless of cardiac rhythm at the time of the arrest. Cardiac rhythms were determined at the scene in 50 per cent of the cardiac arrests and ventricular fibrillation was documented in 63 per cent of these patients. If only patients with ventricular fibrillation are considered, similar relationships between outcome and time to definitive care are found although showing higher percentages for both admission and discharge (e.g., of 52 patients in ventricular fibrillation who received definitive care in less than six minutes, 73 per cent were admitted and 57 per cent were discharged).

Table 1 displays the results of the multivariate analysis (logistic regression). Because several variables are related, multiple specifications of a logistic model were considered. The most significant logistic model occurred with the inclusion of time to initiation of CPR, time to definitive care, and age. Other variables studied (type of service, bystander initiated CPR, sex, response time, collapse witnessed directly, patient's weight) when added to the model singly or in

^{*}Stratification at less than four minutes and four minutes or more was chosen because it resulted in the greatest difference in outcome. Accurate times could not be determined in 106 (22 per cent) episodes.

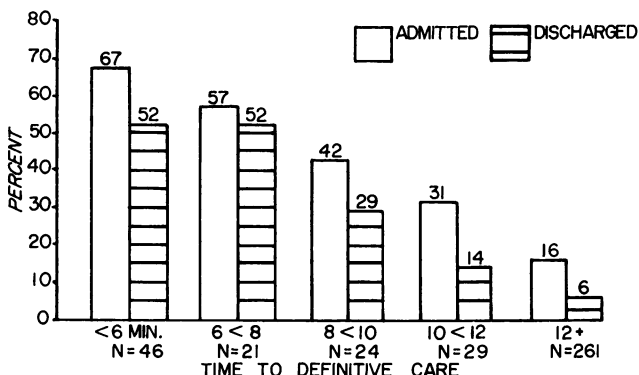


FIGURE 3—Time to Definitive Care for Cardiac Arrests Due to Primary Heart Disease, April 1976-August 1977, King County, Washington

TABLE 1—Results of Logistic Regression Analysis

Variable	Admission	Discharge
1. Time to Initiation of CPR	$p < .01 (-.13 \pm .04)^*$	$p < .01 (-.14 \pm .05)$
2. Time to Definitive Care	$p < .02 (-.054 \pm .01)$	$p < .01 (-.10 \pm .01)$
3. Age	NS	$p < .05 (-.04 \pm .01)$
4. Sex	NS	NS
5. Weight	NS	NS

Constant coefficient for model: .57 (admission); 2.84 (discharge).

*Regression coefficient; \pm one standard deviation are in parentheses

NS = Not significant

groups did not significantly improve the predictive value. The variables "time to initiation of CPR," "response time," "bystander initiated CPR," "collapse witnessed directly" are related and substituting any of the latter three variables for time to initiation of CPR provided a predictive model. The model with any of these related variables was not as predictive as with time to initiation of CPR. Similarly, type of service resulted in a predictive model although not as predictive as with time to definitive care. In sum, knowledge of time to initiation of CPR and time to definitive care provided the best predictive model; knowledge of the related variables did not improve the ability to predict the outcome.

Discussion

We have demonstrated several factors which were significantly associated with a successful outcome from out-of-hospital cardiac arrest. Considered separately, the variables of type of service, time to initiation of CPR, time to definitive care, and bystander initiated CPR were significantly associated with outcomes of admission and discharge. Using multivariate analysis (logistic regression) the best predictive model included time to initiation of CPR and time to definitive care. Age was weakly associated with discharge in this model. The fact that the variables of type of service and bystander initiated CPR did not significantly improve the model should not be surprising. Bystander initiated CPR is invariably synonymous with early initiation of CPR. Since bystanders, as we have employed the term, are by definition at the scene of cardiac arrests, it is logical that CPR will be initiated rapidly (assuming the bystander attempts CPR). Hence when considered alone, bystander initiated CPR seems significant but actually is reflecting the significance of early initiation of CPR.

Similarly the type of service reflects the time to definitive care. The treatment ultimately is the same in both EMT and paramedic areas since patients in EMT areas receive definitive care at the hospital rather than at the scene. However, paramedics bring definitive care (defibrillation, intubation, medication) to the scene of a cardiac arrest while EMTs can only perform CPR and must transport the patient to the hospital for definitive care. Consequently the time to definitive care in EMT areas is much longer (28 minutes) than in paramedic areas (9 minutes). Hence the type of service is largely a reflection of the time to definitive care.

The factors of time to initiation of CPR and time to definitive care are most important in determining successful outcome. A short time to initiation of CPR without a relatively rapid time to definitive care is little better than if the initiation of CPR is delayed. Similarly, a relatively rapid time to definitive care without a rapid time to initiation of CPR also will produce a poor outcome. CPR, no matter how well performed, cannot approximate normal cardiac contraction. Until definitive care can be provided anoxic damage may occur in the vital organs. The sooner definitive care can be provided, the less damage is likely to occur. This is borne out by the linear relationship seen in Figure 3.

The findings of such strongly predictive variables have obvious implications for public policy by confirming that the relatively short time to definitive care provided by paramedics is associated with a higher rate of admission and discharge compared to the longer times and poorer outcomes in EMT areas. This suggests that there may be an intermediate programmatic approach, namely EMTs trained in defibrillation but not certified to perform other definitive procedures.** It also points out that a new paramedic service without CPR being initiated within four minutes is not likely to be successful. One alternative to accomplish early initiation of CPR is with citizen training. Another alternative is to have multiple aid units staffed with EMTs such that a four minute response time is feasible. The latter characterizes the tiered response system which is the foundation of the successful Seattle Fire Department Medic I program. The former alternative is probably the most feasible where population densities are lower and travel times greater. It is interesting to note that the city of Seattle has added wide scale citizen training in CPR to its program and King County has embarked on a similar course of action in 1978. As long as CPR can be initiated within four minutes, it is possible to "buy time" until definitive care can be provided.

The data presented are from the initial period of a before and after outcome evaluation of paramedic services. Since data are from the before period, it is only possible to draw cross-community comparisons. After the initiation of paramedic services in EMT areas, it will be possible to draw before and after comparisons within the same community. Data will continue to be collected in the area that had para-

**This approach will be implemented on an experimental basis in King County.

medic services in the before period and in one portion of the study area that will continue with EMT level service thus providing a quasi-experimental situation¹³ and reducing the possibility of bias due to intervening variables.

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