Automatic External Defibrillation and Its Effects on Neurologic Outcome in Cardiac Arrest Patients in an Urban, Two-Tiered EMS System

Jeffrey Ho, MD; Timothy Held, BA, EMT-P; William Heegaard, MD, MPH; Timothy Crimmins, MD

Abstract

Objective: To describe the use of the Automatic External Defibrillation (AED) device in an urban, two-tiered Emergency Medical Service (EMS) response setting with regard to its potential effects on cardiac arrest patient survival and neurologic outcome.

Methods: A retrospective and descriptive design was utilized to study all cardiac arrest patients that had resuscitations attempted in the prehospital environment over a 30-month period. The study took place in a two-tiered EMS system serving an urban population of 368,383 persons.

Results: In this study, a 20.2% survival to hospital discharge rate was obtained. Seventy-seven percent of these survivors had a moderate to good neurologic outcome based on the Glasgow–Pittsburgh Cerebral Performance Categories.

Conclusion: First responder-based AED usage on patients in ventricular fibrillation or pulseless ventricular tachycardia can be applied successfully in an urban setting utilizing a two-tiered EMS response. In this study, a 20.2% survival to hospital discharge rate was obtained. Seventy-seven percent of these survivors had a moderate to good neurologic outcome based on the Glasgow–Pittsburgh Cerebral Performance Categories.


Introduction

It is well-established that state of the art care for patients in ventricular fibrillation (VF) or non-perfusing ventricular tachycardia (VT) involves early access to the American Heart Association’s “Chain of Survival.” Within this chain, four links are described: 1) early access to the emergency medical services (EMS) system; 2) early cardiopulmonary resuscitation (CPR); 3) early defibrillation; and 4) early advanced cardiac life support (ACLS). Of paramount importance in this chain, the time to defibrillation has correlated most directly with return of spontaneous circulation (ROSC) and overall survival.1-4 With the advent of computer technology, the development of automatic external defibrillation (AED) devices has enabled EMS systems to place “user-friendly” defibrillation into the hands of first responders instead of limiting defibrillation technology only to Advanced Life Support-trained personnel. This, in turn, has translated into earlier access to electrical therapy for victims of cardiac arrest.

In this report, the experience of the City of Minneapolis Fire Department since it implemented a first responder-based AED program is described. Recently, AEDs have received some unfavorable press by the Food and Drug Administration.5,6 However, we have

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Materials and Methods

Setting
The city of Minneapolis, Minnesota, population 368,383, is served by a two-tiered emergency medical response system. Basic life support, first response is provided by the Minneapolis Fire Department (MFD), and advanced life support (ALS) is provided by the Hennepin County Ambulance Service and the North Memorial Medical Transportation Service. The ambulances are staffed by two paramedics who provide service within their assigned coverage areas. During the study period, the mean response time of the MFD was 3.3 ±1.6 (SD) minutes. These data were obtained from the Minneapolis Emergency Communication Center (MECC) computer data bank and the Fire Department’s annual report.7 The mean response time for the Hennepin County Ambulance Service was 5.9 minutes. These data were obtained from the ambulance service annual report.8 Raw data for the ambulance response times were unavailable for further analysis. The City of Minneapolis is subject to a Hennepin County ordinance that requires an advanced life support ambulance to arrive at its destination within 10 minutes from the time of dispatch 90% of the time. The Minneapolis Fire Department has a total of 20 fire stations within the city limits. The fire stations are geographically based upon accessibility within their districts and are staffed daily with about 100 firefighters trained to the basic Emergency Medical Technician level (EMT-Basic). The firefighters are dispatched by the MECC to all possible heart attacks, all unconscious/unresponsive persons, and all shortness of breath complaints. All fire stations and ladder trucks have been equipped with a single PhysioControl First Medic 510 AED (Physio-Control, Redmond, Washington USA) that includes electrode pads, memory modules, and back-up batteries with chargers.

Treatment Protocols and Training
This study included all patients found to be in ventricular fibrillation (VF) or ventricular tachycardia (VT) cardiac arrest with the exception of those who had obvious signs of death at the scene (i.e., decapitation, rigor mortis, lividity), those with valid “Do Not Resuscitate” orders present, those with a traumatic etiology for their cardiac arrest, and those whose weight was less than 90 pounds (40 kg). In addition to their standard EMT-Basic training, the Minneapolis Fire Department firefighters had an additional four hours of instruction in 1991 in the use of the automatic external defibrillator (AED), and were instructed to apply the electrodes and defibrillate such patients as instructed by the AED. A two-hour mandatory refresher class in the use of the AED also is conducted annually. The AED is programmed to recognize VF of >0.1 mv amplitude and VT of >180 beats per minute as shockable rhythms. The units are programmed to shock three consecutive times, starting at 200 Joules. The second and third shocks are delivered at 200 and 360 Joules respectively when there has not been a change in the electrocardiographic rhythm.

Data Collection
After any application of the automatic external defibrillator (AED) (whether a shock was delivered or not), the responding Minneapolis Fire Department crews are required to complete a “Minneapolis Fire Department Defibrillator Report.” The report includes demographic data, AED usage summaries, and hospital destinations.

Table 1—Glasgow-Pittsburgh Cerebral Performance Categories14

<table>
<thead>
<tr>
<th>Cerebral Performance Category</th>
<th>Description</th>
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<tbody>
<tr>
<td>Good Cerebral Performance</td>
<td>Alert, able to work and lead a normal life. May have minor psychological or neuropsychologic deficits (mild dysphagia, non-incapacitating hemiparesis, or minor cranial nerve abnormalities).</td>
</tr>
<tr>
<td>Moderate Cerebral Disability</td>
<td>Conscious. Sufficient cerebral function for part-time work in a sheltered environment or independent activities of daily life (dressing, traveling by public transportation, and preparing food). May have hemiplegia, seizures, ataxia, dystarhria, dysphagia, or permanent memory or mental changes.</td>
</tr>
<tr>
<td>Severe Cerebral Disability</td>
<td>Conscious. Dependent on others for daily support because of impaired brain function (in an institution or at home with exceptional family effort). At least limited cognition. Includes a wide range of cerebral abnormalities from ambulatory with severe memory disturbance or dementia precluding independent existence to paralytic and able to communicate only with eyes, as in the “locked-in” syndrome.</td>
</tr>
<tr>
<td>Coma, Vegetative State</td>
<td>Not conscious. Unaware of surroundings, no cognition. No verbal or psychological interactions with the environment.</td>
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for transported patients. After every use of the AED, the memory module was sent to a central location for downloading into a computer database. The memory module records all rhythms, commands, and executions in real time. The data from the MFD Defibrillator Report and the memory module were recorded in the database. Additional or missing information was recovered from the paramedic run report and also was entered into the database. If a patient had return of spontaneous circulation (ROSC) (defined as a palpable carotid or femoral pulse) and was transported to a local hospital, information was obtained from the patient’s medical record to determine if the patient survived and was discharged alive from the hospital. Surviving patients were graded according to the Glasgow-Pittsburgh Cerebral Performance Categories as outlined in the Utstein methodology for reporting cardiac arrest outcome data (Table 1).16 If the medical record documentation regarding cerebral performance was incomplete, the primary physician was contacted and interviewed regarding the patient’s condition. If the primary physician was not confident about the patient’s neurologic outcome, the Glasgow-Pittsburgh Cerebral Performance Categories criteria were reviewed with the primary physician who then was asked to place the patient into a Glasgow-Pittsburgh Cerebral Performance Categories unit to err on the conservative side. Finally, response times were collected from the Minneapolis Emergency Communication Center for all patients who survived to hospital discharge. Data collection for this project took place from 01 January 1993 through 30 June 1995.

### Results

Over the two and one-half year study period, the AED was applied by the MFD first responders to 358 patients in cardiac arrest, and of these, 271 (75.6%) had cardiopulmonary resuscitation (CPR) initiated. Of these 271 patients, 109 (40.2%) had an initial rhythm of ventricular fibrillation or pulseless ventricular tachycardia, and were shocked by the firefighter first responders according to AED instructions. There were no episodes of equipment failure or improper reading of the rhythm.

Of the 109 patients in ventricular fibrillation or pulseless ventricular tachycardia, 42 had return of spontaneous circulation in the field and were transported to the hospital with 22 ultimately surviving to hospital discharge (20.2%) (Table 2). Of the survivors, 17 (77.3% of survivors) had moderate to good CPC scores at hospital discharge. All of the survivors received at least one shock from the AED. Faster MFD response times appeared to correlate with better neurologic outcomes (Table 3).

### Discussion

Although improvements in survival from out-of-hospital cardiac arrest care have occurred over the past 25 years, sudden cardiac arrest remains the leading cause of death in the USA, as well as in the state of Minnesota.9 An estimated 6,861 deaths from ischemic heart disease occurred in Minnesota in 1994.9 In Minneapolis, ischemic heart disease was responsible for 487 deaths in 1994.9 Minneapolis has had a well-established, two-tiered, emergency response system since 1973; however, no data regarding the City’s cardiac arrest or resuscitation rates have been published.

In the early 1980s, advancement in computerized detection of ventricular fibrillation or pulseless ventricular tachycardia allowed the development of automatic external defibrillators (AEDs) that are useful in the prehospital setting. With a large body of supportive research and a decade of clinical experience, numerous medical and prehospital organizations, such as the American Heart Association, American College of Emergency Physicians, and the International Association of Fire Chiefs, have embraced this potentially lifesaving technology.5

In this study, EMT first responders had significantly faster response times, and therefore, performed earlier defibrillation in patients whose initial cardiac rhythm was VF or pulseless VT. Not surprisingly, earlier response times appeared to correlate with improved neurologic outcome in those patients discharged from the hospital. The resuscitation outcomes of the study compare favorably to those documented in previous studies involving the use of AEDs.410–12

In the best designed prospective study to date on the effect of EMT-D, Kellerman et al failed to show improved ROSC rates, survival to hospital admission

### Table 2—Cardiac arrest experience in the Minneapolis Emergency Medical Services system from 01 January 1993 through 30 June 1995

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>(% total arrests)</th>
<th>(% in VF/VT)</th>
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<tbody>
<tr>
<td>Confirmed Cardiac Arrests</td>
<td>358</td>
<td>(100.0)</td>
<td>(30.4)</td>
</tr>
<tr>
<td>Resuscitations Attempted</td>
<td>271</td>
<td>(75.7)</td>
<td>(30.4)</td>
</tr>
<tr>
<td>Patients Receiving AED Shock</td>
<td>109</td>
<td>(30.4)</td>
<td>(100.0)</td>
</tr>
<tr>
<td>ROSC</td>
<td>42</td>
<td>(11.7)</td>
<td>(38.5)</td>
</tr>
<tr>
<td>Survival to Hospital Discharge</td>
<td>22</td>
<td>(6.2)</td>
<td>(20.1)</td>
</tr>
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</table>

### Table 3—Cerebral outcome of the 22 survivors to discharge using the Glasgow-Pittsburgh Cerebral Performance Categories (n = number)

<table>
<thead>
<tr>
<th>n Shocked by AED</th>
<th>Mean Response Time (minutes)</th>
</tr>
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<tbody>
<tr>
<td>Good</td>
<td>14</td>
</tr>
<tr>
<td>Moderate</td>
<td>3</td>
</tr>
<tr>
<td>Severe</td>
<td>3</td>
</tr>
<tr>
<td>Coma</td>
<td>2</td>
</tr>
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and discharge, and neurologic outcome at hospital discharge in patients treated by EMT-D versus EMT-Basic plus EMT-P personnel.\textsuperscript{10} The Kellerman study was designed specifically to address the impact of early defibrillation by AEDs operated by EMT first responders in a large metropolitan, well-developed, two-tiered EMS system. The study was a double-blinded, crossover project that took place in an EMS setting similar to Minneapolis. As eloquently discussed in the paper, the results mandate that urban EMS administrators, who already are experiencing severe budget restraints, carefully scrutinize the potential benefit of early AED defibrillation by first responders in urban, two-tiered EMS systems. Although we agree with Kellerman's caution, it is important to recognize that while both studies found that first responders equipped with AEDs shortened scene arrival times (and potential defibrillation times) by approximately two minutes, the data from the current study showed an improved survival to discharge rate (20\% vs. 13\%) and a higher percentage of surviving patients with a good neurologic recovery (64\% vs. 60\%). One reason for this difference may be that in Kellerman's study, the AED arrived no sooner than the ALS personnel 55\% of the time. During the study period of the current investigation, there were no calls in which the AED did not arrive first. Differences in separate EMS systems may account for these variations; however, it remains arguable from these non-prospective data that AED use by first responders in well-developed urban EMS systems might favorably impact survival and neurologic outcome in cardiac arrest patients.

Data published by Sedgwick et al has confirmed previous study findings that the most important link in the chain of survival comes down to short cardiac arrest to defibrillation time, which is a function of early 9-1-1 access, quick EMS response, and prompt defibrillation. In the Heartstart Scotland project for out-of-hospital defibrillation of cardiac arrests involving all of Scotland, 55\% of patients who had arrest to defibrillation intervals of less than four minutes were admitted to the hospital. Forty-three percent of the patients admitted survived to be discharged from the hospital, and a majority of the survivors had good neurologic outcome as categorized by the GPCPC.

In the current study, first responders had a mean arrival time that was 2.6 minutes earlier than ALS personnel. As clearly indicated in the literature, the shorter the arrest to response time, the greater the likelihood of finding a patient in VF/VT, and the higher the success at defibrillating the patient into a perfusing rhythm. More importantly, these data indicate that shorter response times appear to correlate with the most important outcome measure after a cardiac arrest, good neurologic outcome.

Conclusion
First responder-based AED usage on patients in VF or VT can be applied successfully in an urban setting utilizing a two-tiered EMS model. In this series, a 20\% survival to hospital discharge rate was experienced. Seventy-seven percent of these survivors had a moderate to good neurologic outcome based on the GPCPC.

References