

## PUBLIC USE OF AUTOMATED EXTERNAL DEFIBRILLATORS

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### ABSTRACT

**Background** Automated external defibrillators save lives when they are used by designated personnel in certain public settings. We performed a two-year prospective study at three Chicago airports to assess whether random bystanders witnessing out-of-hospital cardiac arrests would retrieve and successfully use automated external defibrillators.

**Methods** Defibrillators were installed a brisk 60-to-90-second walk apart throughout passenger terminals at O'Hare, Midway, and Meigs Field airports, which together serve more than 100 million passengers per year. The use of defibrillators was promoted by public-service videos in waiting areas, pamphlets, and reports in the media. We assessed the time from notification of the dispatchers to defibrillation, survival rate at 72 hours and at one year among persons with cardiac arrest, their neurologic status, and the characteristics of rescuers.

**Results** Over a two-year period, 21 persons had nontraumatic cardiac arrest, 18 of whom had ventricular fibrillation. With two exceptions, defibrillator operators were good Samaritans, acting voluntarily. In the case of four patients with ventricular fibrillation, defibrillators were neither nearby nor used within five minutes, and none of these patients survived. Three others remained in fibrillation and eventually died, despite the rapid use of a defibrillator (within five minutes). Eleven patients with ventricular fibrillation were successfully resuscitated, including eight who regained consciousness before hospital admission. No shock was delivered in four cases of suspected cardiac arrest, and the device correctly indicated that the problem was not due to ventricular fibrillation. The rescuers of 6 of the 11 successfully resuscitated patients had no training or experience in the use of automated defibrillators, although 3 had medical degrees. Ten of the 18 patients with ventricular fibrillation were alive and neurologically intact at one year.

**Conclusions** Automated external defibrillators deployed in readily accessible, well-marked public areas in Chicago airports were used effectively to assist patients with cardiac arrest. In the cases of survivors, most of the users had no duty to act and no prior training in the use of these devices. (N Engl J Med 2002; 347:1242-7.)

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CARDIOVASCULAR disease remains the most common cause of death in the United States and most other Western nations.<sup>1-4</sup> Among these deaths, sudden, out-of-hospital cardiac arrest claims approximately 1000 lives each day in the United States alone.<sup>3</sup> Most of these cardiac arrests are due to ventricular fibrillation.<sup>4-7</sup> Though highly reversible with the rapid application of a defibrillator, ventricular fibrillation is otherwise fatal within minutes, even when cardiopulmonary resuscitation is provided immediately.<sup>7-11</sup> The overall survival rate in the United States is estimated to be less than 5 percent.<sup>4,5,7,12-14</sup>

Recent developments in automated-external-defibrillator technology have provided a means of increasing the rate of prompt defibrillation after out-of-hospital cardiac arrest.<sup>15</sup> After minimal training, nonmedical personnel (e.g., flight attendants and casino workers) are able to use defibrillators in the workplace, with life-saving effects.<sup>16-20</sup> Nonetheless, such programs have involved designated personnel whose job description includes assisting persons who have had sudden cardiac arrest. Data are still lacking on the success of programs in which automated external defibrillators have been installed in public places to be used by persons who have no specific training or duty to act.

Beginning in June 1999, the City of Chicago placed highly visible, readily accessible automated external defibrillators for public use at its municipal airports under the auspices of the Chicago HeartSave Program.<sup>21</sup> We evaluated the success of the program.

### METHODS

#### Study Design

This two-year, prospective, observational study evaluated how often bystanders used automated defibrillators placed in high-traffic locations — airports — and determined the resulting survival rates. The study sites were the three Chicago airports: O'Hare (1,735,561 ft<sup>2</sup> of terminal space [161,240 m<sup>2</sup>] and 80 million passengers annually), Midway (259,408 ft<sup>2</sup> [24,100 m<sup>2</sup>] and 20 million passengers annually), and Meigs Field (7000 ft<sup>2</sup> [650 m<sup>2</sup>] and 77,000 passengers annually). The percentage of people with training in cardiopulmonary resuscitation who pass through these airports is not known. Since 1999, basic training in cardiopulmonary resus-

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citation and the use of automated external defibrillators has been provided to a total of 450 airport police, security personnel, and public-safety dispatchers. Similar training has been made available, on a voluntary basis, to other airport-based employees (i.e., personnel without a specific duty to act in a medical emergency) from both the public sector (e.g., customs and immigration agents and members of the airport commissioner's staff) and the private sector (e.g., restaurant vendors and custodial workers). During the study, approximately 3000 of 44,000 airport workers were trained. Other potential users of the defibrillators are flight attendants, who have been trained in the in-flight use of defibrillators.<sup>17,20</sup>

### Defibrillators

On June 1, 1999, 33 publicly accessible automated defibrillators were installed throughout the O'Hare terminals. By February 1, 2001, 9 more had been placed in public areas and 17 had been placed in areas that were not accessible to the public (e.g., maintenance and secured baggage areas). Initially, 7 defibrillators were installed at Midway (10 as of March 13, 2001) and 1 at Meigs.

Defibrillators were housed in glass-faced cabinets a brisk 60-to-90-second walk apart (Fig. 1). Indicator signs similar to those for toilets and telephones were placed in highly visible positions, usually above concourse walkways, adjacent to the defibrillators. Warning signs cautioned against tampering with or inappropriate use of defibrillators. Cabinets were equipped with audible alarms, strobe lights, and dispatcher alerts (to indicate the site) that were activated when the cabinet door was unsealed. Police, security personnel, and emergency-medical-services personnel were then dispatched to the indicated location unless follow-up callers provided more exact information.

Three-minute public-service announcements were played every

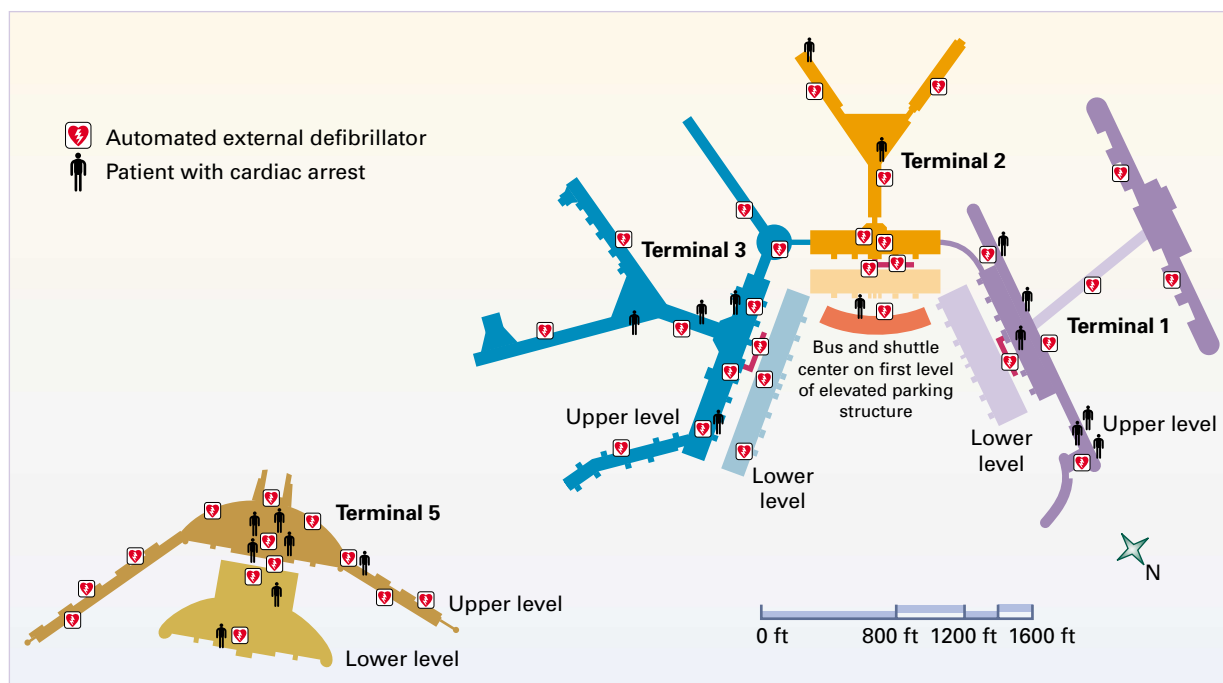
half hour on television monitors in waiting areas, indicating the availability of the automated defibrillators, explaining their purpose, and encouraging their use. Printed materials were made available to the public and distributed to the airlines in bulk. Three public training sessions on the use of automated external defibrillators and cardiopulmonary resuscitation were held at various locations in Chicago, and numerous local and national media reports promoted the program.

The Chicago HeartSave Program was approved by the Chicago municipal government as an adjunct to its emergency-medical-services system. The study was considered part of a routine evaluation of the initiative. Participation by the bystanders was entirely voluntary, and informed consent was neither sought nor obtained. The State of Illinois has good-Samaritan laws that protect those who voluntarily provide cardiopulmonary resuscitation to others against litigation.

The defibrillator used (Model E, ForeRunner, Heartstream) delivers a biphasic, truncated exponential defibrillatory wave form and about 150 joules with each shock.<sup>22</sup> A single-channel, liquid-crystal electrocardiographic tracing is displayed across the surface of the defibrillator.

### Collection of Data

When activated, digital data cards within the defibrillator record electrocardiographic data, rescuers' voices, machine prompts, thoracic-impedance values, the amount of energy delivered, and the time of all events; data from the cards are downloaded for analysis. Security officers also complete incident reports, which include contact information for the patients and those who assisted them, information on whether bystanders performed cardiopulmonary resuscitation, and information obtained from interviews with the



**Figure 1.** Map of O'Hare International Airport, Showing the Locations of Automated External Defibrillators in Public Areas and the Locations of 20 Patients with Witnessed Cardiac Arrest.

To convert distances to meters, multiply by 0.3.

persons who provided assistance. We abstracted data from the paramedics' records on patients' condition at the time of the arrival and departure of emergency-medical-services personnel and at the time they arrived at the hospital.

Although the actual time of the collapse could not be determined definitively, the time from the notification of dispatchers (e.g., as a result of opening the defibrillator-cabinet door or a telephone call) to the delivery of the first shock was documented with the use of automated clocks at dispatch centers and data cards from the defibrillators. Dispatch and data-card-computer clocks were synchronized prospectively and checked regularly to ensure accuracy.

A patient's neurologic status, assessed at the scene and at the hospital and reassessed one year later over the telephone by one of the investigators, was defined as good if the patient had a cerebral performance category score of 1 (normal) or 2 (minimal disability).<sup>23,24</sup> The time from the delivery of the first shock to the patient's initial return to consciousness, defined by a purposeful response to spoken commands, was documented, as was the number of shocks required for initial conversion or restoration of spontaneous pulses.

Complications were defined as defibrillator tampering, inappropriate delivery of shocks by the automated defibrillator, failure of the defibrillator to deliver a shock in response to ventricular fibrillation, malfunction of the audible and visual alarms or prompts of the defibrillator, inappropriate use of the defibrillator by rescuers, or injury of rescuers or other bystanders as a result of use of the defibrillator.

## RESULTS

### Characteristics of the Patients

Between June 1, 1999, and May 31, 2001, an automated defibrillator installed as part of the HeartSave Program was used for 21 persons at O'Hare, 5 at Midway, and none at Meigs. Among these 26 patients, 4 did not have cardiac arrest: 2 persons had seizures, 1 had shortness of breath (the defibrillator was used as a diagnostic tool by an off-duty paramedic), and 1 person, in the custody of immigration officials, feigned a syncopal episode. The defibrillators functioned appropriately — no shock was administered — in the cases of all four patients. Four additional persons with ventricular fibrillation were defibrillated with equipment that was not supplied by the HeartSave Program: three collapsed near gate areas and were defibrillated by nearby flight attendants using defibrillators from airplanes, and a fourth initially underwent defibrillation by paramedics with their own equipment.

Of the 22 patients with cardiac arrest for whom an airport-terminal defibrillator was obtained, a 33-year-old man had an arrest after a long fall and a 60-year-old man was found dead on a transit-system train. Of the 21 patients with nontraumatic cardiac arrest, 2 were women (age, 78 and 81 years) and 19 were men (median age, 58 years; range, 44 to 86). Nineteen were travelers, one was an airport employee, and one was a visitor.

Excluding the patient with trauma and the man who was found dead on the train, there were 20 patients with witnessed cardiac arrest. Although pulse-

less, two patients presented with some organized electrocardiographic activity. The remaining 18 (90 percent) presented with ventricular fibrillation; this group comprised both women and 16 men. The characteristics of these 18 patients are provided in Table 1.

### Outcome of Defibrillation

The automated defibrillator functioned correctly in all 18 patients with ventricular fibrillation, immediately determining the need for and delivering shocks. In all 18 patients, the defibrillators were retrieved and operated by travelers or airport employees before the arrival of the emergency-medical-services crews. In the cases of four of the seven patients who died, the defibrillator was not immediately accessible (e.g., two patients on airplanes) or was not accessed within five minutes after collapse. Three others remained in persistent ventricular fibrillation and eventually died despite rapid use of the defibrillators (within five minutes). Two of these patients received seven and nine defibrillator shocks, respectively, before the paramedics arrived.

Eleven of the patients with ventricular fibrillation regained spontaneous circulation and eventually regained consciousness. Four returned to consciousness before the paramedics arrived, two during transport, two in the emergency department, and another three after hospitalization. For 9 of these 11 patients, defibrillators were retrieved and used by bystanders within five minutes. The other two did not receive a shock for seven minutes, but they received immediate cardiopulmonary resuscitation. All 11 had good neurologic outcomes before discharge (with a cerebral performance category of 1), and 10 were alive at one year. One patient died of other sequelae weeks after cardiac arrest. The long-term survival rate with a good neurologic outcome among all 18 patients with ventricular fibrillation was 56 percent (regardless of the location of cardiac arrest), and it was 67 percent among the 12 patients who underwent defibrillation within five minutes.

### Characteristics of the Rescuers and Complications of Defibrillation

With two exceptions, the operators of the defibrillators were good Samaritans (airline passengers or airport employees) who had no duty to act, and all used the defibrillators voluntarily and correctly (Table 1). In 6 of the 11 cases in which patients were successfully resuscitated and regained consciousness, the defibrillator users had neither operated an automated external defibrillator previously nor been trained in its use, although three were physicians. No complications occurred. One of the 53 defibrillators was stolen during the two-year period.

**TABLE 1.** CHARACTERISTICS OF 18 PATIENTS WITH VENTRICULAR FIBRILLATION WHO RECEIVED DEFIBRILLATOR SHOCKS FROM AUTOMATED EXTERNAL DEFIBRILLATORS (AED) INSTALLED AT CHICAGO AIRPORT TERMINALS BETWEEN JUNE 1, 1999, AND MAY 31, 2001.\*

CHARACTERISTIC	RESUSCITATED AND REGAINED FULL CONSCIOUSNESS (N=11)	NOT RESUSCITATED (N=7)
Mean ( $\pm$ SD) age — yr	67.7 $\pm$ 8.4	67.9 $\pm$ 12.1
Male sex — no. (%)	10 (91)	6 (86)
Purpose at airport — no. of patients (%)		
Travel	11 (100)	6 (86)
Dropping off or picking up traveler	0	1 (14)
Basic cardiopulmonary resuscitation performed before AED used — no. of patients (%)	11 (100)	6 (86)
Time from notification of dispatcher to delivery of first shock — no. of patients (%)		
$\leq$ 5 Min	9 (82)	3 (43)
$>$ 5 Min	2 (18)	4 (57)
No. of shocks required for conversion to organized rhythm — no. of patients (%)		
1 Shock	7 (64)	2 (29)
2 or 3 Shocks	4 (36)	2 (29)
$>$ 3 Shocks	0	3 (43)
Witnessed arrest — no. of patients (%)	11 (100)	7 (100)
Outcome — no. of patients (%)		
Regained consciousness before arrival of EMS personnel	4 (36)	—
Regained consciousness before hospitalization	8 (73)	—
Neurologically intact (CPC score = 1) before discharge†	11 (100)	—
Alive at 1 yr	10 (91)	—
Defibrillation performed by good Samaritan — no. of patients (%)	10 (91)	6 (86)
Defibrillation performed by person with no prior use of AED or training — no. of patients (%)	6 (55)	1 (14)

\*EMS denotes emergency medical services.

†Cerebral performance category (CPC) scores range from 1 through 5, with higher scores indicating more severe disability.

## DISCUSSION

The results of this study demonstrate the lifesaving potential of public access to defibrillation.<sup>15</sup> Most of the patients with ventricular fibrillation in the study were resuscitated within minutes by good Samaritans who had immediate access to an automated defibrillator. The overall one-year survival rate with a good neurologic outcome regardless of location was 56 percent. In contrast, survival rates are estimated to be less than 5 percent with the use of conventional, “rapid-response” emergency medical services.<sup>12</sup> Traditionally, most resuscitated patients are still comatose on hospital admission, and typically, more than half never regain consciousness.<sup>25,26</sup> Our results reflect a substantial change in that traditional clinical course.

Given the expected lifetime of the defibrillators installed by the HeartSave Program (a minimum of about 10 years), the cost of the program at the three Chicago airports, including the devices, cabinets, alarm systems, and quality-assurance measures, averages about \$35,000 a year. On the basis of our results,

this figure translates to a cost of about \$3,000 per patient and about \$7,000 per life saved. Our finding that the majority of patients who underwent successful defibrillation were conscious before reaching the hospital also has implications for the immediate use of medical resources (such as the need for mechanical ventilation and treatment in the intensive care unit) and for long-term cost effectiveness.<sup>27</sup> Nevertheless, further economic analyses are needed to confirm these potential cost savings.

Despite the central role of the automated defibrillator, the performance of cardiopulmonary resuscitation by bystanders may also have contributed to the good outcomes in this study.<sup>7,9,10,28,29</sup> All survivors received cardiopulmonary resuscitation, and one received cardiopulmonary resuscitation for 10 minutes between episodes of ventricular fibrillation before eventually being resuscitated. Even under optimal conditions, some time elapses before the first shock can be delivered. In one case, two HeartSave personnel who were standing next to an automated defibrillator

witnessed the collapse. Still, it took at least two minutes for these experts to ready the patient and the equipment. These considerations and the role of basic cardiopulmonary resuscitation must be kept in mind when program designers are calculating predicted response intervals.<sup>15</sup>

In the cases of four of the seven patients for whom defibrillation was unsuccessful, the arrest occurred far from the main terminal and ticket-counter areas, and the response was thus delayed. Previous work has made clear the inverse association between the time needed to respond and survival. Of the patients who collapsed in a terminal for whom a defibrillator was retrieved and used within five minutes, 75 percent were resuscitated and rapidly regained consciousness.

Three patients remained in fibrillation despite a rapid response. All three had diabetes and were described as obese in medical records. Other data have suggested that obesity and diabetes may decrease the success of external defibrillation.<sup>30,31</sup> We did not systematically collect data on these clinical features, and thus we cannot address their frequency among patients who underwent successful defibrillation.

The program we studied has some unique advantages.<sup>32</sup> Although most cardiac arrests occur at home (70 to 80 percent),<sup>7,32</sup> airports may be the public places with the highest concentration of cardiac arrests.<sup>21</sup> O'Hare is used by many thousands of persons daily, including many health professionals and other persons who are likely to know how to perform cardiopulmonary resuscitation and who thus may feel more comfortable acting in such situations. Three of the seven rescuers without training or experience in the use of an automated external defibrillator had medical degrees. Thus, it is not known whether these results can be generalized to other public places that may be less frequented by health professionals.

Previous studies have demonstrated that targeted nonmedical personnel can be trained as part of their job descriptions to use automated external defibrillators in public venues, including casinos<sup>16</sup> and airplanes.<sup>17</sup> Our findings showed that bystanders will voluntarily aid persons with cardiac arrest and can do so successfully, even without prior training in the use of defibrillators. The survival rates were similar to (or exceeded) those in prior studies.<sup>16,17</sup> Although many rescuers were airport employees (i.e., custodians, customs or immigration officials, or wheelchair assistants), the majority had taken cardiopulmonary-resuscitation courses voluntarily and had no specific duty to act.

Studies demonstrate that even sixth-grade children can use automated external defibrillators without prior instruction.<sup>33</sup> In our study, 6 of the 11 successfully resuscitated patients were resuscitated by persons who had neither previously operated an automated defibrillator nor been specifically trained in its use. Al-

though three had medical degrees and another was a health professional, this attribute does not imply that such persons have a duty to act or are comfortable using an unfamiliar device.

Although training in cardiopulmonary resuscitation and the use of automated external defibrillators is strongly encouraged for everyone, our findings suggest that the lack of such training should not constrain attempts to use a defibrillator in emergencies. Given the safety of these devices and our results, reasonable public health strategies would be to promulgate good-Samaritan laws; encourage the development of less expensive, more user-friendly automated defibrillators for public deployment in appropriate locations; and undertake aggressive public-education campaigns that promote the idea that anyone is capable of immediate action in such situations.<sup>15,33-37</sup>

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