Effect of response times on survival from out-of-hospital cardiac arrest: using geographic information systems

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Abstract: We explored how different response times from out-of-hospital cardiac arrest (OHCA) to defibrillation in the County of Stockholm, Sweden, affect patients’ survival rates. This was done by combining a geographic information systems (GIS) simulation of driving times with register data on survival rates. The emergency resources comprised ambulance alone and ambulance plus fire services. The simulation model predicted a baseline survival rate of 3.9 percent, and reducing the ambulance response time by one minute increased survival to 4.6 percent. Adding the fire services as first responders (dual dispatch) increased survival to 6.2 percent from the baseline level. The model predictions were validated using empirical data.

Keywords: out-of-hospital cardiac arrest; defibrillation; response time; survival rate; geographic information systems; fire services

JEL Code: D61, H43, I10

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1. Introduction

Out-of-hospital cardiac arrest (OHCA) is a frequent and acute medical condition that requires immediate care (Holmberg et al., 2000; Salomaa et al., 2003). Immediate treatment implies a survival chance of approximately 67 percent, while the decline in survival rate without treatment is 5.5 percent per minute and after 12 minutes a patient does not survive (Larsen et al., 1993). Resuscitation of OHCA victims can be improved with early access, early cardiopulmonary resuscitation (CPR), early defibrillation, early advanced care and post-resuscitation care, i.e. the ‘chain-of-survival’ concept (Cummins et al., 1991; Hollenberg et al., 2007). Since survival is extremely time-sensitive, organisation of the emergency medical services (EMS) and other resources involved in the process is important.

Rational decisions about the organisation cannot be made without qualified valuations of benefits and costs resulting from a specific intervention. In the present paper, we evaluate marginal changes in the response time (defined as the interval between the OHCA incident and defibrillation) in the County of Stockholm, Sweden. Both extended and shortened response times were included as well as two alternative organisation forms of EMS defibrillation (ambulance alone and ambulance plus fire services). The latter form was useful for analysing the potential of alternative first-responders, which has been shown to improve the survival rate among patients with OHCA (Hollenberg et al., 2009).

To estimate the survival rates, we use geographic information systems (GIS) simulation and combine it with register data on survival rates. GIS has previously been applied to locate potential areas of high and low rates of survival from OHCA (Warden et al., 2007; Ong et al., 2008), as well as to determine optimal locations for EMS resources (Foo et al., 2010). As far as we know, this is the first study using GIS to analyse the association between response times and survival. Alternatively, the association could be estimated by using logistic regressions on registered OHCA cases (Pell et al., 2001). A limitation of the regression method is that it is bound to use the existing organisation of emergency resources.

We had a unique opportunity to validate the simulation results by using empirical data. As part of the Saving Lives in the Stockholm Area (SALSA) project, all fire stations in the County of Stockholm were first provided with automated external defibrillators (AEDs) and fire and rescue vehicles were then dispatched in parallel with ambulances to all OHCA cases (Hollenberg et al., 2009). The outcome of the SALSA project (16 additional survivors) showed good compliance with the predicted outcome (16 additional survivors). The results from the simulation model can be used to support rational planning processes regarding interventions that affect the
alarm process for OHCAs. We provide some examples of how economic evaluations can be conducted, based on the results of the simulation model.

2. Method

We used a general model to calculate the number of surviving OHCA patients in a specific region. ‘Surviving’ was defined as being alive 30 days after the OHCA and the model was general in the sense that any emergency resources could be applied (e.g. ambulance, fire services, police, lay persons). As the ‘chain-of-survival’ concept shows, the rate of survival depends on a number of factors. In this paper we keep all factors except time to defibrillation constant. The calculations can be summarised into three steps:

1. The number of individuals in region \( i \) who suffer an OHCA and who can be saved by emergency resource \( j \) is given by

\[
R_{i,j} = I_i \times (1 - P_a)
\]

where

\( I_i \) = annual incidence of OHCA in region \( i \)

\( P_a \) = probability that the cardiac arrest was witnessed by ambulance personnel

In our case the region is the County of Stockholm and the emergency resources (\( j \)) comprise either ambulance alone or ambulance plus fire services.

2. The survival rate of patients resuscitated by emergency resource \( j \) in region \( i \) is given by a function of the time (\( t \)) from OHCA to defibrillation, i.e.

\[
S_{i,j} = \sum_{t=1}^{N} \left( \frac{b_{i,t}}{POP_i} \right) \times VF_{i,t} \times s_{i,t},
\]

where

\( N \) = total number of time periods (minutes)

\[2\] The model is modified following Rauner & Bajmoczy (2003).

\[3\] We follow Hollenberg et al. (2009) and include the patients where some type of resuscitation measure was started.
\[ b_{i,t} = \text{population in region } i \text{ reached by emergency resource } j \text{ at time } t \]
\[ \text{POPi} = \text{total population in region } i \]
\[ \text{VF}_{i,t} = \text{probability in region } i \text{ that a patient has ventricular fibrillation (VF) at time } t \]
\[ s_{i,t} = \text{probability in region } i \text{ that a patient having VF survives at time } t \]

3. The number of patients surviving as a result of emergency resource \( j \) in region \( i \) is given by
\[
\beta_{i,j} = R_{i,j} \times S_{i,j}.
\]

Finally, to obtain the marginal effects of an intervention, the procedure was repeated for the relevant alternatives and the difference in survival rates could thus be established.

3. Data

The geographic region chosen was the County of Stockholm, where the total population on 31 December 2007 was 1,949,516 (Statistics Sweden). In 2006 the incidence rate of patients with OHCA, where some type of resuscitation measure was started, was 816 and the probability that the cardiac arrest was witnessed by ambulance personnel was 15 percent (Hollenberg et al., 2009). Below, we report the conditions for the GIS simulations of the times from when emergency services are alerted to when the ambulance and fire services in the County of Stockholm arrive at the incident site. Also, information from the Swedish Cardiac Arrest Register (SCAR) was used to estimate the time-dependent probabilities that a patient has VF and that a patient with VF survives.

3.1 GIS simulation of time from when emergency services are alerted to arrival at the incident site

The first step of our simulation model was to establish the gain in time from an OHCA to defibrillation achieved by dispatching fire services in parallel to ambulances. By using a GIS simulation, we arrived at the share of the population reached per minute by (1) ambulance, (2) fire services and (3) ambulance plus fire services. The simulation was performed by measuring the time from ambulance/fire stations to each person’s home in the County of Stockholm on 31 December 2007. The speed limits of the road network were assumed to be an approximation of the speed of the emergency vehicles. In localities, speed was assumed to be reduced by 20
percent due to e.g. traffic congestion. Only the population in the County of Stockholm was considered, but no limitation for ambulance/fire services outside this area to be called out was set, i.e. a person suffering from an OHCA may be reached by an ambulance or fire services from a neighbouring county.

The station reaction time, i.e. the time from when the emergency services are alerted until the first vehicle departs, was set to 90 seconds for all ambulance stations. For the fire services the station reaction time was more complicated, since there are both full-time and part-time stations. Full-time firefighters usually had a station reaction time of 90 seconds, while the time was longer and varied for part-time stations. Fortunately, the Swedish Rescue Services Agency had data on each fire station’s reaction time and these were included in the simulation.

To be able to perform the simulation, we also needed to assume a specific location where OHCAs occur. Most OHCAs, 65-74 percent, occur in the person’s home (Engdahl & Herlitz, 2005; Iwami et al., 2006; Ong et al., 2008). We therefore used the respondents’ homes as the location of the OHCAs. The risk was assumed to be identical in all homes.

3.2 The time from incident to start of emergency response work
The GIS simulation only displayed part of the alarm process. In addition to the station reaction time and the driving time to incident (time from emergency services alerted to arrival at incident site), which were simulated, we had to account for the process before and after this period of time in the case of an OHCA (see Figure 1). The alarm process after an OHCA starts with the time from incident to first call to the emergency call centre (in Sweden: 112). According to data from SCAR, this time was 2 minutes (median) in 2005-2006 in the County of Stockholm, which was shorter than the Swedish median time of 3 minutes (Herlitz, 2007). Then the emergency call handling time starts. During this time, the operator handles the case and forwards it to the appropriate emergency services. This takes approximately 1.5 minutes on average, according to data from the SALSA project.

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4 ‘A locality consists of a group of buildings normally not more than 200 metres apart from each other, and must fulfil a minimum criterion of having at least 200 inhabitants’ (Statistics Sweden, 2002).

5 Normally there is no stipulated station reaction time. Instead a ‘priority 1’ (highest priority) alarm is supposed to be responded to ‘immediately’. However, in practice and to achieve comparability with the fire services, 90 seconds is a good approximation (Fredric Jonsson, Fire protection engineer, County of Jönköping, Sweden).
Following the emergency call handling time, the GIS-simulated time begins. Finally there is a time interval between arrival at the site and ‘hooking up’ the defibrillator to the patient (preparation time at incident site). With help from experts in the SALSA project, we approximated this time to be 1.5 minute on average. Now, summarising the total time from OHCA to defibrillation yields 2+1.5+GIS simulation time+1.5 minutes = 5 minutes plus GIS simulation time. Since the minimum station reaction time is 1.5 minutes, the shortest time from OHCA to defibrillation would be 5+1.5=6.5 minutes when driving time to incident is shorter than 1 minute.

3.3 OHCA survival rates at various lengths of time from OHCA to defibrillation

Time is extremely important for successful treatment of OHCA and we used data from SCAR to estimate the probability of survival depending on the length of time from OHCA to defibrillation. A number of other factors also influenced the outcome, e.g. whether the OHCA was witnessed by a bystander, whether CPR was started prior to arrival of emergency services and the severity of the arrhythmia recorded by the first emergency responder (Hollenberg et al., 2009). These factors were kept constant, except for the severity of the arrhythmia, which depends on time. Most OHCA begins with VF (Holmberg et al., 2000), which is the only arrhythmia that can be effectively treated with defibrillation. More severe states of ar-

Notes: Modified from the Swedish Civil Contingencies Agency
rhythmia, i.e. asystole and pulseless electrical activity (PEA), are not influenced by a quicker defibrillation response.\

Table 1. Proportion of ventricular fibrillation (VF) on first electrocardiogram (ECG) in relation to time between OHCA and ECG

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>VF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>70</td>
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<td>5</td>
<td>60</td>
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<td>7</td>
<td>50</td>
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<tr>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>31</td>
<td>0</td>
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</tbody>
</table>

Notes: From SCAR. The last proportion (31+) includes all cases above 31 minutes. Number of observations=16 360 (1990-2006).

Table 1 shows how the proportion of VF depends on the time between an OHCA and the first electrocardiogram (ECG). This trend was included in our model and accounts for the decreasing possibilities of survival. Then, we continued to the next variable, which was survival rate of those with VF at a specific length of time from OHCA to defibrillation. Data from SCAR helped us estimate these proportions as well, and the pattern is presented in Table 2. Since there are few observations of OHCA survivors above half an hour, the number of time periods (N) in the model is restricted to 31.

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6 Admittedly, a quicker emergency response is likely to have a positive effect on patients with asystole or PEA as well, e.g. CPR can be performed while waiting for the ambulance. We did not include this effect in the analysis.
Table 2. Proportion of OHCA patients alive (1 month) with VF on first ECG in relation to time from OHCA to defibrillation

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Alive (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<tr>
<td>3</td>
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<td>4</td>
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<td>10</td>
<td>15</td>
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<td>11</td>
<td>10</td>
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<tr>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes: From SCAR. The last proportion (31+) includes all cases above 31 minutes. Number of observations=6156 (1990-2006).

4. Results

4.1 Simulations and marginal effects of response time

Figure 2 shows the GIS simulations of how long it took from when the emergency services were alerted to the arrival at the incident site in the County of Stockholm. A large share of the inhabitants was reached within the time interval of 3-10 minutes. We recognize that the parallel dispatch of ambulances and fire services reached more inhabitants than the ambulance alone in shorter time intervals. Fire services alone came fairly close to the performance of parallel dispatch. Remember that the data displayed in Figure 2 has to be adjusted by adding the remainder of the alarm process, i.e. + 5 minutes in our case. Actually, this implies that the population reached will be zero for the first 6.5 minutes (5 minutes plus station reaction time).
Based on the results from the simulations, we estimated the number of surviving patients $\beta$. The baseline level of survivors per year was 26 (ambulance), or 3.9 percent of the total number of OHCA patients. Engaging the fire services as first responders as well resulted in 42 survivors per year, implying that the number of additional lives saved by parallel dispatch of emergency resources was 16 per year. Changing the time from incidence to defibrillation affected the number of survivors (Figure 3). E.g. shortening/extending the emergency call handling time for the ambulance by 1 minute results in 31 (+5)/22 (-4) survivors per year. One further prediction of the simulation model is that the difference in number of survivors associated with parallel dispatch diminished the longer the time from incidence to defibrillation.

4.2 Is the simulation model valid?

With all due respect for models, we were fortunate to be able to compare the modelled results of parallel dispatch with the ‘real’ outcome of the ‘Saving Lives in the Stockholm Area’ (SALSA) project. As part of the project, which was introduced in 2005, all 43 fire stations in the County of Stockholm were equipped with automated external defibrillators (AED) and fire services were dispatched in parallel with ambulances to all suspected cases of OHCA. The first emergency resource to arrive started CPR and attached an AED. Ambulances were dispatched in exactly the same
manner as before and the length of time from incidence to defibrillation was only affected when the fire services were first on the scene.

The effects of the project were measured and evaluated during a pilot period from 1 December 2005 to 31 December 2006. A Total of 863 patients with OHCA, where some type of resuscitation measure was started, were included and the proportion of patients alive after 1 month increased significantly from 4.4 to 6.8 percent. Since the incidence of OHCA patients in the County of Stockholm was approximately 650-700 in 2006, the estimated number of additional lives saved by the project was 16 per year. A detailed description of the project is presented in Hollenberg et al. (2009).

The simulation model predicted that 26 patients would survive when only an ambulance was dispatched and that 42 patients would survive when ambulance plus fire services were dispatched (baseline level). Thus, the simulation tells us that 16 extra patients would survive through an intervention of dual dispatch, which is also what ‘reality’ tells us. We believe that the compliance of the simulation model with the results of the ‘real’ situation (SALSA) validates our model, although there were a number of uncertainty factors in both cases.

A historical control of the baseline level of survival was also possible. The model predicted that approximately 3.9 percent of the OHCA patients
would survive. Hollenberg et al. (2009) estimated that 4.4 percent would survive (2004), yet earlier studies have estimated survival rates of 2.3 percent (2000) and 3.3 percent (2000-2002) in the Stockholm area (Hollenberg et al., 2005; Hollenberg et al., 2007). In summary, we believe that the model did comply fairly well with the baseline level.

5. Examples of economic evaluation
The result can be used as an input in a model for evaluating the economic efficiency of a specific policy intervention that affects the alarm process. Not only the change in survival rates is interesting in a societal perspective, but also the accompanying costs and benefits. We therefore provide some examples of how to use the results in economic evaluations. Several methodologies can be used to evaluate a policy economically (Johannesson & Jönsson, 1991). In a cost-effectiveness analysis, costs are measured in monetary units and effects in physical units. The physical units in health economics typically comprise the number of survivors or the number of life-years gained. One special case of cost-effectiveness analysis is a cost-utility analysis, where life-years gained are adjusted for quality of life. In a cost-benefit analysis on the other hand, the effect too is measured in monetary terms. This makes it easier to decide whether a policy is efficient since it simply comes down to comparing monetary values of the benefits and the costs. Also, a cost-benefit analysis makes it possible to compare multi-dimensional benefits since they are all expressed in monetary terms. In contrast, for cost-effectiveness analysis a threshold is often used to determine the efficiency, and it is only possible to compare one-dimensional benefits.

Below, we will give two examples of policy interventions that are possible to evaluate with the results of our simulation model in combination with estimations of costs. First, an economic evaluation of the SALSA project is summarised. The policy has a dynamic impact on the alarm process as it changes the locations of the defibrillators. All such interventions require specific GIS simulations to estimate the benefits. Second, the efficacy of any policy that decreases the static time intervals will be discussed.

5.1 The SALSA project – dual dispatch of ambulances and fire services
We used the SALSA case as a way to validate our simulation model. Supplementing these data with information on costs enables us to evaluate the economic efficacy of the policy. An in-depth analysis of the project is summarised in Sund et al. (2010b). Total costs were estimated at €207 8.13 million, including extra costs for materials, more training, extended hospitalisation and health care, additional call-outs, increased overhead costs
and extra costs for the dispatch centre. The quality-adjusted number of life-years (QALY) gained follows Stiell et al. (2003), where the utility of life for OHCA survivors is estimated to be 0.8, and Rauner & Bajmoszy (2003), Walker et al. (2003), van Alem et al. (2004) and Næss & Steen (2004), where the number of life years gained is around 6 years. The valuation of a statistical life (€2007 2.2 million) is taken from Sund (2010a).

Table 3. Economic evaluation of dual dispatch

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

* All benefits are accumulated and discounted over the time horizon of the project

The summary of the economic evaluations are presented in Table 3. The cost-benefit analysis directly tells us that the policy is efficient, since the return on investment was as high as 36. For the cost-effectiveness and the cost-utility analyses, we must refer to thresholds set by some authority. For Sweden, a cost-effectiveness threshold value of € 65 000 is often used and the cost per QALY is categorised as low if it is below € 11 000, medium if € 11 000 – 54 000, high if € 54 000 – 108 000 and very high if it is above € 108 000 (Persson & Ramsberg, 2007; National Board of Health and Welfare, 2007).

The results of the economic evaluations tell us that dual dispatch in the County of Stockholm was a cost efficient intervention. More evaluations will lead to an even better basis for decisions regarding optimal policies to prevent deaths from OHCA or any other cause. Cost-utility and cost-effectiveness analyses can only be used to compare policies where the benefits are number of lives or QALYs, whereas cost-benefit can be used to compare policies that involve multi-dimensional effects, e.g. time savings, environmental effects, restricted freedom and damaged property.
5.2 Decreasing the static time intervals

Trimming of the static time intervals in the alarm process (alarm: 2 minutes; emergency call handling: 1.5 minutes; preparation: 1.5 minutes) is important. Marginal effects of changes in these intervals on survival rates can be evaluated directly by our simulation model. Table 4 shows the general benefits of diminishing the static time intervals by a total of one minute. The gain in number of survivors for ambulance and ambulance plus fire services are 5 and 8 respectively. This information can be seen in Figure 3.

We are able to calculate the threshold levels for the economic evaluations, without specifying the policy that could achieve a one-minute faster emergency response. For the cost-effectiveness analysis the threshold level of € 65 000 per life is used and for the cost-utility analysis we use the ‘low cost’ threshold of € 11 000 per QALY. A value per statistical life of € 2.2 million gives the corresponding threshold level for the cost-benefit analysis. The threshold levels can be interpreted as the maximum total cost of an intervention for it to be deemed effective. For the ambulance alone, we can see that if an intervention costs more than € 325 000 then it is not effective, according to the criteria for the cost-effectiveness analysis.

There are large differences in the threshold values; especially the cost-benefit thresholds are much higher. This reflects differences in value judgments, since cost-effectiveness and cost-utility focuses on health status whereas cost-benefit focuses on utility (Zweifel et al., 2009). The recommendations given will depend on the decision method chosen. Cost-benefit analysis answers the question of whether a specific policy should be carried out. Cost-effectiveness and cost-utility analyses require a fixed budget for health care to assess which policies to carry out.

Table 4. Thresholds for a policy that decreases the static time intervals by one minute

<table>
<thead>
<tr>
<th>Emergency resources</th>
<th>Baseline -1 minute Difference</th>
<th>Thresholds CEA</th>
<th>CUA</th>
<th>CBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulance</td>
<td>26</td>
<td>31</td>
<td>+5</td>
<td>&lt; € 325 000</td>
</tr>
<tr>
<td>Ambulance plus fire services</td>
<td>42</td>
<td>50</td>
<td>+8</td>
<td>&lt; € 520 000</td>
</tr>
</tbody>
</table>
Do any policies fall short of the threshold levels? Although the static time intervals in our model generally seem well-trimmed, we can imagine a potential gain by introducing even faster alarms to ambulance and fire services ('pre-alarms') for suspected cardiac arrests as well as more specific training for emergency operators. This could potentially reduce emergency call handling times and start station reaction times sooner. Pre-alarms including digital alarm technology have been estimated to reduce response times by 60-120 seconds, whereas additional training has been estimated to reduce response times by 5-30 seconds (SOS Alarm AB, 2009). In our model the emergency call handling time is estimated to be 1.5 minutes on average, yet according to SOS Alarm AB, the company responsible for handling 112 emergency calls and coordinating rescue work, it might be as long as 4 minutes on average for ‘priority 1’ ambulance calls. If so, there certainly exists potential to improve this time interval.

Let us assume that the cost of the one-minute gain in response time could be achieved through increased training for emergency operators to accurately and quickly detect a cardiac arrest. There are approximately 100 emergency operators in the County of Stockholm and, assuming that the shadow price per hour of working time is € 21 (Sund, 2010b), the quantity of training hours that could be used before reaching the cost-effectiveness threshold of € 325 000 is 155 per operator. This is a very large number of training hours, and it is therefore likely that this policy would be cost effective. Faster emergency call handling of course implies a risk of e.g. extra call-outs, withdrawal of emergency resources, unnecessary simultaneous alarms and incorrect diagnoses. An in-depth analysis of these effects would shed further light on such a policy.

6. Discussion
We have presented a model that combines geographic information systems (GIS) simulations of the lengths of emergency services times from an out-of-hospital cardiac arrest (OHCA) incident to defibrillation with data on survival rates from the Swedish Cardiac Arrest Register (SCAR). Simulations of ambulance alone as well as ambulance plus fire services were utilised as emergency resources. The results can be used to analyse the benefits (or costs) in terms of surviving OHCA patients of interventions that affect the alarm process. When informed about the costs involved, the decision maker has the opportunity to make a more enlightened policy choice and select the least expensive way to achieve a specific objective.

7 Mikael Björkander, SOS Alarm AB, e-mail 23 October 2008.
Although the simulation model was calibrated for the County of Stockholm, it can easily be generalised to other Swedish counties or regions. Implementation of policies, e.g. changes in regions or dynamic changes such as location of emergency resources or which resources should carry a defibrillator, requires new GIS simulations of the type we showed for dual dispatch. The geographic location of defibrillators is possibly the most interesting factor and it also affects the marginal benefits of static response time changes, e.g. the increase in number of survivors was larger after introducing dual dispatch.

There model has several limitations. Among other things, it was assumed that all OHCAs occur in the patients’ homes and that the risk is identical in all homes, despite the fact that OHCAs have been shown to have definite time-geographic distribution patterns (Ong et al., 2008). E.g. commercial and business areas are more clustered during the day than at night and demographic factors such as age also matter. Also, although a flat rate reduction of the driving speed in localities was included in the model, we are uncertain whether it correctly captures variations in the driving speed of emergency vehicles. Traffic congestion, road works and the choices of route may be factors that complicate the simulation.

Moreover, there are uncertainties regarding the estimations of the static time intervals, e.g. the emergency call handling time. Using SOS Alarm AB’s figure of 4 minutes, the simulation model yields the baseline numbers of survivors of 15 (ambulance) and 24 (ambulance plus fire services); the baseline level of survivors is as low as 2.2% and the additional lives saved through dual dispatch is 9 instead of 16 per year. It is clear that a sensitivity analysis of the results is necessary to provide a good basis for decisions.

On the other hand, the simulation results for dual dispatch comply well with the results from a ‘real life’ intervention. We also recognise that there were a number of factors in the SALSA project that did not work as intended or were unexpected. In addition, Pell et al. (2001) estimated that a reduced ambulance response time from arrival at the scene within 14 minutes in 90 percent of all emergency calls to arrival within 8 minutes would increase the survival rate from 6 to 8 percent; reducing the response time to 5 minutes would increase the survival rate to 10-11 percent. Even if these results are not directly comparable with ours, they are in the same order of magnitude.

In summary, despite the complexity of modelling an intervention of this type, we believe that the results at hand are useful for deploying cost-effective strategies. The possibility of testing where defibrillators should be placed geographically is deemed particularly useful. More applications
using GIS technology in time-sensitive emergency conditions would be equally interesting.
References


Salomaa V., Ketonen M., Koukkunen H, et al., (2003). Decline in out-of-hospital coronary heart disease deaths has contributed the main part to the overall decline in coronary heart disease mortality rates among persons 35
to 64 years of age in Finland. The FINAMI study. Circulation; 108; 691-696.


Economic evaluation, value of life, stated preference methodology and determinants of risks