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Out-of-hospital cardiac arrest-the relevance of heart failure. The Maastricht Circulatory Arrest Registry

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Aims To describe the incidence and aetiology of heart failure in out-of-hospital sudden circulatory arrest (SCA) in the Maastricht area of the Netherlands.
Methods All cases of SCA were studied in the age group 20 to 75 years between 1 January 1997 and 31 December 2000. Demographic characteristics, aetiology and clinical features, related to heart failure were studied.
Results Four hundred and ninety-two patients were included (72% men), mean age of 62±10. The yearly incidence of SCA was 9.2/10 000 inhabitants. Sudden death represented 19% of all deaths, occurring in the same time period. In 52% of the men and 59% of women, SCA was the first manifestation of heart disease. In the SCA group with a cardiac history overt heart failure was present in 26% of the cases, the time interval between the first heart failure episode and SCA being 4.3±6.3 year. In the heart failure group the majority had previously been in a poor functional class and LVEF. Concerning aetiology, of the SCA group, 77% were known with CAD and 72% with an old MI. Also in the group with a LVEF >50% CAD was the most frequent cause.
Conclusions There is an increased risk of SCA at poorer pump function and most SCA victims with previous heart failure are in a poor functional class SCA. However heart failure is seen in only a minority of the SCA population. CAD is by far the most common cause of SCA.

Introduction

In industrialized countries many people die from sudden circulatory arrest (SCA) with coronary heart disease as the most common cause. It accounts for an estimated number of 300 000 deaths annually in the USA and about 16 000 in the Netherlands.[1,2] The most frequent terminal events are ischaemia induced VF or secondary VF.[3] On the other hand the incidence of heart failure is progressively increasing. This is likely due to factors such as the improved survival of patients admitted to the hospital with acute coronary syndromes and the increasing age of the population. Extensive evidence exists that also in heart failure patients SCA is a frequent mode of death. Therefore heart failure is considered a major risk factor for sudden cardiac arrest.[4] The risk of sudden cardiac arrest increases with the severity of heart failure. To prevent sudden death, clinicians try to identify high risk group patients such as individuals with a large myocardial in-

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farction, survivors of circulatory arrest and heart failure patients.[4–10]

It is important to know which part of the SCA population comes from these high risk patients. A major problem in answering this question is the lack of complete and population based data on the incidence of SCA and the underlying aetiology.

To obtain more insight into SCA as a population problem a registry of all SCA victims was started in 1991 (Maastricht Sudden Circulatory Arrest Registry).[11]

In this article we describe the incidence of heart failure in this population and the underlying pathology leading to SCA. For this purpose all SCA victims during the period 1997–2000 in the Maastricht area were studied.

Methods

Study population

Studied were all cases, registered during a four year period (1 January 1997–31 December 2000) of unexpected out-of-hospital SCA between the age of 20 and 75 years and living in the region of Maastricht in the Netherlands. The area encloses 203 km^2 and had a mean of 184 839 inhabitants during this period of whom a mean of 133 809 (72%) were between the ages of 20 and 75 years.[12]

This area is supplied by only one hospital (University Hospital Maastricht), one ambulance service and one office of records what makes this region very suitable for population based studies.

Inclusion and exclusion criteria

Included in this study are all witnessed and unwitnessed victims of out-of-hospital SCA living in the study region. SCA was defined as unexpected, instantaneous loss of vital signs, such as consciousness, arterial pulse, blood pressure and respiration without preceding complaints or within 24 h of the onset of complaints.[11] This definition allows the inclusion of unwitnessed cases who are found dead under circumstances pointing to an unexpected SCA (for example those who died unexpectedly during sleep). Excluded were patients with a circulatory arrest following a traumatic event or intoxication or SCA occurring in the terminal phase of a chronic non-cardiac disease.

Data collection

All victims who were found dead and/or in whom no ambulance was called were reported by the general practitioners in the region. All victims in whom an ambulance was involved were reported by the ambulance personnel. Information about the medical history of victims was gathered by collecting information from the GPs and by examining the medical hospital records. Most data were retrieved from electronic data bases such as the hospital information system (ZIS) and the cardiology information system (CIS). The latter contains reports from echocardiography studies, exercise tests, heart catheterizations, admissions notes and discharge letters.

Victims, known with previous heart disease, were studied in relation to the presence of heart failure. Heart failure is defined as a clinical diagnosis of impaired exercise tolerance and/or signs of congestion due to a cardiac disorder.

Variables were collected regarding demographic characteristics, aetiology, and clinical features, specifically related to heart failure.

Statistical methods

All data were entered into the SPSS-pc statistical program. The data were analysed by using chi-square for groups with discrete variables. Continuous data are presented as mean±standard deviation.

Table 1 Study group

No SCA victims	492		
Age	62±10		
Men	357 (73%)		
Cardiac history	224 (46%)		
Heart failure	59 (12%)		
Cardiac history	Yes	No	*p*
No SCA victims	224	268	
Age	64±8	60±11	0.000
Men	169	188	ns
Heart failure	Yes	No	*p*
No patients	59	165	
Age	67±6	64±9	0.035
Men	46	123	ns

Results

From 1 January 1997 until 31 December 2000, a total of 492 SCA victims were included (Table 1). Of those, 357 (72%) were men and 137 were women (28%) with a mean age of 6210 years. Information about the victims' medical history was obtained in all cases. A history of cardiac disease was present in 224 (46%) patients. Thus in 59% of the women and in 52% of the men SCA was the first manifestation of

heart disease. A history of heart failure was present in only a minority of cases, 59 (12%).

The known cardiac group was older than the unknown group. This was also the case for the SCA group with previous heart failure compared to no heart failure SCA victims.

Yearly incidence of SCA

The mean yearly incidence of SCA in the age group 20–75 year was 123.5/133 808.75 mean population of the Maastricht region or 9.2/10 000 inhabitants. The yearly incidence of SCA was 8.9/10 000 in 1997, 9.7/10 000 in 1998 in 1998, 9.7/10 000 in 1999 and 8.6/10 000 in 2000.

Contribution of sudden death to total mortality

Data on total mortality was available for the 3-year period 1 January 1997 until 31 December 1999. A total of 2019 inhabitants between 20–75 years of age died.[6] In 379 inhabitants (19%) the mode of death was sudden.

SCA victims without a cardiac history

In 268/492 (54%) cases no cardiac history was present. It is likely that in this category no heart failure and no major increase in functional class or worse LVEF was present.

Heart failure characteristics in the known cardiac SCA population (Table 2)

We studied how many victims reportedly had suffered an episode of overt heart failure. In the 224 cases with a cardiac history we studied the number of patients with a previous episode of heart failure consisting of fluid retention and congestion, their worst functional class and LVEF. It was found that only 59 (26%) cases had suffered clinical heart failure. The mean time interval between the first heart failure episode and SCA was 4.3±6.3 year with a median of 3 years. The mean time interval between the last echocardiogram and SCA was 2.3±2.6 year, median 1.5 year.

In 54 cases information about NYHA functional class was available. As shown in Table 2 in this heart failure group the majority of the SCA victims (59%) had been in a poor functional class (4). In this group data on LVEF were available in 52 cases: poor LVEF (0–30%) had been present in almost half of the victims (48%). Functional classification, (although not strictly applicable to a no heart failure population) and LVEF was available in 164/165 and 148/164 victims with no previous heart failure respectively. In contrast to the findings in the heart failure group the majority showed to have been in a good functional class (66%) and a high LVEF (>50%) (61%).

Table 2 Heart failure variables in the SCA group with a previous cardiac history

	Heart failure			No heart failure		
	n	%	*P*-value	*n*	%	*P*-value
Function class						
1	7	13	0.00	108	66	0.00
2	7	13		42	26	
3	8	15		13	8	
4	32	59		0	0	
LVEF						
0–30%	25	48	0.00	13	9	0.00
31–40%	10	19		22	15	
41–50%	7	13		22	15	
>50	10	19		91	61	

Table 3 SCA rate related to LVEF

	n=9258	*n*=200[a]	%*	*p*	*n*=81[b]	%*	*p*
LVEF							
0–30	508	38	7.5	.000	26	5.1	.000
31–40	628	32	5.1		14	2.2	
41–50	1050	29	2.8		12	1.2	
>50	7072	101	1.4		29	0.41	

*% of SCA cases per LVEF class is presented.
[a]*n*=200 all SCA cases with echo data on LVEF.
[b]*n*=81 SCA cases, with echo taken between 1997–2000.

Risk of SCA related to EF

To study the risk of SCA in relation to ejection fraction we assessed its frequency in the echocardiography data base in the respective LVEF subgroups between 20 and 75 and originating from the Maastricht area, irrespective of the aetiology. During the study period echocardiography was done in 9258 patients from the Maastricht area and between 20–75 years of age. Of the 200 SCA victims with echo data, 81 had echocardiography done during the 4 years of the study period. The results of the latter and of the entire SCA group are presented in Table 3: In both SCA group a percentual increase in SCA victims was noticed at lower LVEF, indicating a higher risk with poorer pump function. However, because of the larger population with higher LVEF, the absolute number of SCA victims was highest in the normal LVEF category.

Table 4 Aetiology in known CAD victims

Nr cases	224	
CAD	171/224	77%
New MI	10/171	6%
Previous MI	113/171	66%
Time first MI-SCA	9.7±7.5	Years
Anterior MI	42/113	37%
Inferior MI	60/13	53%
Previous PTCA	40/171	18%
Previous CABG	50/171	20%

Table 5 Aetiology in no CAD group

Aetiology	*n*=53	%
Idiopathic dilated cardiomyopathy	14	26
Hypertensive heart disease	12	23
Valvular heart disease	10	19
Other cardiac causes	3	6
No cardiac abnormalities	2	4
Heart failure cause unknown	4	8
Unknown	8	15

Aetiology

In 224 SCA victims with a previous cardiac history it was found that 171 (77%) were known with CAD (Table 4). In 10 cases a new infarction was the immediate cause for SCA. One or more previous MI were present in 113 (66%). Data on the time interval between the first MI and SCA was available in 92 cases: 9.7±7.5 years (median 9.0, range 0–29). Site of the MI was reported in 104 cases: 42 (37%) anterior, 60 (53%) inferior, 11 (10%) unknown. LVEF during admission was assessed in 41/115 cases: 44±13 (median 44, range 20–60).

In 40 (23%) patients a PTCA and in 50 (29%) patients a CABG had been done. In the no CAD group (Table 5) dilated cardiomyopathy, hypertensive and valvular heart disease are most frequently represented.

We also looked specifically into the subgroup of 101 SCA cases with high LVEF (>50%): CAD again was found to be the most important culprit (71%) (Table 6). This is followed by valvular disease and hypertensive heart disease accounting for respectively 10% and 8%. Within the SCA group with an ejection fraction >50% overt heart failure episodes had only occurred in 9 out of 101 cases. These cases were seen both in the CAD group and in patients suffering from valvular heart disease.

Table 6 Aetiology EF >50% SCA group

Aetiology	*n*=101	HF (9)
CAD	72	4
Infarction	39	3
Valvular heart disease	10	4
Hypertensive heart disease	8	1
Heart failure cause unknown	2	2
Dilated cardiomyopathy	3	2
Other cardiac causes	2	0
No cardiac abnormalities	2	0
Unknown	6	0

Discussion

This population based study shows that SCA is still a major health care problem, being the mode of death in almost 20% of the total mortality in the age group between 20 and 75. It also confirms that CAD, especially previous MI is the most frequent underlying cause. This is in agreement with previous studies from our group[13] and other investigators, who have shown that up to 80% of all individuals who suffer SCA have a cardiovascular cause[2,14] and that up to 70% of all acute myocardial infarction deaths occur out of hospital.[15]

In this article several results are considered to be of importance for developing insight into the SCA problem.

Firstly, heart failure is known to be a major risk factor both for non-sudden and for sudden death. The latter was confirmed in our study, showing that the majority of SCA victims with a previous episode of heart failure had a poor functional class and LVEF (Table 2). We also observed an increased frequency of sudden death at lower LVEF (Table 3) in our echo/Doppler population. Although this population is not fully representative for the general population, we consider the results qualitatively valid: The relatively healthy population (LVEF >50%) will have less echocardiograms, but the sicker population (with lower LVEF) will likely be more completely represented. The under-representation in the better subgroups will therefore in reality lead to an actual lower risk for SCA, as found in our study, which makes the higher risk at lower LVEF even more significant.

Secondly, studying sudden death as a population wide problem, it was found that the majority of sudden death victims either are not known as having heart disease or do not show any of the variables consistent with poor left ventricular function.

This finding may in part be related to the age limit of 75 which was chosen in our study. The

occurrence of heart failure increases with age and above 80 prevalences up to 15% and incidences up to 25% in general populations have been reported.[16]

Thirdly, it was found that CAD, more specifically previous MI, is frequently associated with SCA. Interestingly, the median time interval between previous MI and SCA was many years (9.0) with a very wide variation. Also the LV ejection fraction showed a relatively high median value (44%), also with a marked variation.

We consider our findings of importance for several reasons. They show that the sudden death problem regards mostly victims in an apparently good condition, a population which has been characterized as having hearts 'being too good to die'.[17]

Moreover, about half of the victims is not known with any cardiac problem, thus SCA was the first manifestation of CAD. This finding clearly underscores how difficult it is to identify individuals at risk, in spite of the many tests being developed for his purpose. Different reasons may explain this paradox: (1) SCA may indeed be the first coronary event in a number of cases, i.e. acute ischaemia leading to primary ventricular fibrillation. (2) Victims may have experienced chest pain, but may have denied symptoms. (3) Silent ischaemia may have been present, leading to scar formation and recurrent ischaemia as a substrate and trigger for lethal arrhythmias. The latter possibility is supported by a previous autopsy study from our group[13] and other investigators,[18] showing that many SCA victims have a healed myocardial infarction, multivessel disease and recent ischaemia as a terminal event.

As pointed out above in SCA victims with previous heart failure, most cases were found to have poor functional class and LVEF. Also with worse LVEF the risk of SCA increases. Therefore the logical clinical approach to prevent sudden death is to focus on the population with large infarctions, low ejection fractions and overt heart failure, the risk being highest in the first 2 years following acute MI. However it has also to be realised that most of the SCA victims with a previous MI have a long interval till the SCA event and frequently have an adequate LVEF. In agreement with previous findings from our group,[19] these data show that with the present risk assessment only a minority of SCA candidates will be identified.

Future studies

Apart from the risk assessment in high risk groups, studies have to be done to identify people at risk in the general population, focussing on classical and new risk factors for CAD, environmental influences such as socioeconomical class and education,[20] the presence of an old myocardial infarction and possibly genetic factors such as familial predisposition,[21,22] and related gene polymorphisms[23] and channel mutations. The frequent finding of a silent old myocardial infarction in SCA victims may suggest that screening of the general or a high risk population by means of electrocardiogram could be useful. We have also recently observed other risk markers in pre-existing ECG's of SCA victims compared to control CAD patients,[24] such as negative T waves,[25] ventricular premature beats, atrial fibrillation and left atrial and ventricular hypertrophy. These findings have to be evaluated prospectively to assess their predictive value.

Limitations

Our study area is relatively small and comprises an accordingly small population. Still we consider the results representative because the population and disease characteristics of the Maastricht region are similar to the Dutch population in general. Moreover the restricted size of the area allowed accurate assessment of incidence and underlying pathology of the study group.

We only studied the age group between 20 and 75. Therefore we have no information on the SCA problem in the older age group and in youngsters. We decided to do so, because SCA in the latter group is rare and reflects quite a different aetiology. In the older age group SCA frequently has less emotional and economical impact, although the vitality of the aged population is steadily increasing.

Conclusions

The so called prevention paradox can clearly be applied to the SCA problem: Within the heart failure population the incidence of sudden death increases with the severity of heart failure, but in the sudden death population most victims are either not known with a cardiac problem or have an appropriate LVEF, functional class and no clinical heart failure symptoms.

Focusing on the heart failure population is needed to identify to patients at risk of SCA in the known cardiac population, but it has to be realised that this will only partially solve the SCA problem.

In the SCA population CAD, especially previous MI is the most common cause of SCA. Further studies have also to be directed to the no heart failure population to identify the individuals at risk.

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