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Favourable cost-benefit in an early defibrillation program using dual dispatch of ambulance and fire services in out-of-hospital cardiac arrest

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Abstract:

Aims: Out-of-hospital cardiac arrest (OHCA) is fatal without treatment and time to defibrillation is an extremely important factor in relation to survival. We performed a cost-benefit analysis of dual dispatch defibrillation by ambulance and fire services in the County of Stockholm, Sweden.

Methods and Results: A cost-benefit analysis was performed to evaluate the effects of dual dispatch defibrillation. The increased survival rates were estimated from a real world implemented intervention and the monetary value of a life (€ 2.2 million) was applied to this benefit by using results from a recent stated-preference study. The estimated costs include defibrillators (including expendables/maintenance), training, hospitalisation/health care, call-outs for the fire services, overhead resources and costs for the dispatch centre. The estimated number of additional saved lives was 16 per year, yielding a benefit-cost ratio of 36. The cost per quality-adjusted life years (QALY) was estimated to be € 13 000 and the cost per saved life was € 60 000.

Conclusions: The intervention of dual dispatch defibrillation by ambulance and fire services in the County of Stockholm had positive economic effects. For the cost-benefit analysis the return on investment was high and the cost-effectiveness showed levels below the threshold value for economic efficiency used in Sweden. The cost-utility analysis categorises the cost per QALY as medium.

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Introduction

Out-of-hospital cardiac arrest (OHCA) is a major public health problem. Coronary heart disease is the most common cause of death in the Western World and a majority of these mortalities occur outside hospitals [1]. A vast majority of OHCA cases are due to cardiac causes and the incidence of OHCA is higher among men and increases with age [2]. OHCA is fatal without treatment, and early defibrillation is an important link in the 'chain-of-survival' for resuscitation of a victim [3-4].

The purpose of our study was to evaluate the economic effects of dual dispatch defibrillation by ambulance and fire services in the County of Stockholm, Sweden. Economic effects of OHCA interventions often focus on the duration of life, cost-effectiveness analysis (CEA) or some quality-adjusted measure of the life years remaining, e.g. cost-utility analysis (CUA) [5-11]. We utilised a recent stated-preference study to perform a cost-benefit analysis (CBA) in addition to CEA and CUA [12]. Valuation of statistical lives is essential in fields where optimising policy implies weighting the saving of human lives against other effects and costs.

Methods

Cost-benefit analysis

As a framework for the evaluation method, some general parameters of the CBA were established. Since the effects of the project extended over many years, future costs and benefits were discounted in order to make inter-temporal comparisons. Furthermore, the net present value criterion for evaluation was used. All prices were expressed in 2007 Euros (€) and the Swedish consumer price index was used as a deflator (€1=SEK 9.2583, based on the average exchange rates at the end of each month 2007). The recommended 'Swedish' social discount rate in the transport sector was 4 percent and the number of time periods that defined the life of the project was assumed to be represented by the 10 year life span of an automated external defibrillator (AED) [13]. Market prices (including taxes and subsidies) with an additional cost of 21 percent on factor prices were adopted, to reflect the tax on the productive alternative use of the private consumption [13]. In accordance with the European recommendations no additional cost of public funds were assessed, i.e. the marginal cost of public funds is 1 [13-14].

Benefits

The benefit of dispatching fire services on OHCA alarms was an increase in survival. We used real world data from the 'Saving Lives in the Stockholm Area' (SALSA) project introduced in 2005 [15]. All 43 fire stations in the County of Stockholm were equipped with AEDs and were dispatched in parallel with ambulances to all suspected cases of OHCA. The first rescuer to arrive at the patient started cardiopulmonary resuscitation and attached an AED. Ambulances were dispatched in exactly the same manner as before and the response-times were only affected when the fire services were first on scene. A detailed description of the project has previously been presented by Hollenberg et al [15].

Effects of the project were measured and evaluated during a pilot period: December 1, 2005 to December 31, 2006. Totally 863 patients with OHCA where some type of resuscitation measure was started were included. Among the dual dispatches (474 cases), the fire services was first on scene and initiated treatment in 36 percent of the cases. Using a historical control from 2004, the median time from alarm call to arrival of the first rescuer decreased from 7.5 to 7.1 minutes. Median time from call to first defibrillation decreased from 9.2 to 8.0 minutes, but the change was not statistically significant. The proportion of patients alive after 1 month increased from 4.4 to 6.8 percent, which was a statistically significant effect that to a large extent could be assigned to the dual dispatch. Particularly patients with witnessed OHCA and those found in ventricular fibrillation (VF) experienced increased survival rates. Since the incidence of included OHCA patients in the County of Stockholm was approximately 650-700 during 2006, the estimated number of additional lives saved by the project was approximately 16 per year.

QALY and the value of a statistical life

The cost per QALY (quality-adjusted life years) was estimated by complementing the number of saved lives with estimates of the remaining life years and the quality of these life years. This type of analysis is a cost-utility analysis (CUA) and is widely used in the health care sector. First, the number of life years gained per discharged patient is around 6 years [7-9;16]. Second, the utility of life for survivors of an OHCA has been found to range from 0.7 to 0.8 [17-19] on a scale from 0 (worst/death) to 1 (perfect health). Stiell et al. [19] have performed studies on OHCA patients with large sample size and have used a sophisticated evaluation method. Therefore we choose to use their median value of 0.80 in our analysis.

The monetary value of a statistical life (VSL) is, in essence, the value that society deems economically efficient to spend on avoiding one unidentified premature death. VSL for OHCA victims was estimated in a recent willingness-to-pay (WTP) survey [12]. The technique used to elicit WTP is to directly ask individuals about their trade-off between income and a given mortality risk reduction. The results indicate that a lower-bound estimate of VSL for OHCA would be around € 2.2-3.2 million, which is close to the ‘baseline’

Swedish VSL estimate of € 2.4 million from the transport sector. We chose to be 'conservative' with the benefits, so in the present analysis we use a VSL of € 2.2 million.

Costs

Various frameworks for cost assessment of changes to an emergency medical intervention have been suggested [16;20-21]. In the present study earlier suggestions were combined with the experiences from the SALSA-project. The costs estimated were the purchase of defibrillators, including expendables/maintenance (batteries and electrode pads), extra training (introductory and refresher), increased hospitalisation/health care, more call-outs for the fire services, overhead costs of the project and increased costs for the dispatch centre.

Materials

Initial investments in materials were AEDs and training AEDs. The number of AEDs were multiplied by average costs for an AED (€ 2600) and for a training AED (€ 500) respectively. During the economic lifetime of an AED (10 years) consumption of expendables like batteries and electrode pads will occur and these costs were multiplied by average consumption of items per year times the total numbers of AEDs. Since the investments in expendables are conducted during the economic lifetime of the AED, the costs were discounted by using the social discount rate.

Cost data for the model used (summarised in the Appendix) was mostly based on information from the SALSA project. Some information can be seen as general in the sense that it can be used to model costs for other counties than Stockholm (e.g. the cost for an AED), while others are region specific (e.g. the number of purchased AEDs). The number of used AED electrode pads per year/AED was estimated by assuming that they are changed each time that the fire services used a defibrillator.

Training

All introductory and refresher training was handled by a specific number of instructors, which were initially trained at an average cost per occasion (€ 1600). The cost per occasion was divided by the average group size. Then, the shadow price for all instructors time spend at training was calculated by multiplying the number of instructors by the shadow price for a fireman's working time (see below) and by the average time for an AED instructor course. Cost for introductory and refresher training was calculated in the same way. Refresher training was spread out over the lifetime of the AED and needed to be discounted.

Kågebro [22] calculated the shadow price for a fireman's working time and arrives at two estimates depending on whether the call-outs crowd out other work or not. The full-time fireman's working time was valued at € 0 per hour (no crowding out) or at € 24 per hour (full crowding out). In the present survey the more 'conservative' estimate was chosen and the second one was used, which leads to an opportunity cost of € 21 per hour when also other firemen than full-time firemen are included.

Hospitalisation and health care

The costs of the 'extra' OHCA patients admitted to hospital and eventually discharged, i.e. survives were calculated. There probably are some 'extra' patients that due to the project will be alive when admitted to hospital, but dies after some time of hospitalisation. However, no such effect was found in the SALSA-project. The costs for these patients are therefore not calculated. However, it has been found that hospitalisation costs for non-survivors were much lower than for survivors, between 5-10 percent [6,8], so the potential loss is not significant.

Hospitalisation costs occur before the patient is discharged and health care costs is in the longer term. Average number of life years gained per discharged patient (6 years) implies that the discounting procedure of health care costs continues until all surviving patients are deceased.

To estimate the hospitalisation costs for OHCA patients, data from the Swedish case-costing database for two appropriate diagnoses (I46.0 Cardiac arrest with successful resuscitation and I46.9 Cardiac arrest, unspecified) was processed [23]. The method of case-costing included both direct costs (e.g. personnel, materials) and indirect costs (e.g. administration, maintenance). During 2004-2008 there were 1968 cases and the mean cost per patient was € 13 500. Some patients have extremely high costs and long hospitalisation periods and the mean cost per patient for the 5 percent most expensive cases was € 38 800, i.e. almost 3 times as high as for an average cardiac arrest patient.

We lack information in our project data about long term health care costs for the survivors after discharge. Resource utilisation such as e.g. primary care consultations, later hospitalisation episodes, or home care is not automatically registered after discharge. Instead, the proportion of health care costs to hospitalisation costs for discharged patients from Rauner & Bajmoczy was utilised [16]. The proportion was approximately 25 percent per year, which would imply a health care cost of € 3400 per life year gained. It is comparable to the results of van Alem et al. [8], where in-hospital and post-hospital costs in the first half-year were € 6869 and € 666. We estimate the health care/hospitalisation proportion to 19 percent per year, assuming that health care costs would be the same all year around for the rest of the remaining lifetime.

Higher health care costs are estimated by Nichol et al. [6], following Ebell & Kruse [24], assuming a 28 percent proportion of patients who is dependent of care in nursing homes after discharge. The cost per year is approximately € 6300 in 2007 euros. Rauner & Bajmoczy [16] assigns a higher cost for the last year of life, but due to uncertainty we choose to disregard from this effect. Due to this uncertainty we perform a sensitivity analysis with wide intervals for health care costs in the Results section.

Call-outs

The cost for an extra emergency call-out by the fire-fighters was represented by the average costs for such a call-out times the discounted number of call-outs each year. The average 'personnel' cost per call-out was calculated by multiplying the cost per hour/fireman (€ 21) times the time consumption of a call-out (in hours) times the number of firemen that take part of an alarm. A survey on medical alarms in the County of Jönköping, Sweden, estimated the total time from the fire services are alerted until they are back at the station to be 0.8 hour [25]. This is also a good approximation of the time in Stockholm. In the SALSA-project, a majority of the call-outs made by the fire services was estimated to include four individuals. Summarising these three components gave an estimate of the average 'personnel' cost per-call-out at € 69 and adding a cost for fuel and environmental effect, € 4, the total cost per call-out is € 73 [22].

The proportion of OHCA call-outs that the fire services take part in was 66 percent [15]. They also take part in a number of 'false OHCA alarms' and the multiplier for these alarms were estimated to be 2.5.

Overhead

Overhead costs occur because there was a need to engage extra resources to launch, manage and control a large scale project. In the present study, we assumed that there were no extra costs for research or medical oversight resources involved. Only project managers that handled all necessary routines lead to extra costs that were not negligible. For the ambulance/health care sector one project manager who works 50 percent of full working hours is necessary for a period of the projects first year. The fire services also require overhead resources and a reasonable estimate is that two project managers are engaged during the first year in the County of Stockholm. After the first year, approximately one individual at 50 percent of full-time will be employed.

Dispatch centre

The costs for the dispatch centre include training and overhead costs (all data in this section are provided from Britt Stålhandske, SOS Alarm AB, e-mail 2009-05-04). Material costs, e.g. for computer software or programming, were negliable. The training costs were calculated only for the shadow price of working time because other costs were already included in scheduled education activity. No retraining was assumed for the emergency operators.

Results

Costs of the SALSA-project

Table 1 summarises the costs of the project. Hospitalisation and health care costs varies depending on increased survival rates from the SALSA-project. All other costs were fixed.

Total costs amounted to € 8.1 million. Almost 80 percent of total costs derived from refresher training, hospitalisation and health care costs.

Economic evaluation

When combining the costs with the benefits, all information needed to perform economic analyses of the intervention was available. The benefits are, as well as the costs, accumulated and discounted during the 10 year time horizon of the project. As shown in Table 2, the cost per saved life was € 60 000 and the cost per QALY was € 13 000. The benefits were estimated to be 36 times higher than the costs.

Sensitivity analysis

Sensitivity analysis of one variable at the time revealed that the number of lives saved and the value of VSL had the largest volatile effect on benefit-cost ratios (Table 3). Variation of the key cost variables did not significantly change the benefit-cost ratios. We made marginal changes in the discount rate, life span of an AED, hospitalisation costs and health care costs.

Discussion

We have showed that the project of dual dispatch defibrillation by ambulance and fire services in the County of Stockholm has had positive economic effects. For the cost-benefit analysis the return on investment was high; the health benefits amounts to 36 times the invested amount. There exist few comparable CBA studies in the field of OHCA [11]. Caro et al. [26] found B/C ratios of approximately 5 in a program to prevent sudden cardiac arrest deaths with an implantable cardioverter defibrillator (ICD).

Although we have used a conservative approach, there is a matter of uncertainty regarding the VSL value for OHCA. We are surprised to see that the estimate is in the same order of magnitude as the VSL for road traffic safety in Sweden, which was estimated to be € 2.4 million, because statistical lives are both longer and 'healthier' for road traffic victims [13]. VSL values for road traffic casualties are roughly the same in similar European countries [14]. However, 'break-even' level for the OHCA VSL value, i.e. where the benefits would be equal to the costs, are € 60 000. This level is so low that we, with a high degree of certainty, can say that the project was beneficiary for the society.

As a complement to the cost-benefit analysis, we can also compare the results of the cost-effectiveness analysis (€ 60 000) and the cost-utility analysis (€ 13 000 per QALY). Nichol et al. evaluated the potential effect of standard emergency medical services versus targeted non-traditional responders and found costs per QALY between $\$_{2003}$ 55 000 – 10 325 000 in various public settings [6]. Forrer et al. observed that training police officers as AED equipped responders resulted in a cost per life saved of $\$_{1999}$ 23-71 000 [5]. Locating defibrillators in all major airports, railway stations, and bus stations throughout Scotland resulted in costs per QALY of $£_{2001}$ 41 146 [7].

It has been suggested in international policies that an intervention is cost effective if the cost per QALY is below a predetermined threshold. In the UK, this threshold is £20 000-£30 000, while in the US a generally accepted threshold of $50 000-$100 000 is utilised [27]. For Sweden, a threshold value of € 65 000 (CEA) is often used and the National Board of Health and Welfare categorise the cost per QALY as low if it is below € 11 000, medium if between € 11 000 – 54 000, high if between € 54 000 – 108 000 and very high if above € 108 000 [28-

29]. By these standards, our results show that the project of dual dispatch was a cost efficient intervention.

There are uncertainties in the valuations, but additional support for the effects of the SALSA project is really cost efficient exists. First, there were a lot of ‘noise’ during the pilot period, e.g. the fire services were dispatched 2 minutes later than EMS services among cases with dual dispatch [15]. Second, ‘more hands’ on the accident site increased possibility to perform cardiopulmonary resuscitation, while the defibrillator was prepared and attached to the patient. This effect did not show in terms of faster defibrillation, but would probably result in higher survival rates. Third, more emergency personnel would result in greater opportunities to comfort and support the patient, relatives and other persons present on site, e.g. the fire services may stay a while after the ambulance has left the accident site. Fourth, only the effects from call-outs on ‘genuine’ cardiac arrests are estimated. Fire services are called-out 2-3 times extra per cardiac arrest and it is likely that there are some benefits to account for in these cases as well.

Decision makers should regard the effects of these limitations as well when prioritisation is made. The distribution of costs from the project is primarily distributed equally between fire services (material, training, call-outs and overhead) and the health care sector (hospitalisation, health care and overhead). Individuals most likely to be beneficiaries of the project are those older than 60 years and among them primarily men. Geographic factors are likely to affect the results as well, e.g. population density, the road network and congestions, so transferring the analysis to other counties and countries may not give the same results.

Conclusions

An early defibrillation program using dual dispatch of ambulance and fire services in out-of-hospital cardiac arrest in the County of Stockholm appears to be economic efficient. For the cost-benefit analysis the health benefits amounts to 36 times the invested amount. The cost-utility analysis categorises the cost per QALY as medium and the cost-effectiveness is just below the standard effectiveness threshold. We therefore support a broad implementation of this program under similar conditions.

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Conflicts of interest: None declared

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Table 1. Costs of early defibrillation by the fire services in the County of Stockholm

Cost component	*Resource*	*Cost (€1000)*
Material	Acquisition of AEDs	176
	Acquisition of training AEDs	22
	Maintenance of AEDs	238
Training	Training of instructors	28
	Introductory training	345
	Refresher training	2140
Hospitalisation and health care	Hospitalisation for patients	1822
	Long term health care for discharged patients	2464
Call-outs	Emergency call-outs by the fire services	581
Overhead	Project manager for ambulance and fire services	269
Dispatch centre	Overhead and training	45
TOTAL COSTS		8129

Table 2. Economic evaluation

Analysis	*Benefit*	*Cost (€ 1000)*	*Result (€)**
Cost-effectiveness	16 lives per year	8129	60 000 per life
Cost-utility	77 QALY per year	8129	13 000 per QALY
Cost-benefit			
WTP	VSL=€ 2.2 million	8129	Benefits/Costs=36

** All benefits are accumulated and discounted over the projects time horizon*

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Table 3. Univariate sensitivity analysis

Parameter	*Value*	*Total benefits (€ 1000)*	*Total costs (€ 1000)*	*Benefit-cost ratio*
Baseline		296 924	8129	36
Lives saved				
-5 lives	11 lives per year	204 135	6778	30
+5 lives	21 lives per year	389 712	9480	41
VSL				
-50 percent	€ 1.1 million	148 462	8129	18
+50 percent	€ 3.3 million	445 386	8129	55
Discount rate				
+1 percent	5 percent	285 395	7774	37
-1 percent	3 percent	309 271	8512	36
Life span of an AED				
+2 years	12 years	343 569	9346	37
-2 years	8 years	246 472	6812	36
Hospitalisation costs				
+50 percent	€ 20 000	296 924	9006	33
-50 percent	€ 7 000	296 924	7252	41
Health care costs				
+100 percent	€ 6800	296 924	10 631	28
+50 percent	€ 5100	296 924	9380	32
-50 percent	€ 1700	296 924	6878	43

Appendix

Summary of the cost parameters

Parameter	*Estimate*	*Reference*
Material costs		
General		
Average costs for an AED	€ 2600	SALSA
Average costs for a training AED	€ 500	SALSA
Average costs for an AED battery	€ 400	SALSA
Average cost for AED electrode pads	€ 65	SALSA
Number of used AED batteries per year/AED	0.33	SALSA
Number of used AED electrode pads per year/AED	2.10	SALSA, see text
Region specific		
Number of AEDs purchased in region i	68	SALSA
Number of training AEDs purchased in region i	40	SALSA
Training costs		
General		
Shadow price for a fireman's working time (per hour)	€ 21	[22], see text
Average costs for a AED instructor training course	€ 1600	SALSA
Average costs for a AED training course	€ 900	SALSA
Average group size for a AED instructor training course	4	SALSA
Average group size for a AED training course	6	SALSA
Average time for a AED instructor training course	8 hours	SALSA
Average time for a AED introductory training course	5 hours	SALSA
Average time for a AED refresher training course	3 hours	SALSA
Region specific		
Total number of instructors to be trained in region i	50	SALSA
Total number of firemen to be trained in region i	1323	SALSA
Hospitalisation and health care		
General		
Hospitalisation costs for a discharged patient	€ 13 500	[23]
Health care costs for a patient after discharge (per year)	€ 3400	see text

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Number of life years gained per discharged patients	6	[7], [9], [16]
Call-outs		
General		
Average costs for a fire services call-out	€ 73	SALSA, [22], [25]
Multiplicator for 'false alarms'	2.5	SALSA
Region specific		
Probability that fire services will be called-out on an OHCA in region i	0.66	[15]
Overhead costs		
General		
Average costs for a project manager (per year)	€ 44 000	SALSA
Region specific		
Number of ambulance/health care sector project managers employed first year in region i	0.5	SALSA
Number of fire services sector project managers employed first year in region i	2	SALSA
Number of ambulance/health care sector project managers employed in year t>1 in region i	0.5	SALSA
Dispatch centre		
General		
Shadow price for an emergency operators working time (per hour)	€ 21	SOS Alarm AB
Average time for a instructor training course	8 hours	SOS Alarm AB
Average time for a training course	2 hours	SOS Alarm AB
Region specific		
Total number of instructors to be trained in region i	2	SOS Alarm AB
Total number of emergency operators to be trained in region i	100	SOS Alarm AB
Number of dispatch centre project managers employed first year in region i	0.2	SOS Alarm AB
Number of dispatch centre project managers employed in years t>1 in region i	0.1	SOS Alarm AB