ORIGINAL ARTICLE

Cost-effectiveness of Different Advanced Life Support Providers for Victims of Out-of-hospital Cardiac Arrests

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Background/Purpose: The survival rate of out-of-hospital cardiac arrest (OHCA) is only about 1.4% in Taiwan. The best configuration to achieve optimal outcomes in OHCA is still uncertain for many communities. The purpose of this study was to investigate the cost-effectiveness of two models of providing advanced life support (ALS) services, emergency medical technicians (EMTs) *vs.* emergency physicians (EPs), in a two-tiered emergency medical services (EMS) system.

Methods: This was a prospective, observational, multicenter study comparing ALS provided by EMTs *vs.* EPs for the management of victims of OHCA. The study population consisted of patients experiencing OHCA of non-traumatic origin in Taipei city, Taiwan, between November 1999 and December 2000, for whom ALS was activated. We performed a cost-effectiveness analysis to determine the economic attractiveness of these two ALS provider programs. The outcome measurements were aggregate costs, survival and incremental cost per life saved. Sensitivity analyses were performed on all variables.

Results: The expected total cost per OHCA patient was US$2248.19 and US$832.07 for the EMT and EP programs, respectively. The overall survival rate was 4.4%. The survival rate was 9.3% for the EMT program and 2.6% for the EP program. The incremental cost-effectiveness ratio (ICER) of EMTs *vs.* EPs was US$21,136 per life saved. The ICER was sensitive to hospital admission cost changes and the probability of survival to discharge in patients admitted to hospital in the EMT program. The increased survival rate of OHCA patients in the EMT program may be attributable to the services of the hospital and/or the EMT program.

Conclusion: The use of EMTs as ALS care providers for OHCA patients in the two-tiered EMS system resulted in a reasonable cost-effectiveness ratio. EMTs could be considered as the second tier of EMS systems in urban areas in Taiwan. [*J Formos Med Assoc* 2006;105(12):1001–1007]

Key Words: advanced life support, cardiac arrest, cost-benefit analysis, emergency medical services, emergency medical technician

Currently, the survival rate of out-of-hospital cardiac arrest (OHCA) is only around 1.4% in Taiwan.[1] One of the main reasons is that there is only a one-tier emergency medical services (EMS) system. The general public has been asking for improvements to the EMS system for many years. So far, the most effective EMS system, with the highest OHCA survival rate, is a two-tiered EMS system with basic life support (BLS) followed by advanced life support (ALS),[2,3] which Taiwan can reference.

ALS care may be provided either by emergency medical technicians (EMTs) or emergency

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physicians (EPs). In North America, ALS care is mostly conducted by EMTs,[3] while in Europe, it is mostly done by EPs.[2] There has been no formal analysis comparing the cost-effectiveness between these two types of ALS providers. Considering that developing countries, such as Taiwan, have limited medical resources, this kind of analysis is needed. Therefore, we conducted a study to investigate the cost-effectiveness of two models of providing ALS services, EMTs *vs.* EPs, in a two-tiered EMS system.

Methods

Study design

This was a prospective, observational, multicenter study of ALS services provided by EMTs *vs.* EPs for the management of victims of OHCA. In this study, we performed a cost-effectiveness analysis to determine the economic attractiveness of improvement to the EMS system. We also performed sensitivity analyses wherein the baseline variable was varied to determine the effect on the results. The study was approved by the institutional review board of the Department of Health, Taiwan.

Study setting and population

Taipei city is located in the northern part of Taiwan and has a population of 2.7 million people and is 106.7 square miles in size. During the study period, the EMS system was provided by a single response system, consisting of EMTs and firefighters for BLS without defibrillation, and the transportation of patients to responsible hospitals. All EMTs are trained with a standard 60-hour curriculum, according to guidelines from the Department of Health.[1]

A pilot project of hospital-based ALS service sponsored by the Department of Health was started in mid 1999 with nine participating EMS hospitals. In one of the hospitals, National Taiwan University Hospital (NTUH), five EMTs were specially trained in BLS and ALS skills, and dispatched to ALS services. In the remaining eight hospitals, EPs were dispatched to the scene upon ALS activation. The participating EMTs and EPs were all Advanced Cardiac Life Support (ACLS) certified and followed the same ACLS protocols.

The study population consisted of patients experiencing OHCA of non-traumatic origin with ALS activation, transported by EMS to nine medical centers in Taipei city, between November 1999 and December 2000. When an ALS call was made within an 8-minute perimeter of NTUH, a first responder team, including firefighters and one of the five EMTs, would be dispatched. The dispatched EMT would provide ALS care in the field and transport the patient to the Emergency Department (ED) of NTUH. In the other eight participating medical centers, ALS care was provided by duty EPs. These duty EPs were all well trained in ALS care. If an ALS call was made within an 8-minute perimeter of one of these eight medical centers, a first responder team, including firefighters and a duty EP, would be dispatched. The duty EP would provide ALS care in the field and transport the patient to the nearest medical center.

Measurements and outcome variables

The outcome measurements for this study were aggregate costs, survival and incremental cost per life saved. These outcome variables were calculated for both EMT and EP programs.

We performed our analysis from a government perspective. Costs were converted to US dollars with the use of the average annual exchange rate for 2000 (e.g. US$1 = NT$31.23).[4] Costs were not discounted because of the short time frame of our analysis. Future costs accruing after discharge of survivors from hospital and indirect or intangible costs were not determined.

The EMT and EP programs were run according to the standard two-tiered EMS system. Apart from the difference in personnel costs, the EMT and EP programs shared the same costs of the first-tier of the EMS system and the equipment costs of the second-tier of the EMS system. Therefore, these costs were canceled out in the decision analysis because they have no effect on the incremental cost-effectiveness ratio (ICER). The EMT program personnel costs included wages, benefits and

training. The EP program personnel costs, however, included extra wages for the provision of ALS care by EPs. The average personnel costs of each OHCA patient in the two programs were calculated by the respective personnel costs of these two programs divided by their own number of ALS calls made during the study period. We identified the costs of emergency care in the EDs and hospital admission by averaging the National Health Insurance reimbursement to NTUH incurred by OHCA patients during the study period. The mean cost of hospital admission per patient was separately calculated for patients who were discharged alive and for those who died in the hospital.

Survival was the clinical outcome for this study. All OHCA patients were followed to determine their status on hospital discharge. Survival was defined as discharge from the initial hospitalization after resuscitation. Cost-effectiveness was expressed as incremental cost per life saved. The following information for all OHCA patients was also recorded: age, gender, witnessed collapse, bystander cardiopulmonary resuscitation (CPR), initial cardiac rhythm, ALS response time. The ALS response time was defined as the time from dispatch to arrival of the ALS team on the scene.

Data analysis

The data collected were analyzed under the common principles of economic analysis. We performed a decision analysis by creating a decision model (Figure 1) to estimate costs and effectiveness of the two ALS programs. The baseline analysis was performed with the actual cost and effectiveness data observed in our study. In calculating the ICER, we used the following formula:

$$\text{ICER}=\frac{\text{Cost (EMT)}-\text{Cost (EP)}}{\text{Survival (EMT)}-\text{Survival (EP)}}$$

We also performed sensitivity analyses to determine whether changes in the value of the proportion of survival to admission, the proportion of survival to discharge and the cost components would affect the ICER. A computer program

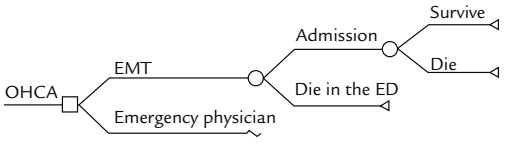

Figure 1. Decision model for advanced life support (ALS) programs. The square node represents the choice of ALS programs. Circles are chance nodes. The subtree following "Emergency physician" is the same as the subtree following "EMT". OHCA = out-of-hospital cardiac arrest; EMT = emergency medical technician; ED = emergency department.

(DATA 3.5; TreeAge Software Inc., Williamstown, MA, USA) was used for all calculations in the decision analysis. Demographic data of all OHCA patients are expressed as mean ± standard deviation or number (%). Comparisons between groups were performed using Fisher's exact test for categorical data.

Results

During the 14-month study period, 158 OHCA patients were identified. The demographic data of these patients are displayed in Table 1. There was no significant difference in age, gender, rates of witness collapse and bystander CPR, initial cardiac rhythm and mean ALS response time between the EMT and EP programs.

Costs and effectiveness of the two ALS programs are displayed in Table 2. It was found that the mean personnel costs per OHCA patient were US$173.80 and US$36.39 for the EMT and EP programs, respectively. The mean cost for emergency care in the ED was US$172.21 per OHCA patient. The mean hospital costs for patients discharged alive and patients who died in the hospital were US$14,203.74 and US$2086.85, respectively. The overall survival rate was 4.4%. The OHCA patients in the EMT program were more likely to survive to admission ($p<0.01$). Four (9.3%) patients in the EMT program (95% confidence interval, CI, 2.6–22.1%) and three (2.6%) patients in the EP program (95% CI, 0.5–7.4%) survived to hospital discharge ($p=0.09$). Unfortunately, they were all discharged in a vegetative state.

Table 1. Demographic data for 158 out-of-hospital cardiac arrests*†

	EMT program ($n=43$)	EP program ($n=115$)
Age (yr)	66.4 ± 18.7	63.4 ± 19.2
Male	26 (60.4)	72 (62.6)
Witnessed collapse	19 (44.2)	48 (41.7)
Bystander CPR	3 (7.0)	20 (17.4)
Initial rhythm		
VF or VT	4 (9.3)	6 (5.2)
Pulseless electrical activity	7 (16.3)	6 (5.2)
Asystole	31 (72.1)	93 (80.9)
Other	1 (2.3)	10 (8.7)
ALS response time (s)	232.8 ± 143.2	293.9 ± 227.3

**Data are presented as mean ± standard deviation or n (%); †there was no significant difference between the two ALS programs. EMT = emergency medical technician; EP = emergency physician; CPR = cardiopulmonary resuscitation; VF = ventricular fibrillation; VT = ventricular tachycardia; ALS = advanced life support.*

Table 2. Cost and effectiveness of two advanced life support provider programs for out-of hospital cardiac arrests (OHCA)

	EMT program	EP program
Cost per OHCA patient (US$)*		
Personnel costs	173.80	36.39
Mean emergency care cost in ED	171.21	171.21
Mean hospital cost for patients discharged alive	14,203.74	14,203.74
Mean hospital cost for patients who died in hospital	2086.85	2086.85
Effectiveness (%)		
Survival to admission	37.2†	14.8†
Survival to discharge	9.3	2.6

**According to average annual exchange rate for 2000; †$p<0.01$ (Fisher's exact test). EMT = emergency medical technician; EP = emergency physician; ED = emergency department.*

Table 3. Results of baseline analysis of one out-of-hospital cardiac arrest patient in two advanced life support programs

Program	Expected total cost (US$)*	Incremental cost (US$)*	Expected effectiveness (life)	Incremental effectiveness (life)	ICER (US$/life saved)
EP	832.07	–	0.026	–	–
EMT	2248.19	1416.12	0.093	0.067	21,136

**According to average annual exchange rate for 2000. EP = emergency physician; EMT = emergency medical technician; ICER = incremental cost-effectiveness ratio.*

Baseline analysis

Table 3 shows the results of the baseline analysis of the two ALS programs. The expected total cost for one OHCA patient was US$2248.19 for the EMT program and US$832.07 for the EP program. The expected survival for one OHCA patient was 0.093 for the EMT program and 0.026 for the EP program. The ICER of the EMT program compared with the EP program was US$21,136 per life saved.

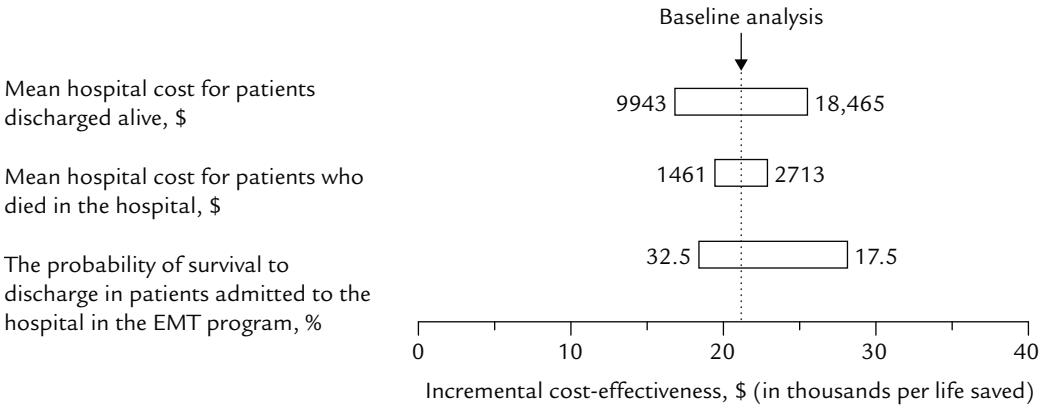

Figure 2. One-way sensitivity analyses of the incremental cost-effectiveness of the EMT program compared with the EP program. The bars indicate the variability of the incremental cost-effectiveness ratio (x axis) caused by changes in the value of the indicated variable, all other variables being held constant. Labels on the horizontal bars indicate the range of each one-way sensitivity analysis. All costs are in US dollars according to the average annual exchange rate for 2000. EMT = emergency medical technician; EP = emergency physician.

Sensitivity analysis

We changed the values of all variables by ± 30% away from their baseline values and each time only one variable was changed. We identified several influential variables on the ICER of the EMT program compared with the EP program (Figure 2). The ICER of the EMT program was fairly sensitive to changes in the mean cost of hospital admission for patients discharged alive. The ICER would increase to US$25,394 per life saved if the mean cost of hospital admission for patients discharged alive increased to US$18,465. However, if this cost decreased to US$9943, the ICER would decrease to US$16,878 per life saved. The mean cost of hospital admission for patients who died in the hospital had an effect on the ICER. When this cost increased to US$2713, the ICER would increase to US$22,603 per life saved. The probability of survival to discharge for patients admitted to the hospital in the EMT program also influenced the ICER. When this probability changed between 0.175 and 0.325, the ICER would change between US$27,642 and US$18,465 per life saved, respectively.

The personnel costs of the EMT and EP programs did not have a significant influence on the ICER of the EMT program compared with the EP program. Our results were also insensitive to changes in the value of the cost of emergency care in the ED and the probability of hospital admission after survival in the ED in the EMT program. The probabilities of hospital admission and survival to discharge in patients admitted to hospital in the EP program did not influence the ICER significantly.

Discussion

Improvement of an EMS system may require huge societal resources. It also competes for resources with other medical programs as well as nonmedical societal priorities. Such competition for resources is especially obvious in developing countries where medical resources are fewer than those in developed countries. Cost-effectiveness analysis is a method used to evaluate the costs and the outcomes of interventions designed to improve health, and it may serve as a guide for resource allocation.[5] We performed such an analysis and found that the use of EMTs for ALS care in a two-tiered EMS system is an economically attractive choice.

In comparison with other medical interventions, the EMT program was more cost-effective than thrombolytic therapy for acute inferior wall myocardial infarction,[6] cholesterol-lowering therapy[7] and activated protein C therapy for severe sepsis.[8] It is also more cost-effective than improvement from a one-tiered to a two-tiered EMS

system.[9,10] The ICER of an EMT program is 1.45 times the 2000 Taiwan gross domestic product per capita[11] (US$14,519). As a result, it is reasonable to choose EMTs, not EPs, as ALS providers if a two-tiered EMS system is going to be implemented.

No previous study of head-to-head comparison of EMTs and EPs as ALS providers in a two-tiered EMS system is available. In our study, the effectiveness of the EMT program was better than that of the EP program for victims of OHCA. However, in North America and Europe,[3,12–14] it seems that the effectiveness of both systems are comparable in terms of survival to discharge. One possible reason that may explain this difference is because our EPs, although well-trained in ALS, were not very familiar with performing resuscitation in the pre-hospital environment. In contrast, EMTs, who work full-time in the pre-hospital field, are more confident with resuscitation in this environment. We performed sensitivity analyses to explore the effects of this clinical uncertainty. Further studies may be needed to confirm our result and explore other reasons.

The personnel costs of the EMT and EP programs did not influence the ICER of the EMT program considerably. This is mainly because the hospital cost for OHCA patients comprised about 85% and 75% of the expected total costs of the EMT and EP program, respectively. The results of our sensitivity analyses showed that when the effectiveness of the ALS programs was getting better and the proportion of hospital admission of OHCA patients became higher, the hospital cost will have greater weight in the projected total cost. In terms of costs, the key issue in treating an OHCA patient was their hospital costs, not the cost of ALS care in the EMS system.

The survival rate of OHCA patients in Taipei city was only 1.4%[1] and is considered very low when compared with the fitted survival of 5.2% in a one-tiered EMS system.[3] The most common initial cardiac rhythm of OHCA in Taipei is asystole,[1] while in Western countries, it is ventricular fibrillation.[15,16] One possible explanation is that the underlying etiologies of OHCA in Oriental countries may be different from those in Western countries.[1] Therefore, we believe that the effectiveness of any improvement of the EMS system in Western countries may not be totally reproducible in Oriental countries. We suggest that the effectiveness should be verified again if a two-tiered EMS system is to be implemented in Taiwan. Based on our study, the use of EMTs as ALS providers in a two-tiered EMS system had significant positive effects on the survival rate of OHCA patients compared with that of a one-tiered EMS system.[1]

There were several limitations in our analysis. Firstly, physician bias may exist in our study. The medical personnel responsible for treating OHCA patients in the medical centers were unblinded to the interventions in our study. However, they were blinded to the outcomes of OHCA patients in other medical centers. Further, only one ALS program was carried out in the pre-hospital care of a medical center. Therefore, the direction and magnitude of this bias is unclear. Secondly, only the personnel cost of the ALS programs in the EMS system was included in our analysis. We did not intend to compare the cost-effectiveness of a two-tiered system to that of a one-tiered system. We also believe that the equipment costs of the EMT and EP programs were similar because these programs complied with ALS standards. The opportunity costs of the EP program were not easy to estimate and therefore were not included. However, if these costs had been included in the study, the ICER of the EMT program would have been lower and the EMT program would have become more favorable. Cost data used in the analysis were not discounted because we only focused on the acute stage of OHCA. We followed our patients until they were discharged from the hospitals and the longest hospitalization was 99 days.

Due to limited funding of the program, the EMT program was carried out in only one medical center (NTUH). The increased survival rate of OHCA patients in the EMT program observed in the study may be attributable to the services of the hospital and/or the EMT program. The external generalizability of our results warrants further studies.

The number of OHCA patients in our study was not very large. However, with the time and resource constraints on the decision to select the appropriate ALS provider model to improve our EMS system, it would be logistically unfeasible for us to conduct a much larger study. Efforts were made in the study, including multiple sensitivity analyses, to improve our ability to deal with the effects of clinical uncertainties. Future studies would involve large-scale, multicenter, prospective, randomized, controlled studies to assess the validity of the costs and benefits estimated here.

Our study demonstrated that in this Asian metropolitan EMS, the use of EMTs as ALS care providers for OHCA patients in a two-tiered EMS system resulted in a reasonable cost-effectiveness ratio. Based on the finding of the study, we suggest that EMTs with ALS capability could be a feasible second tier in EMS systems in urban areas of Taiwan.

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References

1. Hu SC. Out-of-hospital cardiac arrest in an Oriental metropolitan city. *Am J Emerg Med* 1994;12:491–4.
2. Bossaert LL. The complexity of comparing different EMS systems—a survey of EMS systems in Europe. *Ann Emerg Med* 1993;22:122–5.
3. Nichol G, Detsky AS, Stiell IG, et al. Effectiveness of emergency medical services for victims of out-of-hospital cardiac arrest: a meta-analysis. *Ann Emerg Med* 1996; 27:700–10.
4. Statistics Taiwan. *Average Exchange Rate*. Taipei: Statistics Taiwan, 2001.
5. Gold MR, Siegel JE, Russell LB, et al. *Cost-effectiveness in Health and Medicine*. New York: Oxford University Press, 1996.
6. Midgette AS, Wong JB, Beshansky JR, et al. Cost-effectiveness of streptokinase for acute myocardial infarction: a combined meta-analysis and decision analysis of the effects of infarct location and of likelihood of infarction. *Med Decis Making* 1994;14:108–17.
7. Glasziou PP, Eckermann SD, Mulray SE, et al. Cholesterol-lowering therapy with pravastatin in patients with average cholesterol levels and established ischaemic heart disease: is it cost-effective? *Med J Aust* 2002;177:428–34.
8. Fowler RA, Hill-Popper M, Stasinos J, et al. Cost-effectiveness of recombinant human activated protein C and the influence of severity of illness in the treatment of patients with severe sepsis. *J Crit Care* 2003;18:181–91.
9. Valenzuela TD, Criss EA, Spaite D, at al. Cost-effectiveness analysis of paramedic emergency medical services in the treatment of prehospital cardiopulmonary arrest. *Ann Emerg Med* 1990;19:1407–11.
10. Nichol G, Laupacis A, Stiell IG, et al. Cost-effectiveness analysis of potential improvements to emergency medical services for victims of out-of-hospital cardiac arrest. *Ann Emerg Med* 1996;27:711–20.
11. Statistics Taiwan. *Gross Domestic Product Per Capita*. Taipei: Statistics Taiwan, 2000.
12. Herlitz J, Bahr J, Fischer M, et al. Resuscitation in Europe: a tale of five European regions. *Resuscitation* 1999;41: 121–31.
13. Kentsch M, Schlichting H, Mathes N, et al. Out-of-hospital cardiac arrest in north-east Germany: increased resuscitation efforts and improved survival. *Resuscitation* 2000;43: 177–83.
14. Giraud F, Rascle C, Guignand M. Out-of-hospital cardiac arrest. Evaluation of one year of activity in Saint-Etienne's emergency medical system using the Utstein style. *Resuscitation* 1996;33:19–27.
15. Myerburg RJ, Kessler KM, Zaman L, et al. Survivals of prehospital cardiac arrest. *JAMA* 1982;247:1485–90.
16. Herlitz J, Ekstrom L, Wennerblom B, et al. Prognosis among survivors of prehospital cardiac arrest. *Ann Emerg Med* 1995;25:58–63.