

# Survival After Ventricular Fibrillation Cardiac Arrest in the Sao Paulo Metropolitan Subway System: First Successful Targeted Automated External Defibrillator (AED) Program in Latin America

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**Background**—Targeted automated external defibrillator (AED) programs have improved survival rates among patients who have an out-of-hospital cardiac arrest (OHCA) in US airports, as well as European and Japanese railways. The Sao Paulo (Brazil) Metro subway carries 4.5 million people per day. A targeted AED program was begun in the Sao Paulo Metro with the objective to improve survival from cardiac arrest.

**Methods and Results**—A prospective, longitudinal, observational study of all cardiac arrests in the Sao Paulo Metro was performed from September 2006 through November 2012. This study focused on cardiac arrest by ventricular arrhythmias, and the primary endpoint was survival to hospital discharge with minimal neurological impairment. A total of 62 patients had an initial cardiac rhythm of ventricular fibrillation. Because no data on cardiac arrest treatment or outcomes existed before beginning this project, the first 16 months of the implementation was used as the initial experience and compared with the subsequent 5 years of full operation. Return of spontaneous circulation was not different between the initial 16 months and the subsequent 5 years (6 of 8 [75%] vs. 39 of 54 [72%];  $P=0.88$ ). However, survival to discharge was significantly different once the full program was instituted (0 of 8 vs. 23 of 54 [43%];  $P=0.001$ ).

**Conclusions**—Implementation of a targeted AED program in the Sao Paulo Metro subway system saved lives. A short interval between arrest and defibrillation was key for good long-term, neurologically intact survival. These results support strategic expansion of targeted AED programs in other large Latin American cities. (*J Am Heart Assoc.* 2015;4:e002185 doi: 10.1161/JAHA.115.002185)

**Key Words:** automatic external defibrillation • cardiopulmonary resuscitation • ventricular fibrillation

Sudden cardiac arrest is responsible for more than 60% of adult deaths from coronary heart disease.<sup>1</sup> Generally, less than 8% of people who experience an out-of-hospital cardiac arrest (OHCA) survive to hospital discharge<sup>2</sup>, with large metropolitan cities reporting even lower survival rates.<sup>3–5</sup> The issue of heavy traffic as well vertical response makes response in large cities a challenge.

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The chance of a cardiac arrest victim surviving increases if a bystander witnesses the event and performs cardiopulmonary resuscitation (CPR). Long-term survival can increase as much as 2 to 3 times if a bystander/first responder also uses an automated external defibrillator (AED) before emergency medical service (EMS) arrival.<sup>2,6–16</sup> Many studies, including a prospective, randomized trial, have shown that public access defibrillation (PAD) programs improve the rate of survival among patients with an OHCA. As a result of these findings, PAD programs have been introduced in many areas.<sup>8,10–12,17,18</sup>

The most successful PAD programs have resulted from targeted AED programs where a large number of people circulate or congregate on a regular basis. Transportation hubs, such as large international airports and busy railway stations, have been fertile ground for successful PAD programs.<sup>19–21</sup>

The Sao Paulo Metropolitan Company (Sao Paulo Metro), the city subway system, carries ≈4.5 million people per day and represents an important means of transport in Brazil's

largest city (population over 20 million). In September 2006, the Sao Paulo Metro began a targeted AED program by training their security officer employees (laypersons) in CPR and use of AED. Automated external defibrillators were installed in every subway station. The aim and objective of the study was to evaluate the effect of a targeted AED program in the Sao Paulo Metro subway system on the rate of survival with minimal neurological impairment among those who had ventricular fibrillation cardiac arrest.

## Methods

### Study Design and Setting

This was a prospective, longitudinal, observational study of out-of-hospital cardiac arrests based on standardized Utstein data collection and reporting methodology, including using their recommended template for reporting data including time intervals for CPR and predefined clinical outcome measures.<sup>22,23</sup> This study included all cardiac arrests occurring on the blue, red, lilac, and green subway lines in the Sao Paulo Metro. A total of 58 subway stations existed during the study. The yellow line, which began operation in 2012 with just 2 stations, had no cardiac arrests during the study period.

### Subjects

We enrolled all individuals 18 years of age or older who, between September 1, 2006 and November 30, 2012, had an OHCA in the Sao Paulo Metro, were initially responded to and treated by security officers, and then transported to medical institutions by EMS personnel. Subjects who met the inclusion criteria had been unconscious and unresponsive and had no spontaneous ventilation. Although we have collected data of all cardiac arrests, this study focused on patients with ventricular fibrillation as their initial cardiac arrest rhythm.

### Training and Equipment of Responders

Since June 2006, the security officers were required to have Heartsaver First Aid CPR AED training, according to current American Heart Association (AHA) guidelines, approximately every 1.5 years (never more than 2 years). Training sessions were taught by AHA instructors at a simulation center accredited by the AHA's training network. The Heartsaver First Aid CPR AED is a video-based, instructor-led course that teaches critical skills needed to respond to and manage first aid for choking and/or the first few minutes of a cardiac arrest emergency until EMS providers arrive. Students learn skills such as how to treat bleeding, sprains, broken bones, shock, and other first aid emergencies. This course also teaches adult CPR and AED use.<sup>24</sup> Moreover, in January 2010,

the security officers started to receive additional training in CPR (a 60-minute course taught by certified AHA instructors) to refresh their knowledge and reinforce their CPR techniques every 6 months.

At the start of the study, CPR was performed by security officers according to the 2005 AHA guidelines through December 2010. Beginning in January 2011, their instruction was updated and thereafter based on the 2010 AHA guidelines.<sup>25,26</sup> These Metro security officer rescuers were not permitted to terminate resuscitation in the field and so continued their efforts until return of spontaneous circulation or until they were relieved by professional EMS providers. Finally, the security officers were instructed in how to fill out a portion of the data collection instrument and to capture the study information using the agreed-upon Utstein style template. Training of the Metro security personnel proceeded in ongoing training waves. Training rollout continued until March 2009 (31 months) when all Metro security guards (n=2987) had completed at least one training session.

The AEDs used in the study were approved by the National Agency for Sanitary Vigilance of Brazil and were produced by 2 international manufacturers. All the devices provided voice prompts and had electrocardiographic and sound-recording capabilities. Device checks were scheduled to take place weekly. The placement of AEDs in all stations began in June 2006, and by March 2007 all stations had an AED device. The total number of AEDs in the Sao Paulo Metro during the study was 58 (1 per station).

No outcome data exist for cardiac arrest victims within the City of Sao Paulo or its metropolitan subway system before the institution of this project. Before 2006, no protocol existed for the on-site treatment of any medical emergency, including cardiac arrest. All such occurrences were simply transported to the nearest medical facility. Hence, there is no control group for any before and after comparisons. Therefore, a post-hoc decision was made to use the first 16 months of implementation of the Sao Paulo metropolitan subway targeted AED program as a quasi-control group. The rationale was that during the early part of the training and implementation phase of the program both training and provision of AED devices would be relatively slow and incomplete, thereby providing a glimpse of what might have been before the full program was instituted. In fact, during the first year only 50% of stations had an AED by 6 months and 100% had 1 at the end of 12 months. Similarly, only 8% of the security staff had completed cardiac arrest training by 6 months and 22% by the end of the first 16 months.

### Study Protocol

Security guards roamed the Metro areas throughout time of operation (4:40 AM to 12:30 AM). In addition, randomly mounted security cameras scanned the public areas, and

security personnel could focus on unusual events. When the officers were notified by radio or bystander of the presence of a sudden collapse, the nearest pair of officers proceeded to the patient and assessed for responsiveness and spontaneous respiration. If the victim was confirmed to be in cardiac arrest, 1 officer then radioed the central command center reporting the cardiac arrest, the location of the incident, and then initiated manual CPR. The command center immediately notified EMS of the incident and location. The other officer brought the nearest AED to the patient. The defibrillator was immediately attached and activated, and audible prompts (by a recorded voice) were followed. Resuscitative efforts by the security officers continued until the patient had return spontaneous circulation (ROSC) or EMS personnel arrived. The patient was referred and transported by EMS personnel to the hospital nearest to the Metro station where the cardiac arrest occurred. From September 2006 through October 2009, the resuscitation protocol utilized was conventional CPR (30 compressions and 2 ventilations). Owing to difficulty in performing ventilation, the resultant delays in beginning the compressions, and strong scientific evidence supporting hands-only CPR, this latter method of basic life support was adopted in November 2009.<sup>27,28</sup>

## Data Collection

Data from the cardiac arrest events and victims were provided to the study investigators by the medical coordinator of Sao Paulo Metro. The data that were collected included: (1) the sex and age of the patient; (2) time between the collapse and the beginning of CPR; (3) time between collapse and first shock; (4) the initial cardiac rhythm; (5) the number of defibrillations; (6) ROSC before the patient's arrival at the hospital, defined by a palpable pulse of a major artery, usually the carotid; and (7) information on the line and station location where the event occurred. In addition, information about survival to hospital arrival, survival to hospital discharge with minimal neurological impairment, and survival 1 year after the event. The time of collapse and time of initiation of manual CPR for witnessed arrests were obtained by the security officer, who asked witnesses about the interval between the collapse and the call for help. The time of the call for help was documented on the officer's incident report.

The AED record was utilized to verify the initial rhythm and to obtain defibrillation times recorded automatically by the defibrillator devices. Two types of AED devices were used (Medtronic and Philips). Both devices' internal clock is synchronized when contact with the main computer is made to transmit data after an event, or each month if the automated electrical defibrillator is not used. The computer's clock is synchronized daily with an atomic clock in Brasilia, Federal District.

The defibrillators recorded a detailed sequence of events during resuscitation and provided tracings of the cardiac waveform with real clock times and, if the device had audio recording, an audio recording of the resuscitation effort. The time of arrival of the EMS at the arrest scene was obtained from the Metro central control of each station. Data on the subjects' outcomes and their hospital courses were obtained by consulting the medical records from the hospitals to which the subjects were transported. All patients who survived were followed for up to 1 year after the event by investigators. Neurological outcome was determined at the moment of hospital discharge and 1 year after successful resuscitation, with the use of the Cerebral Performance Category (CPC) scale, on which category 1 represents good cerebral performance; category 2, moderate cerebral disability; category 3, severe cerebral disability; category 4, coma or vegetative state; and category 5, death. Study data forms and electronic data from the defibrillators were collected from all Metro stations and were forwarded to investigators at the Heart Institute for review and analysis. All data extraction was performed in duplicate by 2 different individuals to ensure accuracy.

## Endpoints

The primary endpoint was hospital discharge with minimal neurological impairment, which was defined as a CPC category of 1 or 2.<sup>22,23</sup> Secondary endpoints were the return of spontaneous circulation before arrival at the hospital and survival at 1 year. The institutional committee on human research at the University of Sao Paulo approved the study. Consent for review of hospital records was obtained from surviving subjects and family members of those who did not survive.

## Statistical Analysis

Continuous values were presented as mean±SD and categorical values as frequencies and percentages. Continuous values were compared using 2-sided unpaired Student *t* tests for Gaussian, or Mann–Whitney *U* tests for non-Gaussian distributions. Categorical variables were compared by the chi-square test or Fisher's exact test, when indicated. Variables independently associated with the primary endpoint were investigated by logistic regression whose model included the variables with  $P \leq 0.10$  in the univariate analysis. Two-sided  $P < 0.05$  were considered statistically significant. The statistical analysis was performed using SPSS software (version 20.0; SPSS, Inc., Chicago, IL).

## Results

There were a total of 102 sudden collapses in the Sao Paulo Metro system during the 75 months of the study from

September 1, 2006 through November 30, 2012. Eighty-six subjects had a confirmed cardiac arrest. None of them were children. Sixty-two subjects (72.1%) had an initial cardiac rhythm of ventricular fibrillation, 13 (15.1%) had pulseless electrical activity, and 11 (12.8%) had asystole. A flow diagram of the study of cardiac arrest in the Sao Paulo Metro Subway system is illustrated by Figure 1. No subject whose initial cardiac rhythm was nonshockable survived to discharge from the hospital.

This study focused on victims of cardiac arrest resulting from ventricular fibrillation. The following data refer to the 62 patients with ventricular fibrillation cardiac arrest treated in the Sao Paulo Metro system between September 1, 2006 and November 30, 2012. The demographic characteristics of the subjects, the intervals from collapse to various interventions, and other characteristics of event are shown in Table 1.

Ventricular fibrillation cardiac arrest occurred at various locations within the Sao Paulo Metro subway system. Eighteen (29.0%) occurred inside the train, 16 (25.8%) occurred in the mezzanine, 15 (24.2%) occurred on the platform, and 13 (21.0%) happened in other places (escalators, shops, and restrooms). There were no differences in survival rates per location of arrest. Security guards who roam through the various areas of the stations started all treatments.

Twenty-three of the 62 (37.0%) ventricular fibrillation cardiac arrest victims survived to hospital discharge with minimal neurological impairment (primary endpoint). Survivors were younger and had shorter time intervals from cardiac arrest to CPR, to the arrival of the AED, to the first

**Table 1.** Characteristics of 62 Subjects With Ventricular Fibrillation

Characteristics	Outcomes
Age, y	59±13
Male sex, n (%)	48 (77.4)
CPR before the arrival of the defibrillator, n (%)	62 (100)
Interval from collapse to CPR, min	2.7±1.2
Interval from collapse to attachment of defibrillator, min	3.9±1.3
Interval from collapse to first defibrillation, min	4.8±1.4
Number of defibrillations, n	2.7±1.8
Interval from collapse to arrival of EMS, min	15.6±7.2
Return of spontaneous circulation, n (%)	45 (72.5)
Death at the scene or during transport to the hospital, n (%)	11 (17.7)
Arrived alive to the hospital, n (%)	34 (54.8)
Survival with minimal neurological impairment (CPC score=1 or 2) before discharge, n (%)	23 (37.0)
Alive at 1 year with minimal neurological impairment (CPC score=1 or 2), n (%)	23 (37.0)

CPC indicates cerebral performance category scores range from 1 through 5, with higher scores indicating more-severe disability; CPR, cardiopulmonary resuscitation; EMS, emergency medical services.

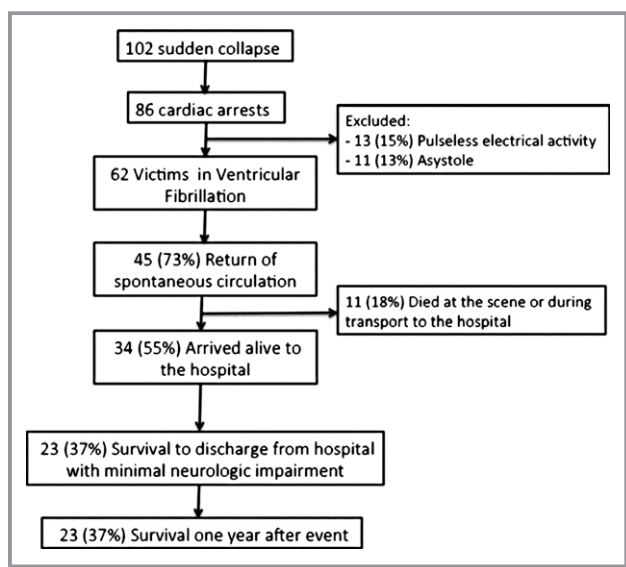
defibrillation shock, and to the arrival of professional emergency medical services personnel (Table 2).

Using the first 16 months of the implementation period (quasi-control period) provided enough cardiac arrests to compare outcomes with when the full program was implemented and functioning (Table 3). No difference in the rate of return of spontaneous circulation was found, but long-term outcomes, survival to hospital discharge with favorable neurological outcome, and survival to 1 year were significantly better with the full implantation of the targeted AED program.

Multivariate logistic regression analysis revealed that the time interval between collapse and first shock was the only variable independently associated with the primary endpoint. There was a dramatic exponential decrease in survival to hospital discharge with minimal neurological impairment as the time from collapse to first shock increased from 2 to 4 minutes (odds ratio=0.13; 95% confidence interval: 0.05 to 0.38,  $P<0.001$ ). Figure 2 illustrates this association between increasing time to shock and survival.

## Discussion

This study provides evidence that a targeted AED program in a Brazilian megametrocity subway system results in improved survival after ventricular fibrillation OHCA. Targeted AED programs for airports, casinos, railway stations, and sports



**Figure 1.** Patient flow diagram of the study of out-of-hospital ventricular fibrillation cardiac arrest in the Sao Paulo Metro Subway system.

**Table 2.** Comparison Between Survivors and Nonsurvivors

Characteristics	No. Patients (n=62)	Survivors* (n=23)	Not Survivors* (n=39)	P Value
Age, y	—	54.5±16.0	63.1±12.9	0.019
Male (%)	48 (77.4)	17 (27.4)	31 (50.0)	0.612
Female (%)	14 (22.6)	6 (9.6)	8 (13.0)	
Hands-only CPR (%)	40 (64.5)	18 (29.0)	22 (35.5)	0.082
Conventional CPR (%)	22 (35.5)	5 (8.0)	17 (27.5)	
CA out of train (%)	18 (29.0)	8 (12.9)	10 (16.1)	0.443
CA in the train (%)	44 (71.0)	15 (24.2)	29 (46.8)	
Rush period <sup>†</sup> (%)	30 (48.3)	11 (17.7)	19 (30.6)	0.945
Out of rush period (%)	32 (51.7)	12 (19.3)	20 (32.4)	
Interval between CA and CPR, min	—	1.5±0.6	2.4±0.9	<0.001
Interval between CA and AED arrives, min	—	2.2±0.7	3.3±1.0	<0.001
Interval between CA and first shock, min	—	2.8±0.7	4.1±1.0	<0.001
Interval between CA and EMS arrives, min	—	12.3±4.4	17.6±8.0	0.001
Number of shocks	—	2.2±1.6	3.0±2.0	0.098
Distance from subway station—hospital, miles	—	1.6±1.0	1.5±0.8	0.662

AED indicates automatic external defibrillator; CA, cardiac arrest; CPR, cardiopulmonary resuscitation; EMS, emergency medical services.

\*Values expressed as mean±SD or percentage.

<sup>†</sup>Between 7 and 10 AM and 5 and 8 PM.

venues in the United States, Europe, and Japan have shown similar positive results, but this is the first report of such a successful program in a large Latin American city.<sup>19–21,29,30</sup>

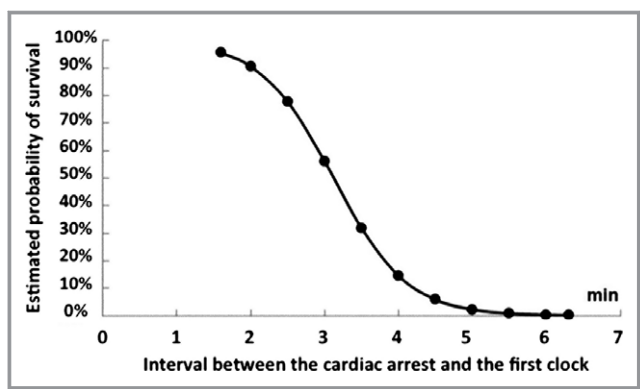
The difficulties associated with treating OHCA in large cities are well documented, with overall survival rates of less than 3% in New York, Chicago, Los Angeles, and Tokyo (Table 4).<sup>3–5,31</sup> Even those with witnessed ventricular fibrillation in large

metropolitan areas do relatively poorly, with survival rates no greater than 10%. No overall survival data exist for the city of Sao Paulo, but it is highly unlikely to be any better than these reports from other large, densely populated cities around the world. A recent longitudinal study of prehospital care in Belo Horizonte, a Brazilian city of ≈5.5 million inhabitants, documented ROSC in 20.5% of 1165 OHCA.<sup>32</sup> In the 67% of

**Table 3.** Comparative Analysis of Quasi-Control Period (2006–2007) Versus the Other Years (2008–2012)

Characteristics	Control Period (2006–2007)	Other Years (2008–2012)	P Value
Cardiac arrest with an initial rhythm of VF, n	8	54	
Age, y	64±11.1	59±14.1	0.286
Male sex, n (%)	7 (87.5)	41 (75.9)	0.670
CPR before the arrival of the defibrillator, n (%)	8 (100)	54 (100)	
Interval from collapse to CPR, min	3.35±0	1.86±1.0	0.001
Interval from collapse to attachment of defibrillator, min	4.2±0.7	2.6±0.9	0.001
Interval from collapse to first defibrillation, min	5.2±0.8	3.3±0.9	0.001
Number of defibrillations, n	2.75±1.8	2.7±1.8	0.970
Interval from collapse to arrival of EMS, min	25.1±8.8	14.2±5.8	0.015
Return of spontaneous circulation, n (%)	6 (75.0)	39 (72.0)	1.000
Arrived alive to the hospital, n (%)	3 (37.5)	31 (57.4)	0.450
Survival to discharge from hospital with minimal neurologic impairment, n (%)	0	23 (43.0)	0.021
Survival 1 year after event, n (%)	0	23 (43.0)	0.021

CPR indicates cardiopulmonary resuscitation; EMS, emergency medical services; VF, ventricular fibrillation.



**Figure 2.** The association between time from collapse to first shock and survival. Survival decreased rapidly as the time interval increased from 2 to 4 minutes.

patients whose hospital course could be verified, only 1.1% (13 of 1165) were discharged with good neurological function (CPC 1 or 2). The results from our targeted Sao Paulo Metro AED program compare favorably with the overall survival data from the city of Belo Horizonte (26.7% vs. 1.1%).

The first 16-month experience during the run-in phase of this program suggests that the previous long-term neurologically intact survival rate in the subway system was probably near zero. We speculate that despite incomplete training and placement of AEDs, the first year of this program probably achieved a higher rate of ROSC than was likely achieved within the city as a whole. Unfortunately, such early success did not translate into longer-term survival.

Targeted AED programs for areas with periodic dense populations have shown better outcomes than those observed in cities as a whole. The key is training staff or personnel working in the targeted areas who can respond to cardiac arrests and perform basic life support, as well as bring and use an AED. An adequate number of AEDs are placed within the venue for the use of such trained employees in providing early public access defibrillation. Advantages of this approach include the provision of “willing and trained bystanders” who are prepared and equipped with onsite AEDs to act in a

**Table 4.** OHCA Survival in Large International Cities

City	Overall Surv (%)	VFCA Surv	Pop (million)
New York (1994) <sup>3</sup>	1.4	5.3	7.3
Chicago (1991) <sup>4</sup>	2.0	10.2	2.7
Los Angeles (2005) <sup>5</sup>	1.4	6.0	3.7
Kanto/Japan (2007) <sup>31</sup> (Toyko region)	2.9	10.5	42.5
Belo Horizonte (2012) <sup>32</sup> (Brazil)	1.1	NA	5.5

NA indicates not available; OHCA, out-of-hospital cardiac arrest; Pop, population; Surv, survival; VFCA, ventricular fibrillation cardiac arrest.

**Table 5.** OHCA Survival With Targeted AED Programs

Locale	N	Overall Surv (%)	VFCA Surv
Chicago Airports <sup>21</sup>	20	55.0	61.1
Osaka Sports Venues <sup>30</sup>	93	51.6	NA
Amsterdam Public Facilities <sup>18</sup>	128	49.2	63.9
Las Vegas Casinos <sup>19</sup>	148	37.8	58.8
London Transport Facilities <sup>29</sup>	172	22.7	28.3
Osaka Railways <sup>30</sup>	118	28.0	NA
Sao Paulo Metro	86	26.7	37.1

AED indicates automated external defibrillator; Metro, Metropolitan subway system; NA, not available; OHCA, out-of-hospital cardiac arrest; Surv, survival; VFCA, ventricular fibrillation cardiac arrest.

cardiac arrest emergency. Successful targeted AED programs have been reported in busy airports, casinos, sports arenas, and railway stations.<sup>19–21,29,30</sup> This Sao Paulo Metro targeted AED program achieved similar survival rates with intact neurological function as those observed with such programs in the United States, Europe, and Japan (Table 5).

Survival is known to be affected by the time intervals from collapse to both starting CPR and to the first defibrillation.<sup>14</sup> In our study, the only independent variable related to hospital survival with minimal neurological impairment was the time from collapse to the first defibrillation shock. If this time interval exceeded 5 minutes, the chance of long-term survival with normal neurological function was virtually zero. This is a shorter interval than others have reported and may indicate that other links in the Sao Paulo “chain of survival” need to be strengthened.<sup>16,19</sup> In the Sao Paulo subway, time intervals from collapse to defibrillation of less than 3.5 minutes were necessary to achieve the highest survival rates. The average time from collapse to defibrillation was  $4.8 \pm 1.2$  minutes. This interval compares favorably with the targeted AED programs in Chicago’s airports and in the Osaka, Japan, railway station.<sup>21,30</sup> This rapid deployment of AEDs (mean time from collapse to attachment of AED of only  $3.9 \pm 1.3$  minutes) may help to explain the high incidence of ventricular fibrillation (72.1%) as the initial rhythm in our study population.

One of the challenges of this targeted AED approach where security officers respond, perform CPR, and bring an AED located in the subway station is the occurrence of some cardiac arrests inside the trains. These events would seem more difficult to respond to in a timely manner, and CPR accompanied by AED use may be delayed until the subway arrives at the next station, given that there is not a security officer inside every train. However, this concern did not materially affect outcome. There were no differences in survival among those arresting in the station or on the train, possibly owing to the small sample size (Table 2).

Performing chest compressions increases the time period in which defibrillation may be effective. In this study, the average time from collapse to initiation of CPR was  $2.7 \pm 1.2$  minutes. All bystander CPR was provided by Sao Paulo Metro security officers. It is remarkable that, over the 6 years of this study, no citizen bystander CPR was noted. Though  $2.7 \pm 1.2$  minutes in interval to CPR is quite good, if citizen bystanders could be taught and convinced to provide hands-only CPR immediately upon collapse, knowing security officers would arrive within 3 minutes to assume primary responsibility, including defibrillation with an AED, further improvements might be possible.

The time from collapse to EMS arrival was significantly shorter for survivors than for nonsurvivors, though the average times for both are considerably longer than in some previous reports.<sup>30,33</sup> Despite the increasing amount of evidence regarding PAD programs, little has been said about the role of EMS in PAD cases.<sup>33</sup> Rea and colleagues in Seattle found that in a community-based PAD program, the majority of those shocked with an AED needed additional CPR and defibrillation by EMS personnel. In those with an initial rhythm of ventricular fibrillation, 33% had ROSC before EMS arrival, which increased to 84% after EMS care. They concluded that effective EMS care is important to achieve optimal results with community PAD programs, and, in fact, inadequate EMS care may limit potential benefits of such programs.

In our study, 34 patients were alive to hospital admission, but only 23 were discharged from hospital with minimal neurological impairment, all of which survived with good neurological function for 1 year of follow-up. These 23 long-term survivors account for 67.6% of the patients who entered the hospital alive. The proportion of out-of-hospital cardiac arrest patients who are successfully resuscitated and hospitalized, and then survive to discharge neurologically intact, varies widely in the literature from 12% to 68%.<sup>13,34</sup> Although ROSC in the field is an important step toward hospital discharge, a significant proportion of patients admitted alive subsequently die, especially within the first days, often from severe brain damage.<sup>35</sup> Patients were referred by EMS to the nearest hospital and since there is no standardized protocol for postcardiac arrest treatment (ie, targeted temperature management and emergent coronary angiography) in Sao Paulo, different postresuscitation care approaches were certainly used depending on the particular hospital. Such differences could have influenced mortality.<sup>36</sup> This variability in postresuscitation care makes the survival to discharge with good neurological function (68%) even more remarkable. Such results again highlight the interaction between links on the “chain of survival.” Very early CPR and defibrillation may result in less need for aggressive postresuscitation care, such as targeted temperature management, given that the resuscitated may be conscious upon arrival at the hospital.

## Limitations

The lack of a true control historical control group is regrettable, but it was considered unethical to delay institution of active therapy with a targeted AED program simply to collect control period baseline data. Therefore, the results achieved with the target AED program were compared with 3 different groups, though none were true controls. First, we used the only existing outcomes data in Sao Paulo during this time, namely, the first year during the implementation or run-in period (Table 3). A significant difference in the primary endpoint was found favoring the years when the program was fully implemented with all security personnel trained and every station equipped with an AED. Second, a comparison of outcome results with the only available data on cardiac arrest outcomes from a large Brazilian city (Belo Horizonte) showed superior survival with the targeted AED program in the Sao Paulo subway system. Finally, a comparison with the historical international experience with target AED programs showed similar results were achieved in the Sao Paulo Metro program (Table 5).

Subsequent to the American Heart Association adoption of “hands-only” CPR for lay rescuers in 2008,<sup>30</sup> the data continued to accumulate, suggesting that this technique was easier to learn and perform, more acceptable to many rescuers, provided better hemodynamic support, and produced equivalent, if not better, outcomes. In pursuing the ultimate goal of improving survival from out-of-hospital cardiac arrest in the Sao Paulo subway system, the decision was made to switch to this technique for all basic life support provided by the Metro security officers. This mid-study change may have affected the later year’s results, thereby confounding the chance to prove whether it was the AED or the CPR technique that saved lives. The pragmatic viewpoint is that though bundles of care may cloud elucidation of what role each therapy contributes in improving long-term survival, what really matters is that outcomes are improved. The goal of the project was to save more lives, and withholding advances in resuscitation science during the 6 years of the study seemed neither practical nor ethical.

No data on the quality of the resuscitation efforts were obtained. Different resuscitation teams participated in each event, something that may lead to heterogeneity of both technique and outcome. No background health information was obtained on those who suffered cardiac arrest.

Time from collapse to EMS arrival was long, a common challenge in large, traffic-congested cities. Yet this very challenge highlights the real success of the Sao Paulo Metro subway-targeted AED program. In one of the most populated cities in all the world (Sao Paulo, New York City, Tokyo, Chicago, and Los Angeles<sup>3-5</sup>), all of which have struggled to

improve survival from OHCA, this targeted AED approach did just that—improved neurologically intact long-term survival for at least a subpopulation in the city of Sao Paulo. This approach should be considered by other large cities in Latin America and throughout the world.

## Conclusions

A targeted AED program involving the Sao Paulo Brazil Metro subway system produced a significant long-term, neurologically intact survival rate of 37% for OHCA victims. This is comparable to the success of other targeted AED programs in Great Britain, the United States, and Japan. A short time interval from collapse to defibrillation was the most predictive measurement for success. In this study, this interval averaged  $2.8 \pm 0.7$  minutes in survivors with good neurological function. These results support a strategic expansion of similar targeted AED programs in other large cities in Brazil and worldwide.

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## Disclosures

None.

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