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Original Article

The Prognosis of Patients who Received Automated External Defibrillator Treatment in Hospital

Isao Kato MD, Toru Iwa MD, Yasushi Suzuki MD, Takayuki Ito MD

Division of Cardiology, Aichi Medical University School of Medicine

Introduction: Unlike cardiac arrest occurring out-of-hospital, the safety and efficacy of automated external defibrillators (AED) in the hospital has not been assessed. This study examined the conditions of AED use in hospital and the prognosis of these patients.

Methods and Results: We examined the condition and prognosis of 32 patients who were given AED treatment while they were in an unconscious state in the hospital, between May 2004 and January 2007. During this period, AED was used only for patients, not for visitors or hospital personnel.

Ventricular fibrillation (VF) or ventricular tachycardia (VT) was observed in 7 patients, and in the other 25 the initial rhythm of the patients did not require AED. Two patients survived with the help of AED, but it did not deliver shock in two patients with VF and VT. There was no significant difference in vital prognosis due to the presence or absence of shock delivery in the VF or VT patients.

Conclusion: The situation of AED use may be different whether it is used in hospital or out-of-hospital. This study suggests that using AED in the hospital may have limited effect when it is used for critically ill patients.
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Key words: AED, Ventricular fibrillation, Resuscitation, Cardiac arrest, Defibrillation

Introduction

The safety and efficacy of automated external defibrillators (AED) on patients with ventricular fibrillation (VF) in out-of-hospital settings has been confirmed.[1–3] AED are also easy to use[4] enabling widespread access to the device which can be operated by the ordinary citizens.[5,6] Indeed, use of AED is spreading in Japan today.[7–9] We also confirmed its efficacy at the Aichi Expo where it was administered by ordinary citizens.[10] Even though the efficacy of AED has been confirmed, there has been no data on their use in hospitals and their effect on patient prognosis.[11] As a result, we examined the in-hospital efficacy of AED by evaluating the prognosis of patients who were administered AED.

Methods

Subjects

In May 2004 we placed 26 commercially available AEDs, which cannot be switched to manual mode, in the wards of our hospital. We held a monthly lecture

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Address for correspondence: Isao Kato MD, Division of Cardiology, Aichi Medical University School of Medicine, 21 Karimata Yazako Nagakute Aichi 480-1195, Japan. Tel: 0561-62-3311 Fax: 0561-63-8482 E-mail: isao@aichi-med-u.ac.jp

on how to use AEDs to train the medical staff, including nurses, so that they could better operate them. Manual defibrillators were placed in the circulatory ward, the intensive care unit and the pediatric ward instead of AEDs. Therefore, AEDs were only used in the general wards. In this study, the users of AED were all medical staffs who did not specialize in circulatory medicine. The AED was used in about 20% by the nurses before arrival of the doctor. We investigated all 32 patients to whom defibrillation pads of the AED were applied in an unconscious state, from May 2004 to January 2007.

Cardiac arrest was observed in 29 patients (15 male and 14 female) whose average age was 69 ± 13 years (average $\pm$ standard deviation). Eighty six per cent of the cardiac arrest patients had grave basal disease such as terminal cancer.

Analysis

The AED we used was "Heart Start FR2, M3860A" manufactured by Philips Medical. As a condition for shock delivery, Heart Start FR2 requires more than five VF amplitudes of 200 μV or higher during five seconds of electrocardiogram, as well as twelve or more amplitudes which are 80 μV or higher each. It also delivers shock for polymorphic ventricular tachycardia (VT) with a heart rate of 150 beats per minute (bpm) or more and monomorphic VT with a heart rate of 250 bpm or more.

After AED use, we analyzed the electrocardiogram by retrieving the electrocardiogram data from inside the Holter system using the Philips' analysis software "Event Review 3.5" from the data card M3854A attached to the main body and manufactured by Philips Medical System. We investigated the patient's basal disease, the condition of the patient and the circumstances of AED use, relying on the medical record of patients on whom AED was used.

Regarding vital prognosis, patients who survived by means of cardiopulmonary resuscitation were included in the survival group; patients temporarily experiencing a return of spontaneous circulation by resuscitation but dying several hours later or several days later were included in the subsequent death group; and patients who died without successful resuscitation were categorized in the instant death group.

Patients who suffered cardiac arrest were divided into two groups according to the time elapsed from the beginning of unconsciousness to cardiopulmonary resuscitation. Cardiac arrest patients who were discovered instantly were categorized under the group cardiac arrest witnessed. Patients who were discovered unconscious by chance during rounds were categorized under the group cardiac arrest not witnessed.

The rate of occurrence was calculated with the Fisher exact probability test.

Results

We categorized 32 patients in which AED was used according to the heart rhythm at the time unconsciousness was first discovered. There were 3 non-cardiac-arrest patients who were unconsciousness, such as vagal reflection after urination, 22 patients with asystole or pulseless electrical activity (PEA) ($22/32 = 69\%$), and 7 with VF or VT (5 VF and 2 VT) ($7/32 = 22\%$) (**Figure 1**). Only 3 of the asystole or PEA patients had heart disease ($3/22 =$

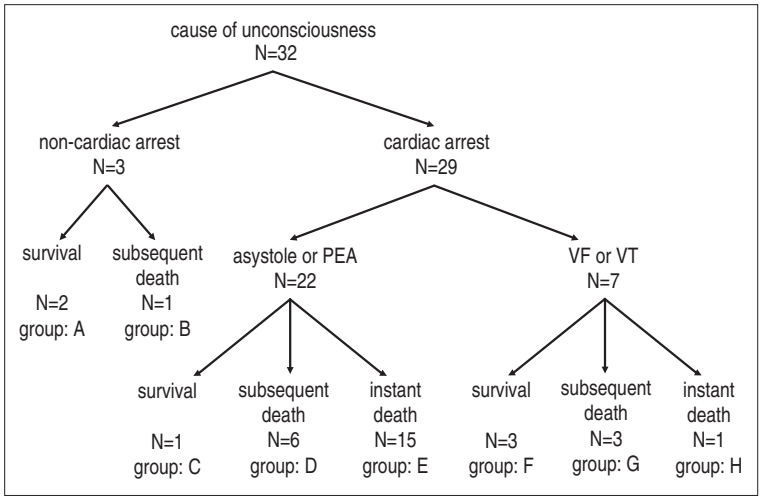

Figure 1 The rhythm of the patients used AED and outcome of the patients.
AED was used for non-cardiac arrest which was not indication of use. AED was used to 22 asystole or PEA cases and seven VF or VT cases.
PEA: pulseless electrical activity

Table 1 List of patients.

Group	Age	Sex	Pulse	Presence of shock delivery	Outcome	Basal disease	Cause of syncope
A	88	F	sinus bradycardia	–	living	hypertension	vagal reflection after urination
A	43	M	sinus rhythm	–	living	nothing	insolation
B	58	F	PVC	–	death after 6 hours	multiple myeloma	septic shock
C	72	F	PEA	–	living with coma	manic-depressive psychosis	unknown
D	67	F	asystole	–	death after 2 days	cervical cancer	unknown
D	81	F	PEA	–	death after 3 hours	otitis media	pneumonia, respiratory failure
D	71	F	PEA	–	death after 10 days	myelodysplastic syndrome	unknown
D	68	F	PEA*	–	death after 10 days	cerebral infarction	bolus asphyxia
D	71	M	asystole*	–	death after 14 days	kidney failure	septic shock
D	67	M	PEA	–	death after 2 days	kidney failure	unknown (post CABG)
E	74	M	PEA	–	death	hemorrhagic colon polyp	unknown
E	77	M	asystole	–	death	interstitial pneumonia	respiratory failure
E	83	F	asystole	–	death	scald of left leg	unknown
E	82	M	asystole	–	death	hemorrhagic gastric ulcer	unknown (with OMI, heart failure)
E	88	M	asystole	–	death	kidney failure	pneumonia, respiratory failure
E	17	F	asystole	–	death	aplastic anemia	cerebral hemorrhage suspect
E	76	F	asystole	–	death	cataract	unknown
E	55	M	PEA	–	death	feet necrosis	hemorrhagic duodenal ulcer
E	65	F	asystole*	–	death	subarachnoid hemorrhage	subarachnoid hemorrhage
E	55	F	asystole*	–	death	liver carcinoid	perforative peritonitis
E	84	M	PEA*	+	death	multiple small intestine ulcer	bolus asphyxia
E	63	M	asystole	–	death	liver cancer	unknown
E	64	M	asystole*	+	death	cerebral infarction	aspiration pneumonia (with post CABG)
E	70	F	asystole	–	death	aplastic anemia	septic shock
E	66	M	asystole	–	death	gastric ulcer	unknown (rupture of AAA suspect)
F	72	F	VF	+	living	liver cancer	acute myocardial infarction
F	74	M	VT (Tdp)	+	living	delirium	drug induced Tdp (with OMI)
F	66	F	VT	–	living	OMI	heart failure
G	64	F	VF	–	death after 1 hour	gallbladder cancer	respiratory failure
G	76	F	VF	+	death after 6 days	kidney failure	heart failure
G	54	M	VF	+	death after 14 hours	arteriosclerosis obliterans	bowel necrosis (post CABG)
H	73	M	VF	+	death	multiple myeloma	pancreatitis

The details of group A-H of Table 1 are shown. Many patients had grave basal disease.
∗: Patients with epinephrine-induced VF or VT
OMI: old myocardial infarction, CABG: coronary artery bypass grafting, AAA: abdominal aortic aneurysm

14%). Five patients with VF or VT had heart disease (5/7 = 71%) (**Table 1**).

Shock delivery

AED did not deliver shock to all the patients with non-cardiac arrest and asystole or PEA. AED did deliver shock in five patients with VF or VT (4 VF and 1 Torsade de pointes). One VF (**Figure 2**) and 1 monomorphic VT patient were not delivered shock. When discovered unconscious, 6 out of 22 patients with asystole or PEA developed VF or VT after intravenous injection of epinephrine during resuscitation (2 VF and 4 monomorphic VT). Two patients with epinephrine-induced VF were delivered shock. However, 4 patients with epinephrine-induced monomorphic VT did not receive shock. All 5 patients with monomorphic VT, including the epinephrine-induced ones, were not delivered shock because their heart rates were too slow to fulfill the diagnostic criteria for Heart Start FR2 (**Figure 3**).

Vital prognosis after AED use

Two out of 3 patients with non-cardiac arrest survived. The remaining 1 patient died from septic shock a few hours later.

One patient among those with asystole or PEA survived, 6 died subsequently and 15 died instantly. The sole survivor from asystole or PEA survived in a comatose state.

Among those with VF or VT, 3 patients survived, 3 died subsequently and 1 died instantly. In the prognoses of those VF or VT patients in which AED did not defibrillate, 1 monomorphic VT patient survived and 1 VF patient died subsequently. As for the prognosis of those VF or VT patients in which AED did defibrillate, 2 (1 VF caused by acute myocardial infarction and 1 Torsade de pointes caused by proarrhythmia with old myocardial infarction) survived, 2 VF patients died subsequently and 1 VF patient died instantly (**Table 2**).

We examined the 7 VF and VT patients for the relationship between the presence or absence of shock delivery and the prognosis for survival, subsequent death or instant death, but failed to find any significant difference. In 29 cardiac arrest patients, we tested for a relationship between the presence or absence of shock delivery (including epinephrine induced VF or VT) and the prognosis for survival, subsequent death or instant death. We found no significant difference between them (**Table 3**).

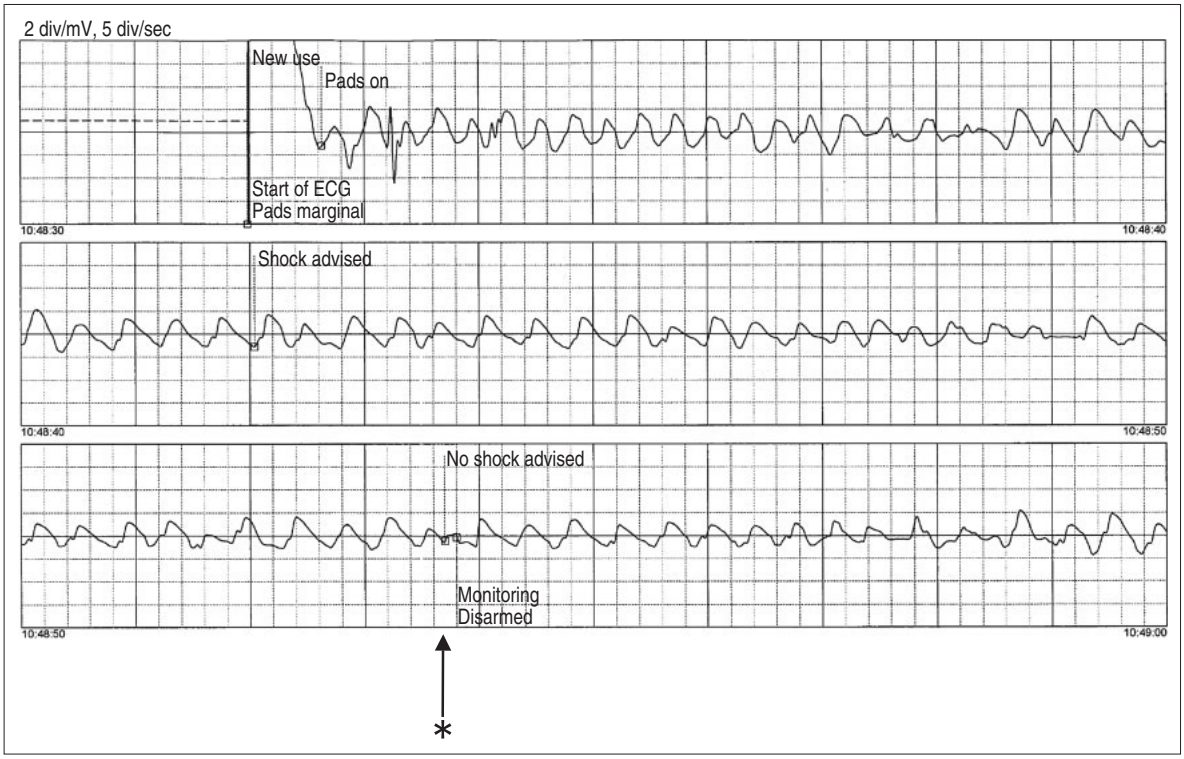

Figure 2 Ventricular fibrillation in which AED did not deliver shock.
The electrocardiogram indicated that the patient had VF but was not delivered shock since the diagnostic criteria for AED was not fulfilled.
*: No shock delivered

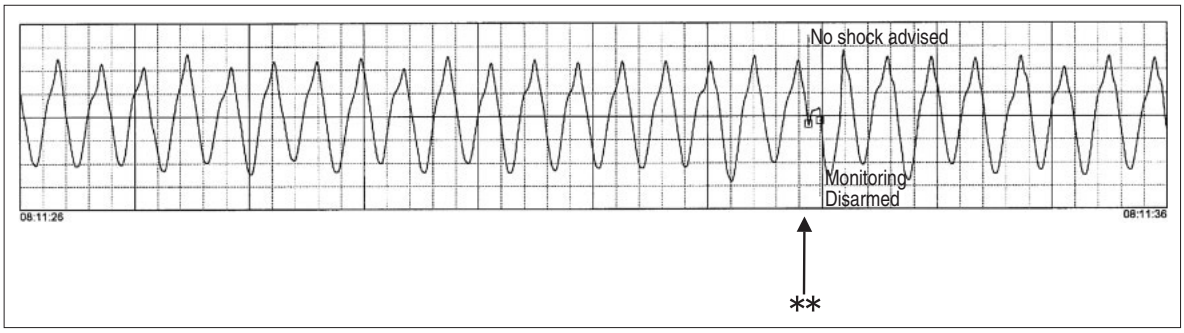

Figure 3 Ventricular tachycardia patient in which AED did not deliver shock.
Monomorphic VT patient with a heart rate of 160 beats per minute did not receive shock since the heart rate was too slow to fulfill the diagnostic criteria for Heart Start FR2.
**: no shock delivered

Prognosis of VF or VT for contributing factors

Four patients had a cardiogenic form of VF or VT such as exacerbation of heart failure and myocardial infarction. Two had VF or VT triggered by acidosis. The contributing factor was unknown for 1 (VF). We had 3 surviving patients (1 VF and 2 VT) and 1 subsequent death (VF) among those with cardiogenic VF or VT. All VF or VT patients that were triggered by acidosis died subsequently (2 VF). Thus, we did not find any significant difference in the survival rate for contributing factors (**Table 3**). Further, 2 epinephrine-induced VF patients received defibrillation but died instantly. Of the 4 epinephrine-induced VT patients, 2 died subsequently and 2 instantly.

Survival rate from onset of cardiac arrest to start of cardiopulmonary resuscitation

The number of cardiac arrest witnessed patients were 22 ($22/29 = 76\%$), while the total number of cardiac arrest patients were 29. The number of cardiac arrest not witnessed patients were 7 ($7/29 = 24\%$). Among both groups — cardiac arrest witnessed and cardiac arrest not witnessed — there were only 2 patients who survived in each group. Thus, we did not find any significant difference in the survival rate for either group (**Table 4**).

In the group of cardiac arrests witnessed, there were 6 patients with VF or VT, while in the group of cardiac arrests not witnessed, there was 1 with VF or VT. We failed to find a significant difference in the VF or VT occurrence rate in either group (**Table 4**). In 6 patients with VF or VT from the cardiac arrest witnessed group, 2 survived ($2/6 = 33\%$), and among the 16 patients with asystole or PEA from the same group, none survived. We did not find a significant difference in the survival rate in either the VF or VT, or asystole or PEA patients (**Table 3**).

There were 6 patients with VF or VT witnessed. AED delivered shock to 4 of them and 1 survived.

Table 2 Condition of shock delivery.

		Survival	Subsequent death	Instant death
Non-cardiac arrest	n = 3	2/0	1/0	0/0
Asystole or PEA	n = 22	1/0	6/0	13/2†
VF or VT	n = 7	1/2	1/2	0/1

Shock was delivered to five out of seven VF or VT patients and two out of six epinephrine-induced VF or VT patients in which asystole or PEA was first recorded.
The number indicates non-delivery/delivery of shock
†: Epinephrine-induced VF or VT

However, in 2 of the 6 pateints, AED did not deliver shock and 1 survived (monomorphic VT). We did not detect any significant difference in the survival rate among the VF or VT witnessed patients, due to the presence or absence of shock delivery (**Table 3**).

Discussion

Regarding vital prognosis

Two out of the 32 patients who were treated with AED survived with the help of defibrillation. Adding the subsequent death to the surviving patients pushed the total percentage up to 13% (4 out of 32). In out-of-hospital cardiac arrest cases, it is said that whether the heart rhythm is VF or VT at the time when emergency medical assistants arrive on the scene is the most important factor in determining the prognosis.[12] The reason why we have not been able to save many patients is that most of the patients experiencing cardiac arrest in the hospital (excepting the circulatory ward) had asystole or PEA, and not VF or VT. According to the report from King County (Washington),[13] the cases that were witnessed by the bystanders were 6,590 among 12,591 cardiac arrest with cardiac etiology cases. The cases

Table 3 Vital prognosis of patients in whom AED was used.

			survival	subsequent death or instant death	p value
VF or VT n = 7	Presence of shock delivery	n = 5	2	3	p > 0.9999
	Absence of shock delivery	n = 2	1	1	
Cardiac arrest n = 29	Presence of shock delivery	n = 7†	2	5	p = 0.2381
	Absence of shock delivery	n = 22	2	20	
VF or VT triggered††	Cardiogenic VF or VT	n = 4	3	1	p = 0.4000
	Acidosis VF	n = 2	0	2	
Cardiac arrest witnessed n = 22	VF or VT	n = 6	2	4	p = 0.0649
	Asystole or PEA	n = 16	0	16	
VF or VT witnessed n = 6	Presence of shock delivery	n = 4	1	3	p > 0.9999
	Absence of shock delivery	n = 2	1	1	

We did not find any significant differences among vital prognosis for VF or VT, cardiac arrest and VF or VT witnessed patients in the presence or absence of shock delivery.
†: Including defibrillation for epinephrine-induced VF or VT patients.
††: Trigger of 1 patient was unknown.

Table 4 Comparison of 29 cardiac arrest patients according to witnessed or not witnessed.

Cardiac arrest n = 29	Witnessed	Not witnessed	p value
VF or VT	6	1	p = 0.6457
Asystole or PEA	16	6	
Survival	2	2	p = 0.2381
Subsequent or instant death	20	5	

We did not find any significant differences between the vital prognosis between witnessed and non witnessed cardiac arrest patients, nor did we find any significant differences in rhythm when the patients were discovered between witnessed and not witnessed cases cardiac arrest patients.

in which the initial rhythm was VF were 4,190 those witnessed. VF accounted for 64% of cardiogenic cardiac arrests witnessed out of hospital. In our hospital, 6 out of 22 cardiac arrests witnessed had an initial rhythm of VF or VT, and there was a significantly small ratio of VF or VT cases in our hospital (except the circulatory ward) compared to the report from King County ($p = 0.0006$). However, since we have fewer mortalities in Japan due to ischemic heart disease, it is likely we have fewer patients with VF or VT compared to Europe and the US.[14] In any case, the situation of AED use may be different whether it is used in or out of hospital. It was thought that a reason for the abundance of asystole or PEA was related to the high incidence of basal disease for in hospital cardiac arrest. Because irreversible basal disease was grave, in most cases, it was thought that it presented asystole or PEA. In our hospital, 16 out of 22 cardiac arrests witnessed had asystole or PEA and none of them survived. Thus, the prognosis for asystole or PEA patients was poor. We compared the survival rates from the patients with asystole or PEA in our hospital and the one in the King County report but we did not find a significant difference ($p = 0.6199$). Although in-hospital asystole or PEA patients underwent instant resuscitation, the survival rate was the same as those that occurred out-of-hospital.

Outcome of VF or VT patients

VF or VT resulted in AED shock delivery. However, 3 out of 5 VF or VT patients that received shock died. Because basal disease was grave, it was considered that they died from basal disease. In the VF or VT patients for who the AED did not operate, a few presented temporary spontaneous sinus rhythm only through cardiopulmonary resuscitation (chest compressions, etc.). Epinephrine induced VT was transient, and the rhythm presented asystole immediately. We did not find a significant difference between the ones that received defibrillation and the ones that did not. The presence or absence of defibrillation did not have any effect on the vital prognosis. We consider that this result stemmed from the fact that VF or VT was triggered by irreversible clinical conditions such as acidosis. We reasoned that even critically ill patients with VF or VT in terminal stage, who received defibrillation, died because the primary disease was not cured. We did not find a significant difference between survival rates of cardiogenic VF or VT and those of acidosis VF or VT. However, we consider that the more cases

we have the worse the prognosis will be for acidosis VF or VT.[15)]

Possible cases of cardiac arrest not witnessed

For 7 patients in whom cardiac arrest was not witnessed, the rhythm was unknown at the onset of unconsciousness. Two of the 7 patients took psychotrophic drugs orally and had PEA when found unconscious; but it is also possible that they had Torsade de pointes from QT prolongation, which is a side-effect caused by psychotrophic drugs, when they became unconscious.[16)] It is considered that at the onset of unconsciousness it was due to VF or VT but that as time passed, when the patient was discovered, conditions had changed to asystole or PEA.

Conditions for shock delivery

Because AED did not deliver shock in all the patients with non-cardiac arrest and asystole or PEA, AED was safe. In this study, since all monomorphic VT cases did not fulfill the diagnostic criteria for Heart Start FR2, it did not deliver shock in these cases. Each AED model has different criteria for shock delivery. When VT is detected, Cardiolife AED-9200 delivers shock at a heart rate of more than 180 bpm, while LIFEPAK LP 500B and LIFEPAK CR Plus deliver at a heart rate of more than 120 bpm (also, at QRS interval of 160 milliseconds and no apparent preceding P wave). Therefore, we consider that defibrillation conditions differ depending on the model used.

Limitations

In this study AED was used in hospital, but it was not used for the patients with heart disease nor relatively healthy people such as visitors or hospital personnel. The AED is reported to be beneficial when it is used in a public space. We believe that the results of this study may change if it were used on other population.

Conclusions

We investigated all 32 patients who were applied AED defibrillation pads in an unconscious state in our hospital. VF or VT was observed in 7 patients and in the other 25 the initial rhythm of the patients did not require AED. Spontaneous rhythm was recovered in 4 patients by defibrillation and 2 survived.

Although the efficacy of AED on patients with VF in out-of-hospital settings has been confirmed, our research indicated the possibility that the placement of AED in hospital (excluding the circulatory ward) may have limited efficacy for critically ill patients.

References

1) Weaver WD, Hill DL, Fahrenbruch C, et al: Use of the automatic external defibrillator in the management of out-of-hospital cardiac arrest. N Engl J Med 1988; 319: 661–666
2) Weaver WD, Hill DL, Fahrenbruch C, et al: Automatic external defibrillators: importance of field testing to evaluate performance. J Am Coll Cardiol 1987; 10: 1259–1264
3) Weaver WD, Copass MK, Hill DL, et al: Cardiac arrest treated with a new automatic external defibrillator by out-of-hospital first responders. Am J Cardiol 1986; 57: 1017–1021
4) Gundry JW, Comess KA, DeRook FA, et al: Comparison of naive sixth-grade children with trained professionals in the use of an automated external defibrillator. Circulation 1999; 100: 1703–1707
5) Nichol G, Hallstrom AP, Kerber R, et al: American Heart Association report on the second public access defibrillation conference, April 17–19, 1997. Circulation 1998; 97: 1309–1314
6) Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 4: the automated external defibrillator: key link in the chain of survival. The American Heart Association in Collaboration with the International Liaison Committee on Resuscitation. Circulation 2000; 102 Suppl. 8: I 60–76
7) Mitamura H: Community interventions for out-of-hospital cardiac arrest. Circ J 2004; 68: Suppl. 1: 38
8) Takayama M, Nagao K, Sumiyoshi T, et al: Prevention against sudden cardiac death in patients with highly risked cardiac disease: Tokyo coronary care home defibrillation program. Circ J 2005; 69: Suppl. 1: 483
9) AED Task Force Committee, Japanese Circulation Society: Proposal of public access defibrillation using AED in Japan. Heart 2003; 35: 303–307
10) Suzuki Y, Iwa T, Kato I, et al: Survivors from arrest by automated external defibrillators in EXPO 2005. Circ J 2006; 70: Suppl. 1: 151
11) Destro A, Marzaloni M, Sermasi S, et al: Automatic external defibrillators in the hospital as well? Resuscitation 1996; 31: 39–43; discussion 43–44
12) Roth R, Stewart RD, Rogers K, et al: Out-of-hospital cardiac arrest: factors associated with survival. Ann Emerg Med 1984; 13: 237–243
13) Rea TD, Eisenberg MS, Becker LJ, et al: Temporal trends in sudden cardiac arrest: a 25-year emergency medical services perspective. Circulation 2003; 107: 2780–2785
14) Nishiuchi T, Hiraide A, Hayashi Y, et al: Incidence and survival rate of bystander-witnessed out-of-hospital cardiac arrest with cardiac etiology in Osaka, Japan: a population-based study according to the Utstein style. Resuscitation 2003; 59: 329–335
15) Camarata SJ, Weil MH, Hanashiro PK, et al: Cardiac arrest in the critically ill. I. A study of predisposing causes in 132 patients. Circulation 1971; 44: 688–695
16) Hoehns JD, Fouts MM, Kelly MW, et al: Sudden cardiac death with clozapine and sertraline combination. Ann Pharmacother 2001; 35: 862–866