Resuscitation (2007) **72**, 458—465

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TRAINING AND EDUCATIONAL PAPER

Advanced cardiac life support training improves long-term survival from in-hospital cardiac arrest☆

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Received 8 February 2006; received in revised form 14 June 2006; accepted 14 June 2006

KEYWORDS
Cardiopulmonary resuscitation (CPR);
Cardiac arrest;
Advanced cardiac life support (ACLS);
1-Year survival after cardiac arrest;
'In-hospital Utstein'

Summary
Context: Advanced cardiac life support (ACLS) training was introduced to bring order and a systematic approach to the treatment of cardiac arrest by professional responders. In spite of the wide dissemination of ACLS training, it has been difficult to demonstrate improved outcome following such training.
Objective: To determine the value of formal ACLS training in improving survival from in-hospital cardiac arrest.
Design, setting, and participants: A multi-center, prospective cohort study examined patient outcomes after resuscitation efforts by in-hospital rescue teams with and without ACLS-trained personnel. A total of 156 patients, experiencing 172 in-hospital cardiopulmonary arrest events over a 38-month period (January 1998 to March 2001) were studied.
Main outcome measures: Primary endpoints included return of spontaneous circulation (ROSC), survival to hospital discharge, 30-day survival, and 1-year survival.
Results: The immediate success of resuscitation efforts for all patients was 39.7% (62/156). There was a significant increase in ROSC with ACLS-trained personnel (49/113; 43.4%) versus no ALCS-trained personnel (16/59; 27.1%; $p = 0.04$). Likewise, patients treated by ACLS-trained personnel had increased survival to hospital discharge (26/82; 31.7% versus 7/34; 20.6%; $p = 0.23$), significantly better 30-day survival (22/82; 26.8% versus 2/34; 5.9%; $p < 0.02$), and significantly improved 1-year survival (18/82; 21.9% versus 0/34; 0%; $p < 0.002$).
Conclusion: The presence of at least one ACLS-trained team member at in-hospital resuscitation efforts increases both short and long-term survival following cardiac arrest.

☆ A Spanish translated version of the summary of this article appears as appendix in the final online version at 10.1016/j.resuscitation.2006.06.039

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doi:10.1016/j.resuscitation.2006.06.039

Introduction

Cardiac arrest continues to be a major cause of premature death in much of the world today.[1] Efforts to improve treatment of sudden cardiac death have focused on training and certification to obtain a more consistent treatment response. The ''chain of survival'' concept epitomizes this approach, emphasizing the need for rapid response to such emergencies through early recognition of the event, rapid activation of the emergency medical system, early CPR, early defibrillation, and early advanced cardiac life support.[2] In order to facilitate the use of these lifesaving steps, formal training courses have been developed for both lay persons and professional rescuers. The advanced cardiac life support (ACLS) programme developed by the American Heart Association (AHA) during the early 1980s represents the beginning of one such program.[3] Every 5–7 years the ACLS course is revised to include recent updates in the resuscitation science.[4–9] Such training is now required for certain medical and paramedical personnel, job certification, and for clinical hospital privileges. The United States alone spends approximately 1 billion dollars annually on personnel, training equipment, and educational materials related to CPR training, including ACLS training.[10]

However, the value of ACLS CPR training for improving long-term outcome after in-hospital cardiac arrest has never been proven. Most prior efficacy studies of ACLS training have reported increased skill acquisition and retention,[11,12] and overall increases in the number of attempted resuscitations,[13] but very few have examined whether such training improves outcome.[14–18] Lowenstein et al. found that after ACLS training of in-hospital housestaff, short-term (1 h) resuscitation rates increased, but no difference in survival to discharge was seen.[14] Likewise, Sanders et al. found improved initial resuscitation rates among a subset of VF/VT cardiac arrest patients after ACLS training among the staff of a rural Arizona hospital, but no difference in overall survival could be identified.[15]

In 1997, in conjunction with the Brazilian National Resuscitation Council, a formalized AHA ACLS training programme was begun in Brazil. More than 3900 Brazilian physicians, nurses and physiotherapists have been ACLS-trained since that time. The American Heart Association recognized this effort in the year 2000 and formally designated those involved as an ''International Community Training Center'' for advanced cardiac life support.[19] This recent effort has allowed a unique opportunity to prospectively evaluate the effect of formalized AHA ACLS training on both short- and long-term survival. The objective of the current study was to assess the effect on long-term survival of having in-hospital ''code teams'' (emergency teams) with and without ACLS-trained personnel. The hypothesis was that ACLS-trained personnel present at the resuscitation effort would increase survival rates from in-hospital cardiac arrest.

Materials and methods

Participating medical centers

In this multi-center, prospective, observational cohort study, the influence of rescue personnel with and without ACLS training on the success of in-hospital CPR was evaluated. The seven participating medical centers from Brazil are listed in acknowledgments. The Heart Institute (InCor) of the University of São Paulo Medical School, a tertiary level university hospital, was the study-coordinating center. The Ethics and Research Committee of the coordinating center approved the study.

To participate in this study, the service (any unit of a participating hospital: an emergency department, intensive care unit, coronary care unit, or regular ward) had to have the following resources available: (1) an around-the-clock medical and nursing team; (2) artificial ventilator support equipment, including a bag–valve–mask system and oral or nasal–tracheal intubation equipment; (3) antiarrhythmic and vasoactive drugs used in emergency care in accordance with AHA protocols; (4) cardiac monitoring and defibrillation equipment; (5) a health care professional in charge of the center who had taken the ACLS course, though this individual would not be involved in every specific resuscitation attempt.

Resuscitation personnel who were deemed ''ACLS-trained'' had completed a 2-day American Heart Association course using the ACLS textbook (1995 edition). The instructor to student ratio was 1:6 and all ACLS instructors had successfully completed a formal instructor course. Instruction was both theoretical and practical including the use of Laerdal Resusci-Annie® CPR manikins. Successful completion of the training required a passing score on both a written examination and a practical (MEGA-CODE) examination.

Those sites designated as not ACLS-trained had no formal training except as received in their general medical or nursing school course work. This training was very fundamental and did not include

any organized approach to cardiac arrest as contained in formal BLS or ACLS training courses.

Study population

All hospitalized patients who suffered cardiac arrest and received CPR while in a designated study ''service or unit'' were included. To be considered an in-hospital event, the arrest must have happened inside the hospital, which included the emergency department. Patients suffering cardiac arrest outside the hospital were not eligible for inclusion. Cardiac arrest was defined according to the following criteria: abrupt cessation of heartbeat, patient unresponsiveness, absent carotid and femoral pulses, and lack of normal, voluntary ventilation.[10]

Patients were excluded from the study if they: (1) were less than 20 years of age; (2) were found dead (rigor mortis present), or resuscitation efforts were considered futile by the attending team within a brief period ($\leq$3 min of starting the resuscitation effort); (3) had a ''do not resuscitate'' order; (3) had recent (<15 days) surgery; or (4) had a cardiac arrest due to either drug overdose or trauma.

Study protocol and outcome variables

Data was collected during and after each cardiopulmonary resuscitation effort according to the ''Recommended guidelines for reviewing, reporting, and conducting research on in-hospital resuscitation: the in-hospital 'Utstein style'".[10] To perform the present study, two additional questions were added to the ''Utstein style'' form: (1) How many people were present on the attending team? and (2) How many of the team members had received ACLS course training? Medical records and phone or mail contact were used to evaluate the post-resuscitation events and outcomes of patients.

To evaluate the influence of ACLS training on the success of CPR attempts, the immediate (return of spontaneous circulation [ROSC]), short-term (survival to hospital discharge) and long-term (30 days and 12 months) survival rates were compared in the following groups of patients:

- Group 1: ''with ACLS''—this group consisted of patients who underwent resuscitation attempts by a rescue team with at least one team member who had taken a formal ACLS course.
- Group 2: ''without ACLS''—this group consisted of patients who underwent resuscitation attempts by a rescue team, in which no one had taken the ACLS course.

Return of spontaneous circulation was defined per the ''Utstein style'' as a palpable central arterial (carotid or femoral) pulse without ongoing CPR.[10] Similarly, in accordance with the Utstein recommendations,[10] the calculation of the ROSC rate was based on total cardiac arrest events (and not number of patients), while calculation of survival rates (hospital discharge, 30-day, and 1-year) was based on number of patients. In analyzing factors that adversely influenced the chances of hospital discharge, data relevant to the first event were considered in cases in which the patient suffered two or more cardiac arrests.

Statistics

The predicted sample size needed for the study was based on an expected survival rate of 15% with ACLS-trained rescuers, with a CI = 95%. This was calculated to an anticipated need for 196 cardiac arrests. Considering a possible 10% data loss due to the exclusion criteria, a total of 216 cardiac arrests were estimated to be necessary to meet the prospectively identified statistical goals.

All variables were analyzed in a descriptive manner. The Mann—Whitney nonparametric test and Student's *t*-test for non-paired samples were used to compare group averages, and the chi-square test or Fisher's exact test was used to compare survival between groups.[19] Two-way analysis of variance was used to evaluate the relationship between previous ACLS training and duration of care.[20] Standard logistical regression techniques were applied to evaluate the effect of the number of ACLS trained rescuers involved in the attempt with resultant ROSC.[21] The acceptable level of significance was prospectively set at a $p = 0.05$. Data are reported as mean $\pm$ S.D.

Results

From January 1998 through March 2001, 232 events of in-hospital CPR were recorded in 216 patients at medical centers involved in this study. Sixty patients (27.8%) met one or more study exclusion criteria, never had resuscitation efforts begun, and were eliminated from analysis. Data from the remaining 156 patients, who suffered a total of 172 cardiac arrests, were analyzed in this study.

Initial return of spontaneous circulation was achieved in 37.8% (65/172) for all cardiac arrest events. Of the 156 patients who underwent in-hospital CPR, 62 (39.7%) achieved at least a temporary return of a pulse, 33 (16.6%) were discharged from the hospital alive, 24 (12.8%)

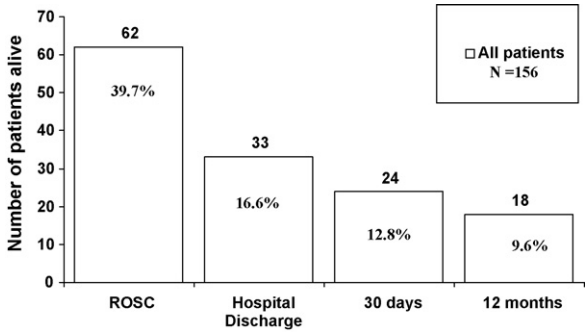

Figure 1 Patient outcome after in-hospital CPR.

survived for 30 days, and 18 patients (9.6%) were alive at 1-year (Figure 1).

Return of spontaneous circulation was increased significantly for cardiac arrests treated by ACLS-trained rescuers compared to those treated by rescuers without such training (Figure 2). No significant differences in patient variables (except for location at the time of arrest) were noted between those treated by rescue teams designated ''with'' ACLS-training and those treated by teams ''without'' ACLS-training (Table 1).

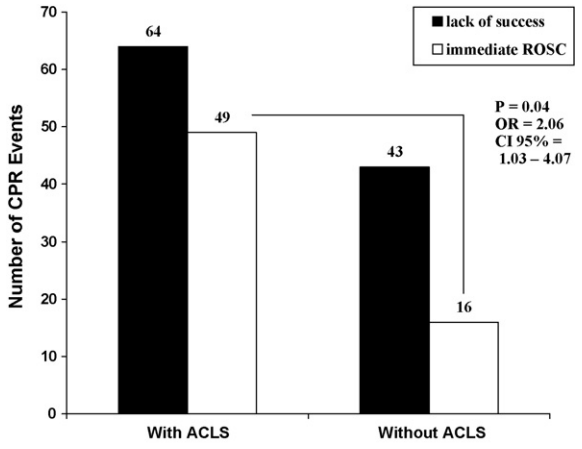

Figure 2 Return of spontaneous circulation among those treated by ALCS-trained rescuers and those treated by rescuers without ACLS training. 'OR' indicates the odds ratio of ROSC with at least one team member trained in ACLS.

Similarly, the cardiac arrest event characteristics were not significantly different between the two groups, though consistently the times to begin CPR, to the first defibrillation shock, to achieving

Table 1 Baseline patient and cardiac arrest event characteristics

	With ACLS ($N = 113$)	Without ACLS ($N = 59$)	p
Patient characteristics			
Age (in years)	64.4 ± 17.2	63.6 ± 15.8	0.76
Male sex	65 (58.6%)	32 (55.2%)	0.67
Location of event			0.001
Monitored beds	102 (90.3%)	44 (74.6%)	
Unmonitored beds	11 (9.7%)	15 (25.4%)	
Precedent hospital length (days)	6.3	3.3	0.08
Cardiac arrest characteristics			
Immediate cause			0.09
Arrhythmia	25 (22.1%)	13 (22%)	
Shock	11 (9.7%)	14 (23.7%)	
Respiratory	18 (15.9%)	13 (22%)	
Metabolic	6 (5.3%)	4 (6.8%)	
Other	3 (2.7%)	1 (1.7%)	
Witnessed event	107 (94.7%)	56 (95%)	1.000
Initial rhythm			0.07
VF	32 (28.3%	9 (15.3%)	
VT	5 (4.4%)	4 (6.8%)	
PEA	34 (30.1%)	13 (22%)	
Asystole	42 (37.1%	33 (55.9%)	
CPR started	1.2 ± 2.8 min	1.7 ± 2.8 min	0.34
First defibrillation shock	5 ± 5.6 min	8.7 ± 10.9 min	0.17
Airway achieved	5.2 ± 5 min	7.4 ± 7.8 min	0.25
First dose of epinephrine	4.6 ± 4.7 min	5.6 ± 5.9 min	0.34
Number of shocks	1.6	2.6	0.12
Total joules used	465.1	792	0.12

Table 2 Time to ROSC or No ROSC

ACLS	Subgroup	ROSC	Time to ROSC or termination, mean ± S.D. (min)
With	A	Yes	11.5 ± 11.1*
	B	No	29.8 ± 11.8
Without	C	Yes	30.0 ± 23.4
	D	No	33.5 ± 25.8

* Mann–Whitney test: A vs. C; $p = 0.005$.

an airway, and to administration of epinephrine (adrenaline), all tended to be earlier in the With ACLS-trained group (Table 1).

In contrast, a significant difference between the ACLS-trained and non-ACLS-trained groups was found for time to ROSC (Table 2). Through a two-way analysis of variance, a significant interaction between the two groups and the duration of resuscitation effort was observed ($p = 0.026$).

The tertiary care university hospital, as well as other hospitals with the highest incidence of emergency events (e.g., intensive care units, coronary units, emergency rooms), were the sites with the highest number of ACLS-trained personnel. However, each of the seven study sites enrolled patients that were treated by non-ACLS-trained rescue teams. The range of such patients enrolled varied between 1 and 18 per site with a mean of eight patients, and a median of seven patients. The tertiary university hospital InCor enrolled seven patients treated by a non-ACLS-trained rescue team. Individual hospital contributions to the patient enrollment are shown in Table 3.

Logistic regression analysis showed that the more ACLS-trained personnel present at the resuscitation effort, the more likely that ROSC would be achieved (Figure 3). The logistic regression model showed that a patient cared for by a team that included at least one person trained in ACLS was 2.06 times more likely to be successfully resuscitated than a patient cared for by a team that did not include anyone trained in ACLS (O.R. 2.06; 1.038–4.078; IC 95%; $p = 0.037$).

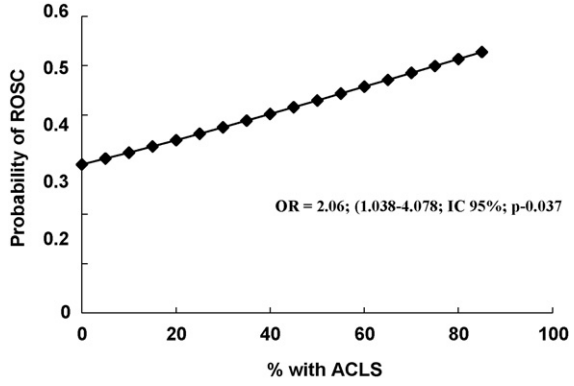

Figure 3 Model of logistic regression with relation to the number of the individuals on the resuscitation team who have ACLS training and the probability of immediate ROSC.

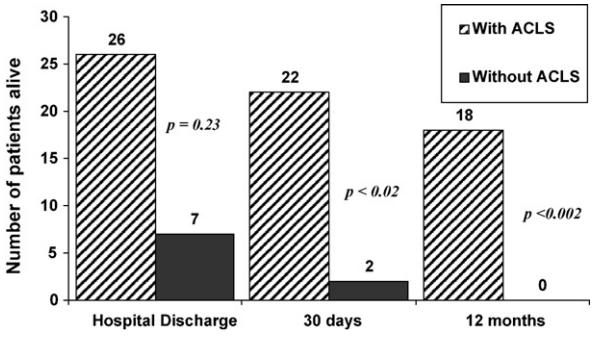

Figure 4 Long-term survival comparing those treated by ACLS-trained personnel and those treated by personnel without ACLS training.

Most importantly, the presence of an ACLS-trained rescuer on the cardiac arrest response team was associated not only with increased rate of ROSC, but with significantly greater long-term patient survival, including survival to 30 days and to 1 year (Figure 4).

Table 3 Individual hospital patient demographics

Hospital (sites)		Wards	ICU	ED	Total	Without ACLS
Secondary	V. Redonda	3 (3)	12 (12)	3 (3)	18	18 (100%)
	Paulínia		12 (12)		12	12 (100%)
Tertiary	IMC	1 (1)	6 (5)	1 (1)	8	7 (87.5%)
	Sírio	1	9 (1)	7	17	1 (5.8%)
	São Luiz	8 (7)	5	3	16	7 (16.6%)
Tertiary and University	Rib. Preto	4 (4)	3 (1)	10 (2)	17	7 (41%)
	InCor	9	21 (2)	54 (5)	84	7 (8.3%)
Total		26 (15)	68 (33)	78 (11)	172	59

Numbers inside brackets are those assisted by caregivers without-ACLS training; ED = emergency department.

Discussion

The overall early survival rate (ROSC = 39.7%) and the survival to hospital discharge rate (16.6%) following in-hospital CPR in this study are similar to those described in the literature from other studies in Brazil,[22] USA and Canada,[23–25] the United Kingdom,[26] and other European countries.[27]

This is the first clinical study to show improved long-term survival from in-hospital cardiac arrest when rescuers are formally trained in ACLS. Although others have observed that ACLS training improves resuscitation skills and knowledge, proving the effectiveness of ACLS training in increasing survival has been difficult.[11–18]

Lowenstein et al. reviewed the effect of mandatory ACLS training for medical house-officers during 6 months prior to such training (1979—80) and in a subsequent 6-month period after such training was required (1982—1983).[14] In their series of 90 cardiac arrests, they found that ALCS training for in-hospital rescue teams improved short-term survival (return of pulse) from 32% in the pre-ACLS training era to 60% during the post-ALCS training period ($p = 0.009$). However, no significant difference for survival to hospital discharge was found (13% versus 23%; p = NS).

Sanders et al. at the University of Arizona reported similar findings.[15] A retrospective case review of cardiac arrests treated at a rural southern Arizona hospital during a 13-month period before and after formal ACLS training was performed. Twenty-nine cardiac arrest patients were included from the pre-ACLS period, and 35 in the post-ACLS period. In this series, the majority of patients had their cardiac arrest in the community and were then brought to the hospital for definitive treatment. Of those with ventricular fibrillation, more were resuscitated after formal ACLS training was instituted than before such training (9/15 versus 0/9; $p < 0.05$). Likewise, in this community the out-of-hospital cardiac arrests were more commonly resuscitated in the period after ACLS training was instituted at the receiving hospital than in the period preceding this training (5/30 versus 0/25; $p < 0.05$). However, a significant difference in survival to hospital discharge could not be demonstrated between the period without ALCS training and after ACLS training was introduced (2/29 versus 7/35; $p = 0.2$).

In 1997, Cooper et al.[16] reported that the institution of a resuscitation training programme in a large non-teaching hospital in the United Kingdom increased immediate survival (1 h) by 5% (38% in the pre-training period and 43% in the post-training period). However, this increase did not reach statistical significance.

Dane et al. found that in-hospital patients whose cardiac arrests were discovered and initially treated by nurses with ACLS training had a four-fold increase in survival to discharge ($p < 0.02$).[17] Although the nurses trained in ACLS could defibrillate and administer drugs during the resuscitation, ACLS-trained physicians arrived within 60 s of the emergency call. The authors could not identify a mechanism from their data why this initial minute of resuscitation care nurse training in ACLS was so crucial. Of note, not all areas of the hospital were evaluated, a potential confounding factor in this study.

Henderson et al. reported in 2001 that the addition of an experienced emergency department physician and nurses from the ICU to the in-hospital cardiac arrest response team significantly increased the return of spontaneous circulation rate ($p = 0.0002$), compared to a period before such individuals were involved.[18] However, the effect of specific cardiopulmonary resuscitation training (ACLS or otherwise) was not evaluated in this ''before and after'' study. No significant difference in longer-term outcome was demonstrated.

The current study is the first to show a significant difference in long-term survival, including 1-year survival after cardiac arrest, when rescuers are ACLS-trained. The relatively recent institution of a national formal ACLS training programme in Brazil, administered according to the guidelines outlined by the American Heart Association,[6] and using AHA materials, provided the opportunity to examine whether formal ACLS-training improves long-term patient outcome. Though non-randomized, the populations compared in this prospective, multi-center, cohort study were well matched (Table 1). Location of in-hospital cardiac arrest was the only variable found to differ between ACLS-trained and the non-ACLS-trained groups. Most likely this reflects the interest in such training by those working in areas of emergency medicine or intensive care units. Such interest appears to have led staff working in these hospital areas to seek and obtain personal ACLS training early in the beginnings of this national training program. Although the ACLS-trained group managed a higher number of cardiac arrest rhythms that could be treated with defibrillation, this difference did not reach statistical significance. Thus the similarity between the ''with ACLS'' and ''without ACLS'' groups allowed an examination of whether the presence or absence of ACLS-trained rescuers on the cardiac arrest response team affected patient survival. The presence of ACLS-trained individuals proved to be important for improving both the immediate success

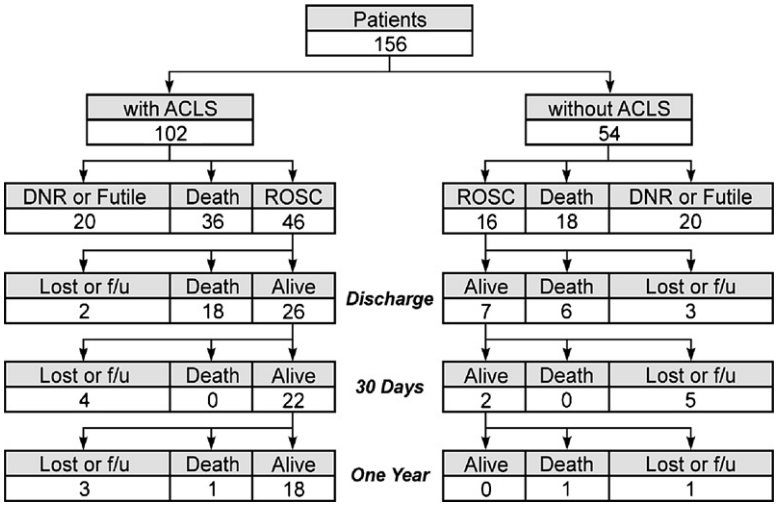

Figure 5 Flow chart of patients suffering in-hospital cardiac arrest.

of CPR efforts (Figure 2) and long-term survival (Figure 4).

Another predictor of good outcome following in-hospital cardiac arrest was the length of time needed to resuscitate. Bedell et al. first reported this relationship for in-hospital cardiac arrests in 1983.[28] Our study showed that the length of time needed to resuscitate successfully was significantly less for patients treated by ACLS-trained rescuers than those who were not (Table 2). Although time needed to resuscitate is not an independent variable, this interval correlated with both immediate success (ROSC) and hospital discharge rates.

This study showed that having even one ACLS-trained professional on the team was enough to improve long-term survival. Increasing the number of ACLS-trained rescuers on the response team has an incremental effect on improving outcome. Logistic regression showed that increasing such trained rescuers from only one of five, to four of five on the response team, can increase the probability of ROSC by more than 10% (38% to 50%, Figure 3).

Study limitations

In cohort studies, even when prospective, ensuring homogeneity between the study populations is crucial. Although none of the major patient or CPR characteristics was statistically different between the two groups, it is important to recognize that this data was derived from a non-randomized, selected cohort.

The major limitation of this study was the impossibility of registering all cases of cardiac arrest. Selected in-hospital areas or 'units' were chosen prospectively for inclusion in the study, based on the frequency of cardiac arrests and the ability of the staff to complete the study forms. Perhaps a mandatory reporting of all cases of cardiac arrest in each participating hospital, as in the study of Timerman et al.,[22] would have been more complete. However, all cardiac arrests occurring in the prospectively identified 'units' were included in the study. In 12 cardiac arrests, (three in ''with ACLS'' group and nine in ''without ACLS'' group), there were data for ROSC and 1-year outcome, but none regarding medications used during the resuscitation effort and the duration of resuscitation efforts. Therefore, only the outcome data of these 12 were used.

In accordance with the ''in-hospital Utstein'' recommendations,[10] patients in whom resuscitation efforts were begun but discontinued within 3 min once a DNR status was discovered or the attending physician determined such efforts to be futile, were eliminated from the final determination of survival outcomes. An account of all enrolled patients is shown in Figure 5.

Conclusions

In summary, this clinical study showed improved long-term survival from in-hospital cardiac arrest when the responding emergency team included ACLS-trained individuals. This is the first report to verify the value of American Heart Association ACLS training using the revised educational materials and case-based approach developed in the mid-1990s. This study also proves the importance and impact of a recently instituted national ACLS-training programme, where such had not been available before. We conclude that such nationally

coordinated ACLS-training programmes as recently conducted in Brazil, are effective at improving survival of patients suffering in-hospital cardiac arrest.

Acknowledgments

Thank you to all who gave of their time to complete the clinical case record forms.

Centers which participated in the study: Heart Institute (InCor) University of São Paulo Medical School and Sírio Libanês Hospital—Luiz Antonio Machado César, MD PhD and Miguel Antonio Moretti, MD PhD; São Luiz Hospital—João Fernando M. Ferreira, MD; PhD Ribeirão Preto Clinical Hospital São Paulo Medical School—Benedito Carlos Maciel, MD PhD, André Schmitd MD PhD and Antonio Pazin Filho, MD PhD; IMC-Coronary Unit of São José do Rio Preto—Gilmar Valdir Gregue, MD and Clotildes Santiago Prates, NP); Intensive Unit Care of Paulínia Hospital—Cristina Terzi, MD; Intensive Unit Care of Volta Redonda Hospital—Paulo José Ferreira Soares, MD.

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