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Exercise-related cardiac arrest in Västra Götaland; Incidence, Prognosis and Outcome

Master thesis in Medicine

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Abstract

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Introduction
Total incidence of out-of-hospital cardiac arrest (OHCA) with attempt to resuscitation in Sweden is around 5.000 cases annually, 11 % of these survives. The incidence of exercise-related OHCA is scarcely studied, as well as the characteristics, prognosis and outcome of these cardiac arrests.

Aim
This study aims to assess the incidence of exercise-related OHCA in Västra Götaland and to compare characteristics, prognosis and outcome for these cardiac arrests with the non-exercise-related OHCAs. A secondary aim is finding high-risk activities and describe incidence and prognosis of the exercise-related OHCA for each activity.

Method
This is a retrospective cohort study including all OHCA's occurring outside of home in Västra Götaland year 2011-2015 that is a part of the online Swedish Cardio- Pulmonary Resuscitation Register (Svenska Hjärt-lungräddningsregistret). A computer software with additional questionnaire was used to collect the data concerning the characteristic of the OHCAs.

Result
1415 OHCAs outside of home where resuscitation was attempted occurred in Västra Götaland year 2011-2015. 90 (6.4%) of the OHCA were exercise related and 86 (95.6%) of these occurred in men. Patients suffering an exercise-related OHCA were on average 10 years younger than those who had a non-exercise-related OHCA, 57.4 vs 67.3 years and they had a significantly better survival rate to 30 days, 53.6 % survival, compared to 19.7% in the non-exercise related group ($p < 0.001$). The sports with most exercise-related OHCA were bicycling, gym- workout and golf.

Conclusion
Exercise related OHCA has a low incidence in the general population, 1 per 100 000 person-years. Cardiac arrests that occur in relation to exercise have a significantly better prognosis and outcome than non-exercise related cardiac arrests.

Introduction

Out-of-hospital cardiac arrest (OHCA) with attempt to resuscitation occurs around 5.000 times each year in Sweden and the chance of survival until 30 days is about 11 % (1). Around 1.5 % of OHCA occur at sport arenas (1). However, the total number of exercise-related OHCA in Sweden is today scarcely studied, but the incidence is approximately 1-3 per 100 000 person-years in young athletes (2). Few studies on incidence, prognosis and outcome have been done in Sweden.

Cardiovascular disease is one of the main reasons for morbidity and mortality, in spite of progress in outcome in recent years (3) (4). Atherosclerotic disease is the most common cause for cardiac events in those over 35 years of age while hereditary or congenital cardiovascular anomalies such as congenital coronary artery anomaly, premature coronary artery disease and arrhythmogenic right ventricular cardiomyopathy are the main reasons for these incidents in those under 35 years (5), (6). Exercise and physical activity prevent the progress of atherosclerosis and decreases the risk for coronary heart disease events (7), (8), (9) . However, the risk of an acute cardiac event such as acute myocardial infarction and sudden cardiac death is momentarily increased during and directly after vigorous exercise, something that's known as the paradox of exercise (6), (10). An example of a typical vigorous exercise may be running (7). However, the risk of a harmful cardiovascular event during exercise is very low for seemingly healthy adults and the risk of partaking in physical activities is therefore outweighed by the significant health advantages that physical activity confers. The paradox of exercise does mainly apply to vigorous exercise since the risk of acute cardiac events related to light or moderate-intensity physical activity is lower than during or directly after more intense exercise (3) (11).

The total number of cardiac arrests, both non-exercise- and exercise-related, is reduced in those who exercise regularly. Those subjects that are the most active do also have the lowest risk for an exercise-related acute cardiac arrest and myocardial infarction (7), (12), (13). This means that maintaining physical fitness by exercising regularly is very important to prevent an exercise-related cardiac incident. This is true for adults over 35 years of age with both unknown or diagnosed coronary heart disease. Physical activity in young individuals with yet unknown cardiovascular disease can on the other hand lead to increased incidence of both non-exercise and exercise-related sudden death (7).

Since the subjects that are the least physically fit are the ones that have the highest risk of an acute cardiac event during or after exercise (14), they should, in theory, benefit from a progressive exercise program (15). If the subjects gradually become in better shape at the same time as they increase their exercise level, the risk for an acute cardiac event may be minimised. The recommendations state that people who have a diagnosed cardiac disease should warm-up for five minutes before each training session, in order to prevent cardiac ischemia that can occur with sudden, vigorous exercise. It's also recommended that these subjects should cool-down for five minutes because a sudden intermission of exercise can lead to decreased central blood volume which also can cause cardiac ischemia (7), (16). Subjects that have a diagnosed cardiac disease and people that are physically inactive should avoid vigorous exercise and physical activity that they are not used to when the temperature is extraordinary hot or cold (7), (17).

Few studies have been performed on specific high-risk activities since exercise-related OHCA is quite uncommon. The risk is related to the interaction of the type of physical activity and the subject's physical fitness – since the same activity enquires different amount of cardiac demand in fit and unfit individuals. However one activity that often has been associated with a higher risk of cardiovascular events is snow shovelling (7). One possible explanation for that is that the shovelling often is performed by unfit persons who shovel the snow because they have to do it. It's also suggested that a vasoconstriction of the coronary arteries during physical activity in cold temperatures can cause angina pectoris at a lower rate pressure product. This means that a lower blood pressure and a lower pulse which wouldn't cause angina pectoris in normal temperature, can do so in cold temperatures (7), (17). In a Dutch prospective cohort study, a study on the incidence and prognosis of exercise-related OHCA, found that exercise-related OHCA were most frequent during cycling, swimming, tennis and work-outs at the gym (6). The study included physical activities that were performed as a recreational activity and organized sports (6).

It's also been studied if acute myocardial infarction and sudden cardiac death happens at any specific time of the day. The results, as well as the causes, differ among people over 35 years of age and younger people; in those over 35 acute cardiovascular events are more likely to occur in the early morning contrary to young athletes where these events take place during

afternoon and early evenings, during or after exercise and competitions (7). The difference is probably due to the different causes of the cardiac arrest, i.e. coronary artery disease (CAD) in the elderly.

In the Dutch study 93 % of the exercise-related OHCA victims were men, and 72 % of the non-exercise related OHCA were also men (6). These numbers are correlating to the results of a French study (11) that also studied sports-related OHCA and sudden death in the general population in a prospective study. Their results showed that 95% of the exercise-related OHCA occurred in men. This difference between the sexes is partly explained by the fact that women develop coronary artery disease later and by the fact that men are participating in sports activities to a higher extent than women. However, this cannot exclude the possibility that men have an increased risk of exercised related OHCA intrinsically (6).

Factors that after an OHCA are associated with improved survival to hospital discharge are: 1) if bystander CPR is being performed, 2) the time from the collapse to start of CPR and 3) the first use of cardiac defibrillation (11).

The aforementioned Dutch study showed a higher survival rate in exercise-related OHCA with increasing age (6), which could be explained by the fact that the cardiac arrests generally have different causes depending on the individual's age. This suggests that a given treatment with defibrillation is more efficient when the cardiac arrest is caused by CAD, which is the main cause of exercise-related cardiac arrest in older patients, as compared with cardiomyopathies and electrical heart diseases that are the most common causes for exercise-related OHCA in young patients, e.g. under 35 years of age. The high rate of coronary revascularisation in the Dutch study (70%), also supports that exercise-related OHCA is mainly caused by CAD in higher age-groups further supporting the hypothesis that patients over 35 years have better outcome (6).

Competing young athletes have a higher risk of a sudden cardiac arrest than non-athletes (2), (5). Pre-participation screening is therefore recommended, internationally and in Sweden exclusively for high risk groups, such as elite athletes from the age of 16 years (2). However, since exercise-related OHCA is a rarity it's been discussed whether the installation of automated external defibrillators (AED) in sport arenas would be more cost-effective than

pre-participating screening (11). Middle age and senior people are increasingly physically active and are therefore participating in activities at sports arenas, gyms etc. These groups don't undergo any pre-participating screening and more sudden cardiac arrests occur in higher age-groups. Since exercise-related OHCA occurring in persons above 35 years of age have proven to have a better outcome than non-exercise-related OHCA in the same age-group, does this highlight the necessity of AED installation on sport arenas and continued CPR education to people engaged in sport-activities, as well coaches, the active participant and bystanders (6), (2). However, the screening and AED are complementary, as screening will never be 100 %, nor will AEDs.

Aim

This study aims to assess the total incidence of exercise-related OHCA in Västra Götaland and to compare characteristics and prognosis of the cardiac arrests that occur in sport arenas and during sport activities in comparison to the non-exercise-related OHCA. A secondary aim is to detect activities associated with high-risk and describe incidence and prognosis of the exercise-related OHCA in these cohorts.

Ethics

This project has been approved by the ethical committee in Stockholm.

Methods

This is a retrospective cohort study including all patients that had an OHCA outside of home in the county of Västra Götaland, population of 1,6 million, during the years of 2011-2015 and is a part of the online Swedish Cardio- Pulmonary Resuscitation Register (Svenska Hjärt-lungräddningsregistret). The register includes all EMS-stations (Emergency Medical Services) in Sweden and is nearly comprehensive (almost 100% degree of covering) (1). Each cardiac arrest is reported to the register by the paramedics and the cases that are failed to report are found by the control of the register compared to the EMS' own register (1). The variables that are recorded in the register have previously been described, *appendix 1*, (18). Only the OHCA that occurred outside of home are included in this study because the risk for an exercise-related OHCA is considered to be higher outside of home than in the residence.

Data collection procedure

A computer software and an additional questionnaire, was used to collect the data concerning the OHCA in Västra Götaland during the period of 2011-2015, all ages were included. The patients in question were selected from the Swedish Cardio- Pulmonary Resuscitation Register and the including criteria was that they should have had an OHCA outside of home during the study period. The additional data was gathered from the Swedish ambulance register Ambulink. The additional questions that were included were;

- Where did the cardiac arrest take place?
- Was bystander CPR initiated?
  - If yes, which was the educational level on the person who performed the CPR?
- Were telephone-instructions of how to perform CPR given by the SOS?
- Was a public defibrillator used?
- Was treatment given by firefighters or police before the ambulance arrival?
- Did they connect and use a defibrillator?
- Did the cardiac arrest occur in association with exercise?
  - If yes – was it in association with official competition?
  - Where did it happen?
  - Did it occur on a sports arena?
    - If yes, who was the victim?
  - In association with which sport/physical activity did the cardiac arrest occur?

- o Was an AED available?
  - If yes, was it used?

The sports that were electable were: Track and field, badminton, bandy, basket, table tennis, boxing, wrestling, curling, bicycle, soccer, golf, gym /group-training, gymnastics, handball, floorball, ice hockey, martial art, running, motorsport with two or four wheels, orienteering, horseback riding, rugby, sailing, swimming, skiing (ski jumping, slalom, cross-country skiing), squash, weightlifting, tennis, volleyball.

If the sport wasn't among the given options, it was classified as "others". The criteria for what was defined as sport was if the sport was included in the Swedish national sports organisation's register (Svenska riksidrottsförbundet). An OHCA was considered to be exercise related if it occurred during exercise or within one hour after physical activity.

The information gained from the Swedish ambulance register Ambulink by described procedure above in combination with already existing data in the Swedish Cardio- Pulmonary Resuscitation Register forms the data where the results of this study is derived.

Statistical methods

Results are expressed as means, medians, percentages and numbers. When comparing groups Fishers exact test was used for dichotomous variables and Wilcoxons two-sample test was used for continuous variables. A p-value < 0.05 was regarded as significant.

Results

Total incidence of OHCA outside of home where resuscitation was attempted in the county of Västra Götaland during the study-period, from year 2011-2015, was 1415. This is an incidence of 17 OHCA per 100 000 person-years.

Of these 1415 OHCAs, 1055 (74.6 %) did occur in men and 360 (25.4 %) occurred in women. 90 (6.4 %) of these OHCAs were exercise related. Amongst the exercise related OHCAs 86 (95.6%) did occur in men and 4 (4.4 %) occurred in women. The incidence of sports related OHCA was 1 per 100 000 person-years. Patients and resuscitation details are shown in *Table 1*.

Tabel 1: Patients- and resuscitation -details regarding exercise related OHCA and non-exercise related OHCA

Did the cardiac arrest occur in relation to physical activity?	Yes	No	P-value
	90	1325	<0.001
Mean age	57.4 years	67.3 years	<0.001
Sex a) Male b) Female	a) 95.6 (86)* b) 4.4 (4)	a) 73.1 (969) b) 26.9 (356)	<0.001
Witnessed	89.5 (77)	80.3 (1027)	0.034
Initial shockable rhythm	74.7 (62)	55.7 (713)	<0.001
CPR before the arrival of the emergency team	78.8 (67)	62.4 (805)	0.002
Median time from cardiac arrest to start of CPR	1 min	1 min	0.873
a) Was an AED connected by bystander? b) If yes, was defibrillation performed?	a) 22.4 (19) b) 94.7 (18)	a) 4.4 (54) b) 64 (32)	a)<0.001 b) 0.014
Median time from cardiac arrest to SOS-contact	2 min	2 min	0.873
Median time from	11 min	13 min	0.149

cardiac arrest to defibrillation			
Was CPR performed by firefighters or police before the arrival of the ambulance?	10.3 (9)	11.1 (141)	1
Was the cardiac arrest caused by a cardiac disease?	71 (54)	67.2 (798)	0.5
Survival 30 days	53.6 (45)	19.7 (250)	<0.001

*=%(n)

As shown in *Table 1,* patients who suffered an exercise-related OHCA were on average 10 years younger than those who had a non-exercise related OHCA, 57.4 vs 67.3 years. Exercise related OHCAs were more often witnessed than non-exercise related OHCA. CPR performed by a bystander was given more frequently to those suffering an exercise related OHCA and an AED was also connected in more cases compared to non-exercise related OHCA. Furthermore, exercise related OHCAs were more likely to have an initial shockable rhythm, i.e. ventricular fibrillation or ventricular tachycardia, than non-exercise related (p < 0.001). In all OHCAs, both exercise and non-exercise related cardiac arrests were CPR performed by firefighters or the police before the arrival of EMS in 10-11 % of the cases.

As *Table 1* also demonstrates, cardiac disease was the cause of the cardiac arrest in around 70 % of the OHCA, both exercise and non-exercise related. However, more than half, 53.6%, of the persons suffering an exercise related OHCA survived to 30 days, in comparison to 19.7% in the non-exercise related group (p <0.001).

Out of 90 exercise-related cardiac arrests, 49 (54%) occurred at a sports arena and 38 (42 %) occurred somewhere else. Data was missing in the remaining 4 % of the cases. Details and characteristics are shown in *Table 2*. Both groups were witnessed to almost the same extent but those who suffered an OHCA at a sport arena received CPR before arrival of the emergency team more often, in 89.4 % of the cases compared to 62.9 % of the cases outside sport arenas. They were also more likely to have an initial shockable rhythm than those who had an exercise related OHCA outside of sports arenas. Delay times from collapse to call for EMS, start of CPR and to defibrillation did not differ between the two groups. The one month survival did not differ significantly between the two groups 58.7 % vs 45.7 % (p=0.269).

Table 2: Patients- and resuscitation -details regarding exercise related OHCA that occurred at sport arena vs outside a sport arena

Did the cardiac arrest occur at a sports arena?	Yes	No	P-value
	49	38	0.314
Mean age	58 years	56.9 years	0.890
Sex a) Male b) Female	a) 98 (48)* b) 2 (1)	a) 92.1 (35) b) 7.9 (3)	0.314
Witnessed	89.6 (43)	88.6 (31)	1
Initial shockable rhythm	82 .2 (37)	65.7 (23)	0.120
CPR before the arrival of the emergency team	89.4 (42)	62.9 (22)	0.006
Median time from cardiac arrest to start of CPR	1 min	1 min	0.231
a) Was an AED connected? b) If yes, was defibrillation performed?	a) 31.1 (14) b) 92.9 (13)	a) 8.1 (3) b) 100 (3)	a) 0.01 b)1
Median time from cardiac arrest to SOS-contact	2 min	2 min	0.919
Median time from cardiac arrest to defibrillation	11 min	11 min	0.708
Was CPR performed by firefighters or police before the arrival of the ambulance?	10.6 (5)	10.8 (4)	1
Was the cardiac arrest caused by a cardiac disease?	71.8 (28)	67.7 (23)	0.8
Survival 30 days	58.7 (27)	45.7 (16)	0.269

* = %(n)

Table 3 and in *Figure 1* demonstrate the sports in which exercise related OHCA occurred. The sports with the highest incidence of exercise related OHCA were cycling (n= 21, 23 % of all exercise related OHCA), gym work out (n=11, 12%), golf (n=9, 10 %) and floorball (n=8, 9 %). The chance of survival was 33.3 % for those who got their cardiac arrest in relation to cycling. 54.5 % of the sudden cardiac arrests (SCA) that occurred during or directly after gym work-out or group training survived and the survival of golf-related SCA was 33.3 %. The survival of floorball-related SCA was 62.5 %.

The group "other" is a heterogeneous group including several different sports like bowling, kayaking, roller ski, catch, track and field, aquaerobics and exercise unspecified when the specific kind of exercise can't be decided by the journal. As a group, they suffered 14 (15.6 %) exercise-related OHCA with 71.4 % survival.

Only four exercise related OHCA occurred in relation to official competition during the study period and they occurred during or within one hour after running (Göteborgsvarvet n=2), orienteering (n=1) and during a track and field competition (included in "other", n=1).

Table 3: High-risk activities

Sport	Number of cardiac-arrests	Number of survivors	Survival percent (%)
Cycling	21	7	33.3
Other	14	10	71.4
Gym work-out / Group training	11	6	54.5
Golf	9	3	33.3
Floorball	8	5	62.5
Running	6	4	66.7
Swimming	5	4	80
Badminton	4	1	25
Soccer	3	3	100
Motor sport (on four wheels)	2	0	0
Bandy	1	0	0
Tennis	1	1	100
Cross-country skiing	1	0	0
Orienteering	1	1	100
Motorsport (on two wheels)	1	0	0
Ice skating	1	-	-
Gymnastics	1	0	0

Other sport includes; Bowling, kayaking, roller ski, catch, track and field, aquaerobics, and exercise unspecified when the specific kind of exercise can't be decided by the journal.
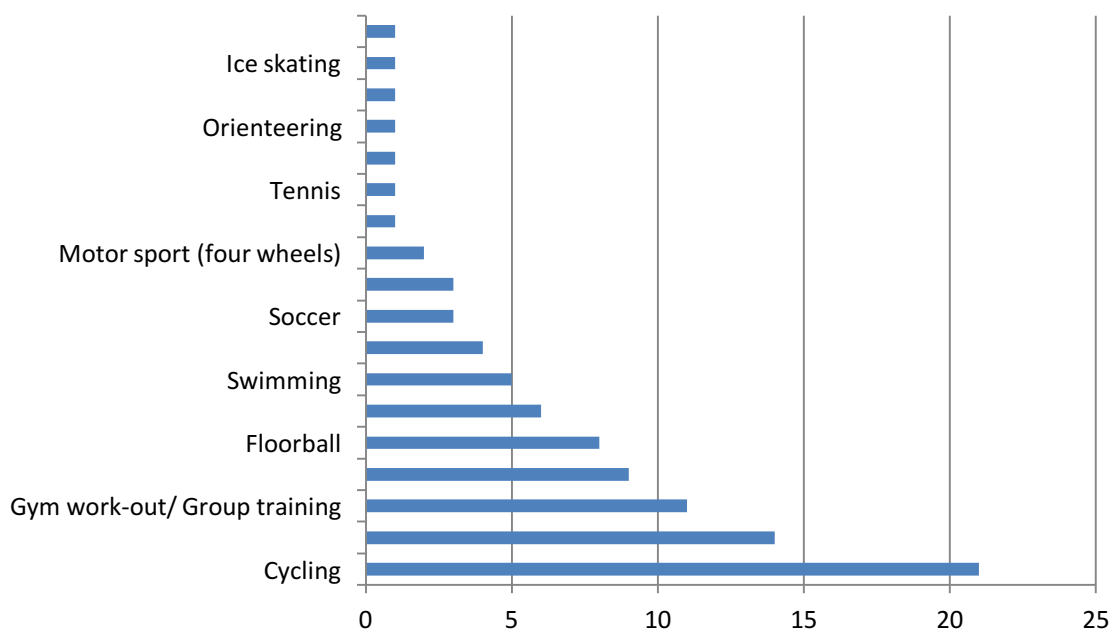
Figure 1: The number of exercise related cardiac arrest in each sport.

Location details are shown in Table 4. The most frequent location for exercise related OHCA were public places (n=14, 15.6 %), fitness centre (n=12, 13.3 %), sports hall (n=12, 13.3 %) and golf course (n=9, 10 %), which reflects the result that the sports associated with high risk are performed at these places. Cycling is often performed at public places such as in the city when people commute to work, gym work out are being performed at a fitness centre, several different sports are being performed in a sports hall for example floorball, badminton and soccer. Golf is of course played at a golf course.

Table 4: Location for exercise-related OHCA

Where did the exercise-related OHCA take place?	Number of cardiac arrests	Percent out of all exercise related OHCA (%)
Public place	14	15.6
Fitness centre	12	13.3
Sports hall	12	13.3
Golf course	9	10
The street	7	7.8
Residence	5	5.6
Bathhouse	4	4.4
Ambulance	3	3.3
Göteborgsvarvet	2	2.2
Bowling saloon	2	2.2
Soccer field	2	2.2

Go-cart track	2	2.2
Bicycle lane	1	1.1
Traffic casualty	1	1.1
Workplace	1	1.1
Sport association	1	1.1
Sports field	1	1.1
Ski trail	1	1.1
Campsite	1	1.1
Motocross field	1	1.1
Driveway	1	1.1
The beach	1	1.1
Ice rink	1	1.1
Jogging trails	1	1.1
Forrest track	1	1.1
Frozen lake	1	1.1
River	1	1.1
Care centre	1	1.1

Discussion

The main result of this study is that 6.4 % of the OHCAs in whom resuscitation was attempted and which occurred outside home are exercise related and that 53.6 % of those survived 30 days, in comparison to 19.7 % of those who suffered a non-exercise related OHCA. The incidence of 1 per 100 000 person-years is lower than previously approximated (2).

The study demonstrates a male predominance where 70 % of the OHCAs occurred in men and 95.6 % of the exercise related OHCAs did afflict men. The male predomination is best explained by a higher participation rate in sports among men and a higher risk profile in men who develop coronary artery disease earlier in life than women do, as previously described (6), (11), but the possibility that men have a higher risk for acute coronary events intrinsically compared to women cannot be excluded (6).

Patients who suffer an OHCA and are found in a shockable rhythm have a 5-10 times greater chance of surviving compared to those who are found in a non- shockable rhythm. Around 60 % have ventricular fibrillation as initial rhythm but with time, seconds to minutes, this arrhythmia converts to asystole. This means that the longer the patient has to wait for defibrillation the smaller are the chances that the initial registered rhythm is shockable. This leads to the conclusion that very early defibrillation is the most important factor for increasing the chances of survival (1). This is the reason why we have seen an increased number of public AED's in Sweden. In the year 2014, there were 15 458 AED registered. The AEDs are located at public places where one could expect a lot of people spending time, for example at stores, at shopping malls, at work places, at sports arenas, bathhouses and gyms etc. (1).

 Several different factors could explain the higher survival rate after an exercise related OHCA. First, they were more often witnessed, they received CPR more frequently before the arrival of a dispatched unit and they were more likely to have an initial shockable rhythm. Furthermore, those who suffered an exercise related OHCA were more often connected to a public AED. These are all factors that are known to improve survival (1).

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A cardiac disease is more likely to be the cause of a cardiac arrest with augmented age and the survival of a non-exercise related cardiac arrest is reduced with increasing age. According to the Swedish Cardio- Pulmonary Resuscitation Register report from 2015 just over 30 % of the people 19-29 years old did survive a witnessed sudden cardiac arrest (SCA). Then there is a descending scale with increasing age, with 20 % surviving a witnessed SCA in the age group 50-59 years, 10 % surviving in the age group 70-79 years and only around 2 % in the age group above 90 years of age survived a witnessed SCA (1).

Those who suffer an exercise related OHCA are on average 10 years younger than the ones that get a non-exercise related OHCA. This age difference could implicate that these subjects haven't developed arteriosclerosis to the same extent simply because they are 10 years younger and therefore had less time to develop the disease. The fact that the cardiac arrest occur during or shortly after exercise could imply that these subject are more physically fit and therefore have lower cardiovascular risk factors with less developed arteriosclerosis and because of that are better prepared to withstand and survive a cardiac arrest (1) (6) (7). The fact that the SCA occurred in relation to exercise could also imply that the physical activity is a trigger and that the subjects wouldn't have had a cardiac arrest if they hadn't exercised at that time, but maybe they would have suffered a non-exercise related SCA at a later time (7) (19).
This could, in addition to the above mentioned favourable factors, lead to a higher survival rate.

The mean age of the subjects that had an exercise related OHCA were 57.4 years and around 71 % were caused by a cardiac disease, which in these cases most likely reflect CAD since this disease is the main cause of cardiac arrests in older patients, e.g. patients over 35 years of age (10). The better survival rate in this study than previously reported, where exercise related OHCA in young athletes have the same survival rate as non-exercise related OHCA (6), could empower the following suggestion: defibrillation is more efficient when the cardiac arrest is caused by CAD rather than inherited conditions such as cardiomyopathies and electrical heart disease which are the main reasons for cardiac arrests in young athletes (6).

There was no significant difference in outcome when relating the exercise related OHCA to whether it took place in a sport arena or not. The study was, most likely, underpowered to

adequately address this research question. There were however interesting trends indicating a higher chance of survival if the cardiac arrest took place in a sport arena.

The sports in which an exercise-related OHCA occurred most frequently were cycling, gym work-outs, golf and indoor hockey. One possible explanation why OHCAs occurred most frequently during cycling is that it is performed as a sport activity, recreational activity and as a mean of transport. Golf was the sport with highest participation rate in Sweden in year 2014 (20). Work-out at the gym is becoming more and more popular, and the selling of gym memberships is constantly increasing (21).

The fact that only four out of 90 exercise related cardiac arrests occurred during or after a competition is worthy of note. The number is surprisingly low and an under-reporting of cases could be suspected.

The variation in the proportion of survivors in the different sports should be interpreted with caution due to the low number of cases.

The results of this study correlates with the previously mentioned Dutch study's results in several aspects. They performed a prospective cohort study in the general population which included all subjects that suffered an OHCA where resuscitation was initiated in the province of North Holland between the years 2006 -2009. They sampled their data from a prospective database maintained by The Amesterdam Resusciation Studies research group. Their study shows a survival rate of 46 % for exercise related OHCA, compared to 17 % survival amongst the non-exercise related OHCA (6). CPR were performed in 87 % of the cases of exercise related OHCA. The sports that had the highest number of exercise related OHCA were cycling, work-outs at the gym, tennis and swimming. This differs from previous studies where soccer has been the sport shown to be associated to most acute cardiac events (6). This difference is explained in the Dutch report by the fact that their study did not only address organized sports but also included exercise in general (6). After adjusting for the favourable circumstances that exercise-related OHCA were related to in the Dutch study, for example that they more frequently took place in public places, were witnessed to a higher extent, received CPR and AED-use more frequently and more often had shockable initial rhythm, exercise related OHCA still had a 163 % higher chance of survival than non-exercise related

OHCA (6). This implies that regular exercise might have cardio-protective effects beyond improvement in cardiovascular risk factors and possibly also improvements in the endothelial function in the coronary blood vessels as well as enhanced development of coronary collateral circulation. Patients with exercise-related OHCA also have a higher arousal level of their sympathetic nervous system when the cardiac arrest occurs, which, in combination with the favourable effects of regular exercise, may be an important factor that explains the better outcome of exercise-related OHCA (6).

The present study is similar to the Dutch study in several aspects, for example how the study is composed and the including- and excluding criteria. The outcome of the exercise related OHCA in our study is somewhat better than the result of the Dutch study, 53.6 % survived to 30 days in this study compared to 46 % in the Dutch study, but the result is comparable. It's possibly that the Swedish Cardio- Pulmonary resuscitation register is more comprehensive than the database from which the Dutch study group collected their data, but on the other hand their study did investigate more factors than this study did. They examined for example the outcome of the exercise-related OHCA for several different age-groups while this study only studied mean age.

Another French study, investigated sports-related OHCA and SCA in the general population as a prospective study (11). They collected data from a nationwide EMS, 51 % of the reports, and by screening of media releases, 49 % of reported cases. Their result showed a survival rate of 15.7 % for exercise related OHCA. Higher survival rates were found in two districts in the north of France, around 50 % survival. The significant difference in outcome in different regions is probably a consequence of more frequent performed bystander CPR in those northern provinces, in more than 90 % of the cases in comparison to 30.7 % of the cases which was the average percentage of CPR in the whole of France (11). This empowers the fact that bystander CPR is an important factor to enhance the chance of surviving a SCA.

Both this study and the Dutch study presents a better survival rate than the French study does. This could be due to several different factors. First, the French study might not be as comprehensive since it was not based on a database including all resuscitation efforts, but had to rely on media screening to detect the missing cases. Secondly, CPR were performed in a significantly lower number of cases in comparison to our and the Dutch study. This could be

an important factor to explain the poorer outcome for those who suffered an exercise related OHCA in the French study, compared to our and the Dutch study.

The male predomination in this study, 95.6 %, correlates with the result of the Dutch study, 93 %, and with the result of the afore mentioned French study, 95 % (6) (11).

The risk of an exercise-related SCA is augmented with increasing age (22). The trend of increasingly physically active middle-age and senior people could therefore result in more exercise-related cardiac arrest in the future. Since the incidence of exercise-related SCA is increasing in those over 40 years of age (22) and this age group don't undergo any screening in Sweden (2), the chance of identifying high-risk individuals is small. In order to further increase survival of exercise-related SCA, other interventions need to be done. The accessibility of AED on public places and sports arenas are of outmost importance, since time from cardiac arrest to defibrillation is a known factor to improve survival (1), and more frequent installation of AEDs could therefore be an important intervention. Improvement in education of patients regarding symptoms of an upcoming acute cardiac event could also be of importance since studies have shown that many people ignore prodromal cardiac symptoms and don't seek medical attention (7). If more people recognised these symptoms and went to the closest EMS station, the prognosis of surviving an SCA could improve, for both exercise- and non-exercise related SCA.

Minimising the kind of exercise performed alone without bystanders could be a simple safety precaution for all physical active people, for example go jogging in the city instead of alone in the forest, since the chance of surviving a SCA is considerably better if the event is witnessed (1).

Limitations

The study's limitations are to be mentioned. The relatively low number of exercise related OHCA limits the conclusions that could be made and the results need to be interpreted with caution, especially the characteristics regarding each individual sport where the cohort groups sometimes were very small.

The general limitations regarding a retrospective study applies for this study as well. Furthermore, it was sometimes a question of interpretation whether the cardiac arrest was exercise related or not. For example could a cardiac arrest that occurred in water be due to exercise, due to drowning but also in some cases be due to suicide. There was in some cases also difficult to know if an activity could be classified as sport or physical activity since many activities can be performed with different intensity.

Conclusions and implications

In conclusion, this study demonstrates that the incidence of exercise related OHCA is low in the general population, one per 100 000 person-years. Out of hospital cardiac arrest that occurs during or within one hour after physical activity has a significantly better prognosis with a greater chance of survival compared to those who suffered a non-exercise related OHCA. In fact, more than 50% survived to 30 days after suffering an exercise related OHCA.

The increasing number of physically active middle aged and senior people might lead to an increasing incidence of exercise related OHCA. This group of people don't undergo any screening, which means that high-risk individuals will not be identified beforehand. However they appear to have a better chance of survival than non-exercise related OHCA and this should imply the requirement of public AED on sports arenas, and in public places for sports performed outside stadiums, as well as education of CPR to those engaged in sport activities; participants, coaches and bystanders since sports are performed by sport participants of all ages.

Future directions

More research on the subject involving other areas of Sweden needs to be done before any general conclusions can be made since this is a small study including relatively few patients. Especially more studies that look at specific age-groups, sports and sexes in order to find both high risk individuals and activities that are associated with high risk. But if future studies show the same incidence and results with better outcome in exercise-related OHCA, this could lead to implications for public recommendations and health programs, to avoid exercise-related sudden death. It could also lead to recommendations to do exercise-testing or screening of high-risk individuals before starting a vigorous exercise-program.

Populärvetenskaplig sammanfattning på svenska

Hjärtstopp utanför sjukhus där återupplivningsförsök med hjälp av hjärt-lungräddning utförs inträffar ca 5000 gånger varje år i Sverige. Överlevnadschansen för de drabbade personerna är ca 11 %. Ca 1.5 % av dessa hjärtstopp sker på idrottsplatser, men hur många som faktiskt sker under idrottsutövning, som ju kan utföras utanför sportanläggningar, har inte studerats tidigare och är därför okänt.

Målet med denna studie var därför att kartlägga hur många idrottsrelaterade hjärtstopp som sker, studera hjärtstoppens karaktär, det vill säga utvärdera om det finns något som utmärker de idrottsrelaterade hjärtstoppen från de icke-idrottsrelaterade hjärtstoppen, t.ex. initial hjärtrytm vid defibrillering. Målet var även att undersöka prognosen för de som drabbas, alltså hur stor chansen är att man överlever hjärtstoppet.

I studien inkluderas alla patienter som under åren 2011-2015 fick ett hjärtstopp utanför sjukhus och utanför hemmet och där hjärt-lungräddning påbörjades inom Västra Götalands län och som finns registrerade i Svenska Hjärt-lungräddningsregistret. Med hjälp av ett dataprogram som bestod av ett frågeformulär med frågeställningar gällande hjärtstopp under idrottsutövning kunde patientdata inhämtas från det svenska ambulansregistret.

Resultatet visade att det inträffade 1415 hjärtstopp utanför sjukhus under de aktuella åren i Västra Götalands län och att 90 fall, dvs. 6.4 %, var idrottsrelaterade. Hjärtstopp var vanligare förekommande hos män och 86 av dessa 90 idrottsrelaterade hjärtstopp, dvs. 95.6%, drabbade män. Medelåldern för de som fick hjärtstopp utanför sjukhus i samband med idrottsutövning var 10 år lägre än för de som fick icke-idrottsrelaterade hjärtstopp utanför sjukhus, 57.4 år jämfört med 67.3 år.

Chansen att överleva ett idrottsrelaterat hjärtstopp under de första 30 dagarna var 53.6 % vilket var signifikant högre än chansen att överleva ett hjärtstopp utanför sjukhus som inte var idrottsrelaterat där endast 19.7% överlevde. Detta kan dels bero på att de idrottsrelaterade hjärtstoppen var bevittnade i större utsträckning och att personer som fick idrottsrelaterade hjärtstopp oftare fick hjärt-lungräddning innan ambulansens ankomst samt att de anslöts till en public hjärtstartare och defibrillerades i fler fall. En defibrillerbar rytm förelåg också i högre grad bland dessa patienter. Detta är alla faktorer som ingår i "kedjan som räddar liv"

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som redovisats av Svenska Hjärt-Lungräddningsregistret och som belyser vikten av tidig kontakt med SOS, tidig start av hjärt-lungräddning och tidig defibrillering.

Att personerna som fick de idrottsrelaterade hjärtstoppen var 10 år yngre än de som fick de icke-idrottsrelaterade hjärtstoppen samt att hjärtstoppet just skedde under eller i samband med idrottsutövning skulle kunna betyda att dessa patienter är i bättre fysisk form och därmed har större chans att klara av ett hjärtstopp som naturligtvis är en oerhörd påfrestning för kroppen.

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Appendix A

Survival after cardiac arrest outside hospital in Sweden

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Abstract

The voluntary Swedish Cardiac Arrest Registry has collected and analyzed 14 065 standardised reports on cardiac arrests up until May 1995. The reports have been collected from approximately half of Sweden's ambulance districts, which cover 60% of the population. Resuscitation was attempted in 10 966 cases. The median age was 70 years. In 70.0% the arrest was witnessed, and in 43.3% the first recorded rhythm was VT/VF. Bystander-CPR was initiated in 32.3% of the cases. Most cardiac arrests took place at home (65.8%) and 67.1% were judged to be of cardiac origin. In 1692 cases (15.4%), the patient was admitted alive in hospital and 544 patients (5.0%) were alive after 1 month. Survival to 1 month in the subgroup which presented with VT/VF was 9.5%. We found no significant difference between survival in large cities and smaller communities. The survivors were analysed in relation to time to defibrillation and we found a strong correlation between a short time and increased survival. © 1998 Elsevier Science Ireland Ltd.

Keywords: Cardiac arrest; Survival; Outside hospital; Sweden

1. Introduction

Sudden unexpected cardiac arrest accounts for a high proportion of the deaths in western societies. The majority of these cases occur outside hospital [1]. Until recently death was almost inevitable for these cardiac arrest victims. The introduction of techniques for basic cardiopulmonary resuscitation (CPR) and defibrillation has dramatically changed the chances of survival. There are numerous reports of effective resuscitation with a wide variation of survival rates [2].

Some of these reports have shown very positive results, but it has been claimed that survival rates on a national level probably are very low, perhaps as low as 2–5% [3,4].

Most reports are based on data from a city or a limited region, and information on survival from larger regions or countries is rare [5–7].

Sweden, like most European countries, has been slow in introducing the techniques for resuscitation; both for basic and advanced cardiac life support (ACLS). In 1983, a basic CPR national training program was introduced in Sweden, which has been rapidly adopted both by the medical professionals and lay people and is now widely used all over the country. In 1987, a national ACLS training program was introduced and rapidly accepted.

In the late 1970s, there were a few ambulance systems equipped with defibrillators in different parts of Sweden. After the introduction of the semiautomatic defibrillators in 1986 there has been a rapid development/expansion and now approximately 90% of Swedish ambulances are equipped with semiautomatic defibrillators.

With an ongoing large scale CPR training programme in society and with effective ambulance systems it is interesting and important to evaluate the

efficiency of the ambulance systems in their efforts to resuscitate patients with cardiac arrest.

The aim of this study was to investigate the survival rates for out-of-hospital cardiac arrests in Sweden.

2. Methods and patients

2.1. Methods

2.1.1. Ambulance registry

This study is based on material collected by the Swedish ambulance cardiac arrest registry. The registry, which is voluntary, started in 1990 with a few ambulance services. It has successively been joined by more, and by now the registry is based on reports from 57 ambulance services. These services cover 5 million out of a total of 8.7 million inhabitants in Sweden.

Most of the ambulance organisations which were included serve smaller communities with less than 100 000 inhabitants, and only recently have the larger cities, i.e. Stockholm, Gothenburg and Malmoe, joined the registry. Twenty-three percent of all case reports now emanate from these three cities.

2.1.2. Ambulance dispatch centres

All parts of Sweden are served by ambulance dispatch centres with similar protocols for responding to those who call for ambulances. All interviews are begun with a few simple questions to identify suspected cardiac arrest victims. In such cases, an ambulance is immediately dispatched before the interview is continued.

2.1.3. Ambulance organisations

Sweden is sparsely populated, and approximately 80% of the population lives in cities or small towns and villages. Most of these, but not all, have their own ambulance station.

Approximately 100 ambulance organisations operate in Sweden. They all have a physician as a medical director. Sixty percent of ambulances are based at hospitals and the other 40% are co-ordinated with and based at fire brigade stations.

The ambulance organisations differ somewhat, but the typical system has an ambulance crew of two, each with 20 weeks training, including the use of semiautomatic defibrillators but not the administration of drugs. Approximately 90% of Swedish ambulances are equipped with defibrillators, the majority of which are semiautomatic.

In an increasing number of ambulance systems there are 1–2 members of the crew with more advanced training, resulting in a capacity for advanced cardiac life support intervention. Some ambulances have a registered nurse as a constant or intermittent member of the crew and a few ambulance systems have a crew with full paramedic training.

Thus, in some ambulance systems, the only treatment for cardiac arrest victims is CPR and defibrillation, while in others a full ACLS protocol can be applied including early intubation and drug treatment.

2.1.4. Study design

For each case of out of hospital cardiac arrest the ambulance crew filled in a form with demographic information and standardised description of the resuscitation procedure including times of interventions such as CPR, defibrillation, intubation, drug treatment, and status at first contact.

In ambulances with manual defibrillators, the initial rhythm was defined as ventricular fibrillation (VF), pulseless electrical activity (PEA) or asystole. For semiautomatic defibrillators the rhythm was defined as shockable rhythm (VT/VF) or another rhythm.

The time of arrest was estimated in witnessed cases by interviewing a bystander. Thereafter, the ambulance crew recorded the time of receipt of call, the time of arrival at the patients side, the time of start of CPR, the time of first defibrillation, the time of spontaneous palpable pulsations, the time of start of transport to hospital and arrival at hospital.

Immediate outcome was reported by the ambulance crew as dead on arrival, dead in the emergency department or admitted alive to hospital.

The form was filled in during and immediately after the acute event. Each form was reviewed by the medical director and a copy was sent to the central registry. Subsequently another copy was sent with the additional information of whether the patient was dead or alive after 1 month.

2.1.5. Statistical methods

In the evaluation of proportions, Fisher's exact test, which is a special form of Pilman's non-parametric test, was used. A p value less than 0.05 was regarded as significant.

2.2. Patients

2.2.1. Inclusion criteria

All patients with cardiac arrest to which the ambulance responded were included in the registry, with one exception. Patients, who obviously had been dead for a long time and where the bodies were not brought to hospital by the ambulance, were excluded. For all others the standardised form was completed by the ambulance crew.

2.2.2. Probable cause of cardiac arrest

In the form, the crew recorded the probable cause of cardiac arrest choosing from nine alternatives (cardiac

disease, lung disease, accident, sudden infant death syndrome, suicide, intoxication, suffocation, drowning and other).

It should be emphasised that these diagnoses were not re-evaluated by the medical director.

3. Results

3.1. Demographics

The distance for the ambulances to travel from ambulance station to the collapsed patient is shown in Fig. 1. The median driving distance was 4.9 km and 28% of the ambulances had more than 10 km to the place of arrest. The distance from the patient to the nearest hospital was often longer as there are more ambulance stations than there are hospitals. This is also illustrated in Fig. 1.

3.2. Patients

From January 1990 to May 1995, 14 065 forms were received. As the number of ambulance systems included in the register have increased over time, there was an increasing number of forms per time unit. This successive recruitment of ambulance districts made it impossible to use our information to estimate the incidence of cardiac arrest in Sweden or even in single ambulance districts.

Resuscitation was attempted in 10 966 cases. In the remaining 3099 cases, no resuscitation was attempted and the patient was only transported to the hospital to be pronounced dead.

All figures presented in the article are based on the 10 966 patients where resuscitation was attempted.

The age and sex distribution of the patients is given in Fig. 2. The median age was 70 years and the age range was 2–101 years. In all, 28% of the victims were females. As expected, the proportion of females in-
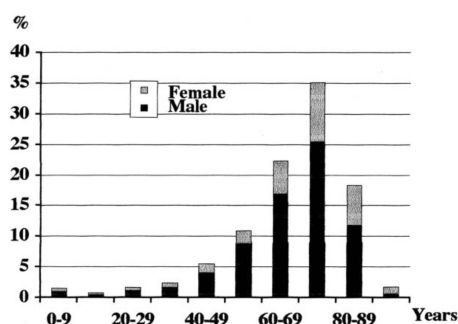

Fig. 2. Age and sex distribution.

creased with age. One-hundred and forty patients were children under 10 years of age.

In 70.0% of cases the arrests were witnessed; in 60.2% by bystanders and in 9.9% by the ambulance crew. In 43.3%, the first recorded rhythm was VT/VF. Bystander CPR was initiated in 32.3%.

In Fig. 3, the patient material is presented according to the Utstein model.

3.3. Time intervals for witnessed cardiac arrests

3.3.1. Time from collapse to call for EMS (n = 4560)

The estimated time from collapse to call for EMS is given in a cumulative curve in Fig. 4. The median delay time was 4 min. In 15.5%, the interval was less ≤ 1 min, and in 30.2% it was ≤ 2 min.

3.3.2. Time from collapse to first defibrillation (n = 2809)

The estimated time from collapse to first defibrillation is given in a cumulative curve in Fig. 4. The median delay time was 13 min.
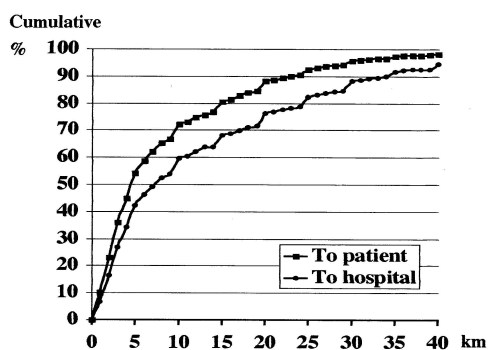
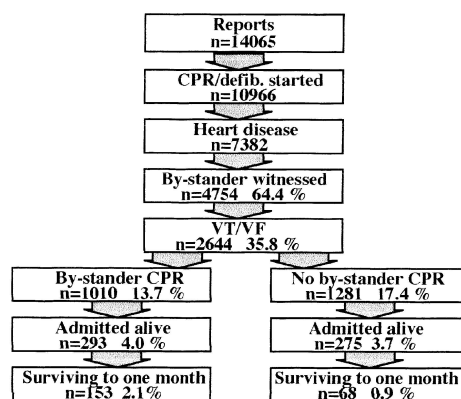

Fig. 1. Driving distances for ambulances.
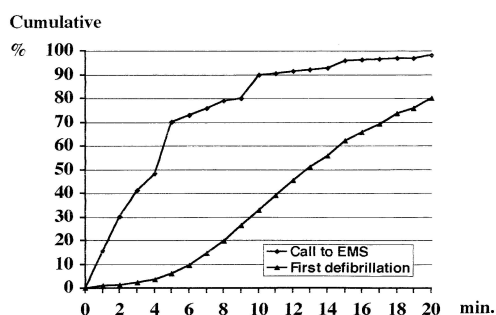

Fig. 3. Utstein presentation.

Cumulative

Fig. 4. Time between cardiac arrest and call to dispatch centre and time to first defibrillation.

3.4. Place of cardiac arrest

As shown in Table 1, the majority of cardiac arrests took place at home. Remarkably few occurred at work, which probably is related to the high median age of the population studied with the majority retired from work. Only 4.2% took place in an ambulance.

3.5. Probable cause of cardiac arrest

The majority of deaths (67.1%) were judged as being of cardiac origin, as illustrated in Table 2. In 22.9% of the victims, the cause of arrest was judged as 'other' or 'unknown'. All other specified causes of death together amounted to 8.9%. It is possible that most of 'other' and 'unknown' were of cardiac origin.

3.6. Survival

The overall survival, defined as admitted to hospital alive, was 15.4% ($n = 1692$). Five percent ($n = 544$) were alive 1 month after discharge from hospital. In the group with witnessed cardiac arrest with VT/VF as first rhythm, survival to 1 month was 9.5%. In the group with crew-witnessed cardiac arrests with VT/VF, the 1 month survival was 12.7%.

3.6.1. Survival in relation to the Utstein model

When survival is analysed it should be emphasised that in our series the patients who represented the final selection in the Utstein model (Fig. 3), i.e. those who had

Table 1
Place of cardiac arrest

Place	n	%
At work	244	1.8
In a nursing home	514	3.7
In an ambulance	578	4.2
In a public place	1532	11.0
At home	9139	65.8
Other places	1886	13.6

Table 2
Probable cause of cardiac arrest

Cause	n	%
Suffocation	108	1.0
SIDS	89	0.8
Drowning	109	1.0
Suicide	120	1.1
Lung disease	325	2.9
Trauma	190	1.7
Drug overdose	169	1.5
Heart disease	7382	67.1
Other/unknown	2515	22.9

cardiac disease, with a witnessed arrest and were still in VT/VF represented only 24% of our cases. Fifty-nine percent of the survivors came from this group.

3.6.2. Survival in relation to initial arrhythmia, aetiology and witnessed arrest

In Table 3, the cases were divided into witnessed/non witnessed, cardiac disease/no cardiac disease and initial rhythm VT/VF or not. Survival to 1 month was calculated for each subgroup. A substantial number (123 of 544) of survivors were found among arrest victims who did not have VT/VF or with an unwitnessed arrest. In the group with non-witnessed cardiac arrests, 51 survived and of those 37 still were in VT/VF when the ambulance crew arrived. Among those with non-VT/VF 86 (0.9%) survived.

3.6.3. Survival in relation to interval between collapse and first defibrillation

Those with witnessed cardiac arrest obviously have better chances of survival and have been separately analysed. Of the 7689 that were witnessed, 4747 were in VT/VF at first ECG recording. In 2467 cases, both the time of cardiac arrest and the time of first defibrillation was known.

The relationship between survival and the interval between collapse and first defibrillation is shown in Fig. 5. Survival for each 2-min interval was calculated, both for the group of patients admitted to hospital alive and the patients who were alive 1 month after the arrest.

The median interval was 13 min.

The chances of survival decrease rapidly with increasing interval between collapse and first defibrillation.

The proportion of patients surviving to 1 month among those initially hospitalised fell from $\approx 60\%$ in the 0–2-min interval to 30% in the 11–12-min interval.

3.6.4. Survival in small and middle sized communities versus large cities

Survival rates were compared between those living in large cities, i.e. Stockholm, Gothenburg, Malmoe ($n = 124$) and those living in smaller communities ($n = 420$). Survival to 1 month in the two groups, respectively, was 5.5 and 4.8% (NS).

Table 3
Survival to 1 month in relation to initial arrhythmia, probable ethiology, and if witnessed

Witnessed	Probable heart disease				Total	
	Yes		No			
Yes	VF	$n = 2601$	VF	$n = 411$	$n = 3012$	
		Survivors = 322		Survivors = 32	Survivors = 354	
	Non-VF	$n = 2058$	Non-VF	$n = 889$	$n = 2947$	
		Survivors = 49		Survivors = 23	Survivors = 72	
No	VF	$n = 714$	VF	$n = 186$	$n = 900$	
		Survivors = 29		Survivors = 8	Survivors = 37	
	Non-VF	$n = 1225$	Non-VF	$n = 781$	$n = 2006$	
		Survivors = 2		Survivors = 12	Survivors = 14	
Total		$n = 6598$		$n = 2267$		
		Survivors = 402		Survivors = 75		

4. Discussion

4.1. Representation and validity

This study is based on a voluntary registry from 57 out of approximately 100 ambulance organisations in Sweden. It can only be speculated as to whether the data from these organisations are representative for all of Sweden. One might expect that the organisations which choose to participate were especially active and interested. Furthermore, the areas of Sweden which were not included, have to a large extent a sparse population and long driving distances for ambulances and hence lower survival rates. For these reasons survival rates might be expected to be lower in non-participating areas.

The ambulance districts also included mainly middle sized and smaller communities. Only 23% of the patients came from the three largest cities, Stockholm, Gothenburg, Malmoe with a population ranging between 1 500 000–250 000 inhabitants.
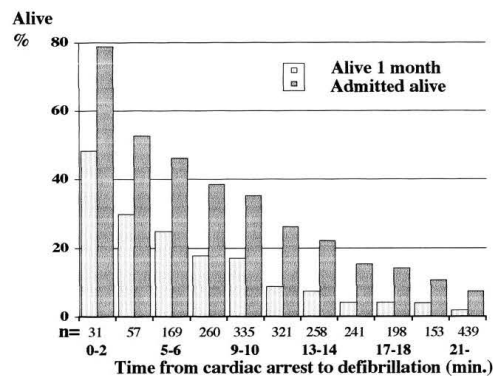

Fig. 5. Proportion of patients with witnessed cardiac arrest and VT/VF ($n = 2462$) admitted alive and surviving to 1 month in relation to delay time to defibrillation.

In this study, all patients, where resuscitation was started, should have been included plus all patients who were not resuscitated but were transported to hospital for final confirmation of death. The fact that 22% ($n = 3099$) of all documented patients belonged to the latter category strongly suggests that no patients where resuscitation attempts were started were excluded.

No absolute validation of adherence to the protocol has been performed as it would have been extremely complicated and expensive to do this in 57 different ambulance districts. Instead, a questionnaire has been sent to all medical directors of the ambulance organisations participating in the registry. They were asked to estimate the accuracy of the representation of the study population. This was expressed as the percentage of the study population that they estimated were wrongly omitted from the study in their own district. Percentage values from this survey varied from 0% to 30% (mean 5%).

4.2. Survival rates

The survival rates for all patients in cardiac arrest in this study was 5.0%. This is low when compared to reports from more effective areas. Seattle and King County, Washington have demonstrated, over the past decade, that survival rates of 14–18% can be achieved [8,9].

Recently, good results have also been reported from the Scandinavian metropolitan areas with 13% survival in Gothenburg and 17% in Helsinki [10,11]. Most reports of high survival rates come, however, from a few metropolitan areas with long experience and mature organisations with enthusiastic leaders. It may be assumed that the results published from these areas demonstrate better than average results. However, two recently published reports from Chicago and New York demonstrate very low survival rates in spite of well developed and costly emergency medical systems [3,4].

This shows that, even within metropolitan areas, the survival rates may vary widely.

Our results reflect 'national' survival rates. It could be expected that in our study, mainly from middle sized or smaller communities with long driving distances for ambulances and sometimes suboptimal organisations, the survival rates should be lower than in the best organised area.

Part of the difference in survival rates could also be explained by different patient selection in different studies, e.g. the proportion of patients in asystole included in the study. Inclusion of all patients will give lower overall survival rates as survival for patients in asystole is very low.

4.3. Survival of patient subgroups

4.3.1. Patients with VT/VF

In most reports, survival rates for patients still in VF when the ambulance arrives is separately documented. In our study, the survival rate for this group of patients is 9.5%, also low compared to what is reported from the best centres, Seattle, King County, Washington 30–31% [8,9], Helsinki 33% [11], Gothenburg 30% [10], but still better than Chicago and New York with 4–5% survival.

There are remarkably few reports on survival rates from larger regions or nations to compare with. From four rural areas in the US, survival rate for 566 patients in VF has been reported to be 9%. Approximately half of the patients came from smaller communities of 'less than 15 000 inhabitants' with 6% survival rates and the other half from larger communities with 15% survival [5]. Scotland with approximately 5 million inhabitants has reported a 9% survival rate for 912 patients in VF [7] and recently the UK National Health Service reported survival rates of 2–7% in regions of England [12].

4.3.2. Patients with 'non VT/VF'

Patients in a 'non shockable rhythm' have a very low overall survival rate, 0.9% ($n = 86$). However, as these patients constitute the majority, they still contribute significantly to the total number of survivors, and amounted in our study to 18% of all patients who survived to 1 month. In other studies, they also represent 10–20% of all survivors [13].

4.4. Why is the survival rate so low?

The majority of survivors come from the subgroup still in VF when the ambulance arrives. Many studies have demonstrated that the chances of survival for this subgroup decreases with increasing time interval between cardiac arrest and first defibrillation [7,14,15]. Our analysis of 2-min intervals confirms the high sur-

vival rates for patients with a short interval between arrest and first defibrillation and the dramatic reduction in survival rate with an increasing interval up to 20 min.

In our study, the median interval from cardiac arrest to first defibrillation was 13 min. This alone, is an explanation of the low survival rates. In studies from metropolitan areas with high survival rates, the corresponding interval has been short—6 min in Gothenburg and 3–4 min in Seattle.

The long intervals in our study may be divided in two different components. Firstly, delay from collapse to call for help is much too long with a median value of 4 min. Secondly the ambulances have long driving distances to the patient with a median value of 5 km. These are probably the most important factors relating to the lower survival rate in this study, compared with studies from the best metropolitan areas.

Another factor with a proven effect on survival is bystander CPR [2]. The proportion of patients given bystander CPR in our study, 32%, is as high as that reported in most other studies. Lack of bystander CPR, therefore, does not seem to explain the lower survival rate.

Early advanced cardiac life support, including early intubation and early drug administration, have been claimed to increase survival rates [16]. In this study, only a minority of patients have been given drugs or intubated in the field and this could possibly partly explain our low survival rates.

One more factor may be of importance for survival. Of all patients admitted alive into hospital a significant proportion die later. The majority die within the first days and the cause of death is often severe brain damage. In our study, only 32% of those admitted alive survived to 1 month, while in some other studies 40–60% are discharged alive [7,17,18]. This suggests that a contributing factor to the low survival rate in our study could be suboptimal hospital care, possibly due to a lack of standardised treatment schemes in some hospitals. The importance of this factor can, however, only be speculated upon at present.

4.5. How can survival rates be increased?

Improvements can be considered for each link in the chain of survival.

4.5.1. Early access

The chance of survival for patients potentially would increase considerably if pre-arrest symptoms were taken seriously and an ambulance called before the collapse. However, it has been demonstrated that 50% of patients have no pre-arrest symptoms [1]. Even for the remaining 50% with symptoms of acute ischemic heart disease, there is a typical delay time of 2–3 h before the

EMS system is alerted. Intensive campaigns to overcome this hesitation to call for an ambulance have had a limited effect offering little hope for a significant increase in the number of patients who are under medical supervision when the collapse occurs.

However, it seems quite possible that the delay time in calling for help after a cardiac arrest could be reduced by public campaigns to 'phone first' [19], and by large scale public CPR training, where early access is an important part of the message [20].

4.5.2. Early CPR

Previous studies have shown that bystander CPR increases survival rates 2–3-fold [1,21,22]. Although the rate of bystander CPR in this study is already fairly high, a further increase would enhance survival rates. One important way to increase the proportion of bystander CPR in the future is by telephone instructed CPR. This helps both bystanders with no previous CPR training and those who have some knowledge of CPR but need support through telephone instructions [23].

4.5.3. Early defibrillation

It seems obvious that a shortened time to defibrillation is by far the most important improvement to increase survival rates. It may be calculated from our data that shortened interval of 6–8 min would approximately double survival rates.

It seems possible to shorten delay times somewhat by scrutinising all routines and streamlining the ambulance organisation. The most important change, however, must be to decentralise defibrillators and place defibrillators closer to the patients especially in smaller communities. With effective ambulance dispatch centres, which can identify cardiac arrest victims with a few questions, with modern communication techniques that allows dispatchers to contact first responders quickly, with new groups of first responders placed in every small community, the time to defibrillation could be shorter. The first responders could be fire brigade personnel, police, district nurses or any other group of persons, who are willing to co-operate and can be contacted by modern communications systems.

4.5.4. Early ACLS

Little is known about the effect of early intubation and early drug administration, but it seems likely that further training of ambulance crews in ACLS procedures also would further increase survival [16].

4.6. Value of a 'national' cardiac arrest registry

A national cardiac arrest registry helps to introduce standardised methods of data collection in out-of-hospital cardiac arrest and makes it possible to compare the effectiveness of different ambulance systems.

A long-term registry makes it possible to follow changes in methods of treatment and the ensuing results, hopefully resulting in increased survival.

It should be an important stimulus for the individual ambulance services to study reports and compare national figures with their own local results and initiatives.

5. Conclusion

The data presented are retrieved from an ongoing national registry for out-of-hospital cardiac arrest, where the basic concept is that data should be reported back to the individual ambulance districts, both national data and data specific for that ambulance district. This feed-back process is considered to be a very powerful mechanism for quality assurance and quality improvement. Through the feed-back of information, each ambulance district can discover their own weak points and try to eliminate them.

The ambulance registry will continue to collect data and over time it will be possible to monitor effects of the improvements in the system.

It seems clear that delays could be reduced, both the time to call the EMS system and the interval to ambulance dispatch and transport time.

The results demonstrates that out-of-hospital cardiac arrest victims can survive even in middle-sized and smaller communities. A cardiac arrest registry can be used as an instrument for quality control and quality improvement.

Appendix A. Participating ambulance district physicians

Å Andren-Sandberg MD, L-Å Augustsson MD, S Berlind MD, J Bennis MD, U Björnstig MD, K Brunnhage MD, J Castenhag MD, B Eriksson MD, A Elvin MD, B Engerström MD, L Engerström MD, M Erlandsson MD, L Fernandez MD, J Fischer MD, B Gustavsson MD, S Hagman MD, M Helfner MD, H Huldt MD, M Johansson MD, R Johansson MD, M Kjeldgaard MD, M Larsson MD, O Lennander MD, S Leward MD, T Lindgren MD, T Lorentz MD, G Morin MD, J Olsson MD, PO Persson MD, T Samuelsson MD, M Schwartz MD, B Sjölund MD, A Skjöldebrand MD, E Skole MD, G Skoog MD.

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