Automated external defibrillators and survival after in-hospital cardiac arrest: early experience at an Australian teaching hospital

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ABSTRACT

Objective: To evaluate the effect of the introduction of automated external defibrillators (AEDs) on survival after in-hospital cardiac arrest.

Design, setting and participants: Before-and-after study that compared patients during the 2 years before (8 November 2005 to 7 November 2007) and the year after (8 November 2007 to 7 November 2008) the deployment of AEDs to the non-critical care areas of a university teaching hospital.

Main outcome measures: Return of spontaneous circulation (ROSC) and survival to hospital discharge.

Results: 55 in-hospital cardiac arrests occurred in the 2-year pre-AED period and 31 in the 1-year AED period. Patients had similar baseline characteristics in the pre-AED and AED periods including witnessed arrest (53% v 48%), arrest in an acute inpatient ward (78% v 90%), and initial arrest rhythm of pulseless ventricular tachycardia or ventricular fibrillation (18% v 16%). The proportions of patients with ROSC were similar in the pre-AED and AED periods (42% v 55%), as were the proportions who survived to hospital discharge (22% v 29%). In the AED period, the relative risk of ROSC was 1.31 (95% CI, 0.84–2.04) and the relative risk of survival to hospital discharge was 1.33 (95% CI, 0.63–2.80).

Conclusions: ROSC and survival to hospital discharge did not change significantly after deployment of AEDs. The existence of a timely and robust resuscitation response with relatively good baseline outcomes, and the low proportion of initial shockable arrest rhythms may have limited the capacity of AEDs to improve survival.

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Early defibrillation is a key determinant of survival after cardiac arrest.[1,2] Automated external defibrillators (AEDs) can analyse the cardiac rhythm, charge automatically if a shockable rhythm (ventricular fibrillation [VF] or pulseless ventricular tachycardia [VT]) is recognised and provide the operator with audible and/or visual prompts for the safe delivery of an electrical shock.[3] AEDs permit effective defibrillation by "first responders" with little training.[4-7] There is high-level evidence supporting the use of these devices in the management of out-of-hospital cardiac arrest.[8] Australian Resuscitation Council guidelines include the use of an AED, when one is available, as a component of basic life support.[9]

The role of AEDs in the management of in-hospital cardiac arrest is unclear. To our knowledge, there have been no randomised controlled trials of AEDs for in-hospital cardiac arrest. Large case series of successful resuscitation from in-hospital cardiac arrest when AEDs were available have been reported,[10,11] and a single-centre study of in-hospital cardiac arrest found a significant improvement in survival to hospital discharge after implementation of an early defibrillation program that included use of AEDs.[12] However, a more recent single-centre study found that replacing manual defibrillators with AED-capable defibrillators made no difference to survival to hospital discharge after in-hospital cardiac arrest.[13]

Here, we present what we believe are the first published Australian data on survival after in-hospital cardiac arrest where AEDs were used. We assessed the effect on patient outcomes of introducing AEDs into the non-critical care areas of a teaching hospital. In addition, we compared cardiac arrests that occurred in the non-critical care areas where the AEDs were deployed with those that occurred in areas where the devices were not available, chiefly the critical care areas of the hospital.

Methods

St Vincent's Hospital, Melbourne, Victoria, is a university-affiliated teaching hospital that, at the time of the study, had about 300 acute and 80 subacute inpatient beds for adults. Prospective, Utstein-style[14] data were gathered by intensive care staff on all cardiac arrests that occurred at the hospital and were associated with a medical emergency call. Data were checked against a log of these calls from the hospital paging system to ensure that all cases of cardiac arrest associated with such a call were captured. Cardiac arrests in the emergency department and intensive care unit were not always the subject of a medical emergency call, whereas cardiac arrests in other areas almost certainly were.

Table 1. Inpatient admissions, medical emergency response calls and cardiac arrests during the study period

Period	Total inpatient admissions	Emergency (MET and Blue) response calls	Cardiac arrests	
			AED area	Non-AED area
8 Nov 2005 – 7 Nov 2006 (pre-AED)	51 599	576	35	25
8 Nov 2006 – 7 Nov 2007 (pre-AED)	52 965	570	20	11
8 Nov 2007 – 7 Nov 2008 (AED)	51 578	756	31	30

MET = medical emergency team. AED = automated external defibrillator.

Cardiac arrest was deemed to have occurred when a patient was treated with cardiac compressions or electrical defibrillation. The Medical Director of Intensive Care (J D S) oversaw data collection. Approval of the local human research ethics committee was obtained for this study.

Introduction of automated defibrillators

In May 2007, 18 AEDs (Heartstart FR2+, model M3860A, Philips Medical Systems, Seattle, Wash, USA) were purchased. Included in the purchase were two training AEDs and software for managing information recorded by the AEDs. The AEDs permitted biphasic waveform defibrillation and had an electrocardiographic display that allowed basic rhythm interpretation and manual override capability to permit manual defibrillation. The AED shock energy level was fixed at 150 J. Synchronised shock delivery and transcutaneous pacing were not possible with the AED.

On 8 November 2007, AEDs were deployed to 17 clinical areas, including outpatient clinics, outpatient dialysis, day procedures, medical imaging departments, the rehabilitation ward, physiotherapy department, mental health and most of the acute inpatient wards. Little continuous cardiac monitoring was available in these areas, and most first responders could not perform manual defibrillation. Manual defibrillators were retained in the emergency department, operating theatres, intensive care and coronary care departments, cardiology and cardiothoracic wards, and cardiac catheterisation laboratories.

Two types of medical emergency response were available during the study period: a "Respond MET" was available for inpatients who displayed serious (but non-arrest) signs and symptoms, and a "Respond Blue" was available for patients suffering cardiac arrest, respiratory arrest, threatened airway or another condition that was perceived as immediately life-threatening. The medical emergency team (MET) consisted of a medical registrar, intensive care registrar and senior intensive care nurse. The Respond Blue team consisted of the MET personnel and either an anaesthetic registrar (for inpatient areas) or an emergency registrar and a senior emergency nurse (for non-inpatient areas). The MET and Respond Blue teams supplemented care provided by medical and nursing staff of the patient's primary treating unit. The Australian Resuscitation Council algorithms for basic life support and advanced life support were followed.

Nursing and allied health staff undertook mandated annual competency assessment in basic life support. Medical and nursing members of the MET and Respond Blue teams undertook training in advanced life support. In the 3 months before the AED deployment, a staff education program provided instruction in the use of the AEDs to over 80% of clinical staff. The use of AEDs was then incorporated into the hospital's usual resuscitation training programs.

Statistical analysis

Statistical analysis was performed using the statistical software program Stata, version 10.1 (StataCorp, College Station, Tex, USA). Categorical variables were presented as percentages. Normally distributed continuous variables were presented as mean and standard deviation, while non-normally distributed variables were presented as median and range. Differences in categorical variables were assessed using χ^2 or Fisher exact tests. *P* values less than 0.05 were taken to signify statistical significance. Risk ratios and 95% confidence intervals for return of spontaneous circulation (ROSC) and survival to hospital discharge in the AED period were calculated.

Results

During the 3 years of the study, there were 156 142 inpatient admissions, 1902 medical emergency calls and 152 cardiac arrests at the hospital. These inpatient admissions included day cases and acute and subacute care admissions but not outpatient appointments or emergency department attendances. Hospital activity with respect to inpatient admissions, medical emergency calls and cardiac arrests is shown in Table 1.

Cardiac arrests

In the 3 years of the study there were 58 098 acute inpatient admissions (excluding day cases — admissions for day haemodialysis, day chemotherapy, day endoscopy or

Table 2. Characteristics of patients who suffered a cardiac arrest (no. [%]*)

	AED areas		Non-AED areas
Characteristic	Pre-AED period ($n = 55$)†	AED period ($n = 31$)‡	Pre-AED + AED period ($n = 66$)
Age in years, median (range)	74 (39–93)	78 (56–90)	70 (40–85)
Sex, no. of males	34 (62%)	17 (55%)	42 (64%)
Medical unit	41 (75%)	19 (61%)	48 (73%)
Witnessed arrest	29 (53%)	15 (48%)	61 (92%)
Location			
Acute inpatient ward	43 (78%)	28 (90%)	na
Medical imaging	8 (15%)	2 (6%)	na
Other AED area	4 (7%)	1 (3%)	na
Coronary care	na	na	32 (48%)
Cardiology and cardiothoracic	na	na	18 (27%)
Cardiac catheter laboratory	na	na	8 (12%)
Intensive care	na	na	5 (8%)
Other non-AED area	na	na	3 (5%)
Initial rhythm			
Asystole	17 (31%)	9 (29%)	10 (15%)
Pulseless electrical activity	26 (47%)	17 (55%)	23 (35%)
VT or VF	10 (18%)	5 (16%)	30 (45%)
Not known	2 (4%)	0	3 (5%)

AED = automated external defibrillator. na = not applicable. VT = pulseless ventricular tachycardia. VF = ventricular fibrillation.
* Unless otherwise specified. † 8 Nov 2005 – 7 Nov 2007. ‡ 8 Nov 2007 – 7 Nov 2008.

any other day treatment or investigation). After excluding cardiac arrests in coronary care, the cardiac catheterisation laboratories, intensive care and the emergency department, the cardiac arrest rate for the 3 years of the study was 1.81 per 1000 acute non-day-case inpatient admissions.

Cardiac arrests in AED areas

There were 86 cardiac arrests in AED areas: 55 during the 2-year pre-AED period and 31 during the 1-year AED period. These 86 cardiac arrests involved 85 different patients. An AED was used in all 31 cases that occurred in the AED period, and manual override was required on one occasion to deliver a shock for VT.

Patients who suffered a cardiac arrest in the AED areas had similar characteristics in the pre-AED and AED periods, including median age (74 years v 78 years), sex (62% v 55% male), assignment to a medical unit (75% v 61%), witnessed arrest (53% v 48%), event occurred in an acute inpatient ward (78% v 90%), and initial arrest rhythm of VT or VF (18% v 16%). The characteristics of patients who suffered a cardiac arrest are shown in Table 2.

Outcomes after cardiac arrest: the effect of AEDs

Of the patients who suffered a cardiac arrest in an AED area, there were similar proportions in the pre-AED and AED periods with ROSC (42% v 55%) and survival to hospital discharge (22% v 29%). In the AED period, the risk ratio for ROSC was 1.31 (95% CI, 0.84–2.04, $P = 0.25$), and for survival to hospital discharge was 1.33 (95% CI, 0.63–2.80, $P = 0.45$). Outcomes of patients after cardiac arrest are shown in Table 3 and Table 4.

There were similar proportions in the pre-AED and AED groups with ROSC and survival to hospital discharge for each category of cardiac arrest rhythm. For patients with an initial rhythm of VT or VF, the risk ratio in the AED period for ROSC was 1.67 (95% CI, 1.00–2.76, $P = 0.23$) and for survival to hospital discharge was 1.20 (95% CI, 0.47–3.09, $P = 1.00$).

Unwitnessed cardiac arrests in AED areas

Of the 86 cardiac arrests that occurred in AED areas before and after the AED deployment, 44 (51%) were witnessed. Among those whose events were witnessed, 32% were discharged alive from hospital; this compares with 17% of patients whose events were unwitnessed. The proportion of patients with an initial shockable rhythm was similar whether the cardiac arrest was witnessed or not witnessed: 19% and 17%, respectively.

Comparison between critical care and AED areas

Over 95% of cardiac arrests in a non-AED area occurred in a critical care area, with 48% in the coronary care unit. Patients in these non-AED areas differed from those in the

Table 3. Return of spontaneous circulation and survival to hospital discharge among patients who suffered cardiac arrest (number [%])

	AED areas		Non-AED areas
Outcome	Pre-AED period ($n = 55$)*	AED period ($n = 31$)†	Pre-AED + AED period ($n = 66$)
Return of spontaneous circulation			
All rhythms	23 (42%)	17 (55%)	50 (76%)
Asystole	5 (29%)	3 (33%)	6 (60%)
Pulseless electrical activity	12 (46%)	9 (53%)	13 (57%)
VT or VF	6 (60%)	5 (100%)	28 (93%)
Survival to hospital discharge			
All rhythms	12 (22%)	9 (29%)	32 (48%)
Asystole	2 (12%)	2 (22%)	2 (20%)
Pulseless electrical activity	5 (19%)	4 (24%)	6 (26%)
VT or VF	5 (50%)	3 (60%)	23 (77%)

AED = automated external defibrillator. VT = pulseless ventricular tachycardia. VF = ventricular fibrillation.
* 8 Nov 2005 – 7 Nov 2007. † 8 Nov 2007 – 7 Nov 2008.

non-critical care AED areas. For example, they had significantly higher proportions of witnessed arrest (92% v 51%, $P < 0.01$) and an initial rhythm of VT or VF (45% v 17%, $P < 0.01$). Outcomes also differed between these groups: patients in the non-AED areas had significantly higher proportions of ROSC (76% v 47%, $P < 0.01$) and survival to hospital discharge (48% v 24%, $P < 0.01$) compared with those in non-critical care AED areas.

Table 4. Risk ratios for patients who suffered cardiac arrest when an AED was available

Outcome	Risk ratio* (95% CI)	P†
Return of spontaneous circulation	1.31 (0.84–2.04)	0.25
Survival to hospital discharge	1.33 (0.63–2.80)	0.45

AED = automated external defibrillator. * For AED group.
† P for χ^2 tests that compared pre-AED and AED groups.

Discussion

AEDs were deployed to 17 non-critical care areas of a teaching hospital. We found that cardiac arrest patients in these areas before and after the AED deployment had similar standard demographic characteristics, initial cardiac arrest rhythms and survival to hospital discharge. The most favourable cardiac arrest outcomes at the hospital were in the critical care areas, where manual defibrillation was performed and where both the proportion of witnessed cardiac arrest and proportion of initial shockable rhythms were significantly higher than in the AED areas. The cardiac arrest rate for the 3 years of the study, of 1.81 per 1000 acute non-day-case inpatient admissions, was comparable with rates reported at other Australian hospitals.[15,16]

Several factors may have limited the ability of AEDs to improve outcome. The response times of MET and Respond Blue teams to the scene of most cardiac arrests were probably less than 10 minutes and, in many cases, less than 5 minutes. The potential for an AED to improve outcome from VT or VF by shortening the time to effective defibrillation was less than in other settings where the response time from advanced life-support providers is longer. Secondly, most of the cardiac arrests in AED areas involved an initial rhythm that was not shockable. Finally, ROSC and survival to hospital discharge after cardiac arrest were relatively good before AEDs were introduced. In comparison with a large cohort of in-hospital cardiac arrest patients in the United States,[17] baseline survival to hospital discharge at our hospital was more favourable for initial asystole (12% v 10% in the US), initial pulseless electrical activity (19% v 10%), and initial VT or VF (50% v 35%). There may not have been substantial room for further improvement in our inpatient population. The use of a MET system to intervene early when patients show physiological decline, along with a timely and robust response to assist victims of cardiac arrest, and judicious use of treatment limitation orders are possible factors in the comparatively favourable baseline outcomes we observed.

Our results differ from those of Zafari and colleagues, who reported a statistically significant improvement in survival following in-hospital cardiac arrest after implementation of a program encouraging early defibrillation, which included AEDs.[12] The increase in survival was attributed solely to the improvement in outcome for those who presented with VT or VF. The low baseline survival rate (4.9%) was probably an important factor in this improvement. In another single-centre study, Forcina et al reported no significant change in survival to hospital discharge from in-hospital cardiac arrest after AEDs became available,[13] a finding that was consistent with our experience.

The impact of AEDs on chest compressions and on the broader resuscitation effort needs consideration. While AED rhythm analysis may delay chest compressions in comparison to manual defibrillation,[18] other AED features may enhance their delivery. Prompts from AEDs indicate the beginning and end of each resuscitation cycle and also encourage rescuers to commence resuscitation after each rhythm analysis or shock. Anecdotally, less experienced rescuers at our hospital report feeling more confident providing basic life support when an AED is in use.

Our study was limited by its before-and-after design and the small number of cardiac arrest cases involved. ROSC and survival to hospital discharge appeared similar in the pre-AED and AED periods, but we cannot exclude the possibility of an improvement or deterioration. In addition, although patients in the pre-AED and AED periods were similar with respect to standard demographic characteristics and the initial cardiac arrest rhythm, we did not collect data on severity of underlying illness, treatments or limitation of treatments, and it is possible that the groups differed in these respects. Despite these limitations, this study sheds some light on the nature of in-hospital cardiac arrest and the potential for AEDs to influence survival.

AEDs may have only a modest overall effect on survival after in-hospital cardiac arrest in the non-critical care areas of a teaching hospital when there is an established and timely medical emergency response system, baseline outcomes are relatively good, and the proportion of cardiac arrests with an initial shockable rhythm is low. Patients in hospitals or areas of a hospital without access to a timely and robust medical emergency response are most likely to benefit from an AED. AEDs change the resuscitation paradigm, and further evaluation of their use for in-hospital cardiac arrest should consider their effect on staff satisfaction, safety of defibrillation, resuscitation training, delivery of chest compressions and rescue breathing, organisation of the resuscitation effort and cost.

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