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Incidence of EMS-treated out-of-hospital cardiac arrest in Europe☆

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Abstract

Background: The potential impact of efforts in Europe to improve survival from out-of-hospital cardiac arrest is unclear, in part, because estimates of incidence and survival are uncertain. The aim of the investigation was to determine a representative European incidence and survival from cardiac arrest in all-rhythms and in ventricular fibrillation treated by the emergency medical services (EMS).
Methods and results: We used Medline to identify peer-reviewed articles published between 1 January 1980 and 30 June 2004 that reported a European community's EMS cardiac arrest experience. Inclusion criteria required the study to include at least 25 cases, report of the total number of all-rhythm and/or ventricular fibrillation arrests, and information about population size and study duration. The incidence was computed by dividing the total number of events by the product of the community's population and the study duration.

Reports from 37 communities met the inclusion criteria. A total of 18,105 all-rhythm EMS-treated cardiac arrests occurred during 48 million person-years of observation, resulting in an overall incidence for all-rhythm arrests of 37.72 per 100,000 person-years. Incidence of ventricular fibrillation arrest was 16.84 per 100,000 person-years. Survival was 10.7% for all-rhythm and 21.2% for ventricular fibrillation cardiac arrest. Applying these results to the European population, approximately, 275,000 persons would experience, all-rhythm cardiac arrest treated by the EMS with 29,000 persons surviving to hospital discharge.
Conclusion: The results provide a framework to assess opportunities and limitations of EMS care with regard to the public health burden of cardiac arrest in Europe.

Keywords: Heart arrest; Incidence; Survival; Emergency medical services

1. Introduction

Out-of-hospital sudden cardiac arrest is a leading cause of death in Europe and the United States. To improve outcome from sudden cardiac arrest, measures are needed to strengthen the "chain of survival" that includes quick activation of emergency services, prompt bystander cardiopulmonary resuscitation, early defibrillation, and timely advanced cardiac life support [1]. The public health implications of improvements in the chain of survival depend, in part, on the extent and effectiveness of current emergency medical services (EMS) care for sudden cardiac arrest. In a systematic assessment of communities in the United States, the incidence of EMS-treated sudden cardiac arrest was, approximately, 55 per 100,000 person-years for all-rhythm arrests and 21 per 100,000 person-years for ventricular fibrillation arrests with survival estimates of 8% for all-rhythm arrests and 17% among ventricular fibrillation arrests [2].

No such population-based estimates are available for Europe. Health behaviours and preventative care that influence the risk of sudden cardiac arrest can differ between Europe and the United States [3]. Moreover, cultural differences between the US and Europe may influence community activation and EMS involvement in the chain of survival [4]. Finally, care of the cardiac arrest patient may vary, for exam-

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ple many European EMS-systems are staffed by physicians, while most in the US systems consist of emergency medical technicians and/or paramedics. The aim of this investigation was to determine a representative European incidence and survival of EMS-treated all-rhythm and ventricular fibrillation sudden cardiac arrest.

2. Methods

2.1. Study design and population

The study was a systematic review of peer-reviewed European community reports of EMS-treated sudden cardiac arrest due to heart-disease. The estimates of incidence included only persons where the EMS attempted resuscitation and not those where EMS was summoned but did not initiate resuscitation or those where EMS was not summoned. Inclusion criteria required that the study contain at least 25 cases, report the total number of all-rhythm arrests and/or ventricular fibrillation arrests for the community, provide information about the study duration and the size of the population served by the system. The reports needed to be available in English, as we did not have translation resources to determine if the article met inclusion criteria. Ten communities did not state explicitly an underlying cardiac etiology [5–12]. Preliminary analyses indicated that incidence and survival in these studies was similar to those that stated explicitly a cardiac etiology. These studies were, therefore, included in primary assessment, though sensitivity analyses evaluate results excluding studies that did not state explicitly a cardiac etiology.

We searched PubMed and Embase to identify articles published between 1 January 1980 and 30 June 2004. The search terms were cardiac arrest, heart arrest, pre-hospital, out-of-hospital, survival, and resuscitation. The exact search strategy was (cardiac arrest OR heart arrest) AND ("out-of-hospital" OR pre-hospital OR pre-hospital) AND (surviv* OR resus*). We also searched using the terms (in process[sb] OR publisher[sb]) to find articles that had not yet been indexed. Pertinent references from manuscripts were also reviewed. If more than one study was available for a community's experience, generally we used the most recent.

2.2. Variables

Information was abstracted about the total number of all-rhythm and ventricular fibrillation arrests, the duration of the study, the size of the population, and survival to hospital discharge.

2.3. Statistical analysis

We computed the incidence by dividing the total number of EMS-treated sudden cardiac arrests by the product of the number of years of the study and the community's population and reported as cases per 100,000 per year. For the incidence of ventricular fibrillation, the numerator included only arrests presenting with ventricular fibrillation. Survival rates were reported in percentages. Sensitivity analyses were computed: (1) estimate excluding the 10% of communities with the lowest and highest incidence; (2) estimate excluding the 10% of communities that were potentially the most influential (those with the greatest number of events and person-years); (3) estimate using the number of events and person-years standardized to a single year of the community's experience (i.e. estimates from a community that reported a 10-year experience would be based on a single-year average (events divided by 10 and person-years divided by 10); (4) estimate weighting each community equally (Σ(incidence in each community) divided by the total number of communities); (5) the median; and (6) estimate including only reports that stated an underlying aetiology of heart-disease. The low and high results from the sensitivity analyses were used to construct a range for the incidence and survival estimates.

In addition, we sought to determine if survival was related to incidence to improve the understanding of the factors influencing incidence and survival [13]. The relationship between survival probability and incidence was assessed by modeling the logit of the probability of survival for a particular community (p_i) versus incidence for a particular community (r_i), where the logit(p_i) of survival is expressed as the $\log[p_i/(1-p_i)]$. Thus, we modeled the linear relationship between the logit of survival probability and incidence using the form $\text{logit}(p_i) = \alpha + \beta(r_i)$ [13].

3. Results

A total of 37 communities, described in 32 studies, met inclusion criteria [5–12,14–37]. The communities had a variety of EMS-systems that included single-tier and two-tier systems that were staffed by paramedics, nurses, physicians, or some combination of these. Community populations ranged from 34,500 persons in Bodo, Norway to 2.2 million persons in West Yorkshire, England [5,37].

The incidence and survival of all-rhythm and ventricular fibrillation cardiac arrest for individual communities is shown in Table 1. A total of 18,105 all-rhythm EMS-treated cardiac arrests occurred during 48 million person-years of observation, resulting in an overall incidence for all-rhythm arrests of 37.72 per 100,000 person-years (Table 2). A total of 7758 ventricular fibrillation EMS-treated cardiac arrests occurred during 46 million person-years of observation, resulting in an incidence for ventricular fibrillation arrests of 16.84 per 100,000 person-years (Table 2). When the all-rhythm and ventricular fibrillation incidences are applied to the estimated 2004 European population of 729 million, approximately, 275,000 persons experience all-rhythm cardiac arrest treated by the EMS, and 123,000 persons experience ventricular fibrillation treated by the EMS, annually in Europe [38]. In sensitivity analyses, the incidence of all-rhythm arrest var-

Table 1
Incidence of EMS-treated all-rhythm and ventricular fibrillation cardiac arrest

Community	Population served	Person-years	All-rhythm arrests	All-rhythm incidence	All-rhythm survivors	Survival (%)	VF arrests	VF incidence	VF survivors	Survival (%)
West Yorkshire, UK[a]	2,200,000	5,874,000	1196	20.36	65	5.4	456	7.76	64	14.0
Lombardia region, Italy	2,013,774	503,444	178	35.36	10[b]	5.6	38	7.55	6[b]	15.8
Vienna, Austria[a]	1,508,120	1,508,120	249	16.51	27	10.8	117	7.76	24	20.5
Amsterdam, Netherlands	1,300,000	2,821,000	1046	37.08	134	12.8	631	22.37	–	–
Nottinghamshire, UK	1,000,000	4,000,000	1547	38.68	94	6.1	728	18.20	85	11.7
Friuli Venezia Giulia region, Italy	940,088	940,088	344	36.59	23	6.7	104	11.06	–	–
Leicestershire, UK	900,000	900,000	159	17.67	19	12.0	85	9.44	19	22.4
Nottingham, UK[a]	800,000	936,000	51	5.45	3	5.9	–	–	–	–
Edinburgh, Scotland[a]	750,000	750,000	297	39.60	39	13.1	160	21.33	37	23.1
Norfolk, UK	600,000	600,000	147	24.50	11	7.5	67	11.17	–	–
Rotterdam, Netherlands[a]	598,694	4,190,858	898	21.43	276	30.7	603	14.39	234	38.8
St-Etienne, France	571,191	571,191	113	19.78	8	7.1	45	7.88	8	17.8
Helsinki, Finland	516,000	516,000	255	49.42	50	19.6	126	24.42	41	32.5
Oslo, Norway	500,000	1,000,000	328	32.8	33	10.1	166	16.60	–	–
Copenhagen, Denmark	465,000	1,395,000	703	50.39	82	11.7	414	29.68	74	17.9
Gotheburg, Sweden	462,470	8,749,932	3871	44.24	340	8.8	1545	17.66	–	–
Bochum, Germany	410,000	479,700	197	41.07	–	–	–	–	–	–
South Glamorgan, UK	407,300	1,071,199	712	66.47	45	6.3	264	24.65	43	16.3
Ljublijana, Slovenia	397,306	1,191,918	337	28.27	19	5.6	120	10.07	15	12.5
Katowice, Poland	338,000	338,000	147	43.49	15	10.20	74	21.89	–	–
Heidelberg, Germany	330,000	9,900,000	338	34.14	48	14.2	106	10.71	36	34.0
Stavanger, Norway	273,000	1,092,000	526	48.17	104	19.8	269	24.63	–	–
Three units of Stockholm, Sweden[a]	257,000	257,000	307	119.46	11	3.6	140	54.47	9	6.4
Ostfold, Norway	246,000	738,000	353	47.83	40	11.3	154	20.87	–	–
Bonn, Germany	240,000	960,000	464	48.33	74	16.0	210	21.88	56	26.7
Gent, Belgium[a]	200,000	934,000	367	39.29	31	8.5	126	13.49	26	20.6
Glasgow, Scotland[a]	200,000	200,000	158	79.00	13	8.2	54	27.00	10	18.5
Akershus, Norway	197,250	789,000	241	30.54	30	12.5	140	17.74	–	–
Leiden area, Netherlands	196,193	686,676	309	45.00	42	13.6	200	29.13	40	20.0
Mainz, Germany	180,000	255,600	211	82.55	19	9.0	90	35.21	15	16.7
Piacenza region, Italy[a]	173,114	332,379	354	106.50	22	6.2	67	20.16	22	32.8
Trondheim region, Norway	154,000	770,000	442	57.40	52	11.8	255	33.12	48	18.8
Brugge, Belgium[a]	135,000	675,000	240	35.56	25	10.4	89	13.19	20	22.5
Tartu area, Estonia	100,000	600,000	248	41.33	13	5.2	72	12.00	–	–
Austrian alpine area	88,255	529,530	338	63.83	31	9.17	118	22.28	26	22.0
Stralsund, Germany	75,000	525,000	273	52.00	28	10.3	111	21.14	–	–
Bodo, Northern Norway	34,500	241,500	123	50.93	23	18.7	62	25.67	20	32.3

Incidence is reported per 100,000 person-years. Ventricular fibrillation is abbreviated VF.
[a] Medical cardiac arrests.
[b] Survival at 1 month.

Table 2
Sensitivity analyses of incidence estimates for EMS-treated all-rhythm and ventricular fibrillation arrest

	All-rhythm cardiac arrest			Ventricular fibrillation arrest		
	Events	P-Y	Incidence	Events	P-Y	Incidence
Primary estimate	18,105	47,996,000	37.72	7758	46,059,000	16.84
Model 1	16,712	44,171,000	37.83	6645	36,889,000	18.01
Model 2	12,140	29,181,000	41.60	5154	27,245,000	18.92
Model 3	6758	18,377,000	36.77	2658	17,610,000	15.09
Model 4	–	–	46.17	–	–	18.63
Model 5	–	–	41.20	–	–	20.16
Model 6	13,548	32,159,000	42.13	5929	32,159,000	18.44

P-Y: person-years. Incidence is per 100,000 person-years. Model 1 excludes the 10% of communities with the lowest and highest incidence. Model 2 excludes the 10% of communities that were potentially the most influential (those with the greatest number of events and person-years). Model 3 uses the number of events and person-years standardized to a single year of the community's experience. Model 4 weights each community equally (Σ[incidence in each community] divided by the total number of communities). Model 5 reports the median. Model 6 includes only reports that stated an underlying heart-disease etiology.

Table 3
Sensitivity analyses of survival estimates for EMS-treated all-rhythm and ventricular fibrillation arrest

	All-rhythm cardiac arrest			Ventricular fibrillation arrest		
	Survivors	Events	Survival (%)	Survivors	Events	Survival (%)
Primary estimate	1907	17,761	10.7	989	4668	21.2
Model 1	1418	14,533	9.8	621	3127	19.9
Model 2	1226	11,796	10.4	691	3609	19.1
Model 3	643	6370	10.1	438	1959	22.3
Model 4	–	–	10.7	–	–	21.1
Model 5	–	–	10.3	–	–	20.3
Model 6	1341	13,351	10.0	504	2839	17.8

Model 1 excludes the 10% of communities with the lowest and highest survival. Model 2 excludes the 10% of communities that were potentially the most influential (those with the greatest number of events). Model 3 uses the number of events and survivors standardized to a single year of the community's experience. Model 4 weights each community equally (Σ[survival in each community] divided by the total number of communities). Model 5 reports the median. Model 6 includes only reports that stated an underlying heart-disease etiology.

ied from 36.77 to 46.17 per 100,000 person-years and the incidence of ventricular fibrillation cardiac arrest varied from 15.09 to 20.16 per 100,000 person-years Table 3.

Taken together, survival was 10.7% (1907/17,761) for all-rhythm cardiac arrest and 21.2% (989/4668) for ventricular fibrillation arrest treated by the EMS. Applying these summary incidence and survival estimates to the 2004 European population, approximately, 29,000 persons would be successfully resuscitated from all-rhythm cardiac arrest and, approximately, 26,000 persons from ventricular fibrillation in Europe each year. In sensitivity analyses of all-rhythm cardiac arrest, survival from all-rhythm arrest varied from 9.8% to 10.7% and survival from ventricular fibrillation arrest varied from 17.8% to 22.3%.

In Fig. 1, survival is plotted against incidence for all-rhythm cardiac arrest. The incidence of all-rhythm arrest was not associated with probability of survival [$\text{logit}(p_i) = -0.87 + (-0.009 \times r_i)$ with statistical significance for β term $p = 0.20$)]. In Fig. 2, ventricular fibrillation survival is plotted against incidence for ventricular fibrillation SCA. The incidence of ventricular fibrillation arrest was not associated with probability of survival [$\text{logit}(p_i) = -0.464 - (0.006 \times r_i)$ with statistical significance for β term $p = 0.12$)].

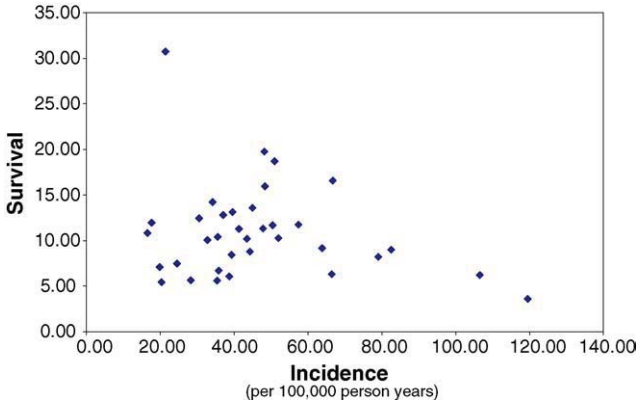

Fig. 1. Survival from all-rhythm arrest according to incidence.

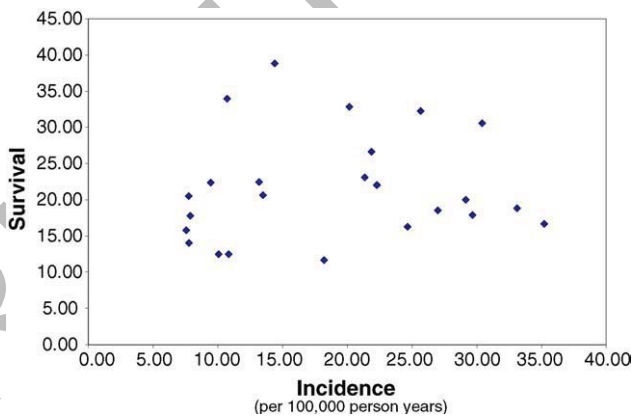

Fig. 2. Survival from ventricular fibrillation arrest according to incidence.

4. Discussion

In this systematic assessment of cardiac arrest treated by the EMS in European communities, the summary incidence estimates were 38 per 100,000 person years for all-rhythm cardiac arrest and 17 per 100,000 person years for ventricular fibrillation cardiac arrest. These estimates would translate to 275,000 all-rhythm and 123,000 ventricular fibrillation cardiac arrests treated by the EMS annually in Europe. Summary estimates of survival were 10.7% for all-rhythm arrests and 21.2% for ventricular fibrillation arrest, which in turn would translate to 29,000 survivors from all-rhythm and 26,000 survivors from ventricular fibrillation arrest each year in Europe.

An accurate population-based estimate of cardiac arrest incidence enables an insight into the potential public health gains of improvements in resuscitation. The incidence across individual communities varied six-fold for all-rhythm cardiac arrest and five-fold for ventricular fibrillation arrest. The variation likely reflects differences in community cardiac arrest risk, EMS activation, and/or EMS threshold to initiate care. Cardiovascular risk can vary considerably depending on the region, for example, the risk of myocardial infarction or coronary disease death ranged, approximately, 10-fold across

countries participating in the MONICA study [39]. Although some of this difference may be due to case ascertainment, a portion is likely to be due to true differences in risk. In addition, cultural differences across communities potentially may influence how and if EMS is activated for cardiac arrest [3]. Finally, EMS may have different practices with regard to initiating resuscitation [13].

As a consequence of these factors, estimating a population-based incidence determined from a single or handful of communities is challenging. In sensitivity analyses, the summary estimates of all-rhythm incidence varied considerably less than the individual community estimates, though the summary all-rhythm estimates still ranged from 36.77 to 46.17 per 100,000 person-years. For ventricular fibrillation, summary incidence estimates ranged from 15.09 to 20.16 per 100,000 person-years. The summary estimates are derived from 19 to 48 million person-years of observation. The population, however, constitutes only about 3% of the total European population. Thus, although the investigation makes a careful effort to estimate incidence, further study involving additional communities with a representative spectrum of risk, culture, and EMS-systems may improve the accuracy of assessment of the public health burden of cardiac arrest in Europe.

Survival also varied considerably across individual communities. As with the incidence, differences in survival may also be due to differences in EMS activation and EMS threshold for care. However, we did not see any relationship between incidence and survival, indirectly suggesting that some of the differences in survival may be due to variation in the links in the chain of survival rather than factors such as EMS threshold for resuscitation. In contrast to individual community survival, the summary estimates of survival for all-rhythm and ventricular fibrillation arrest varied only modestly. When applied to the incidence estimates, the survival estimates enable an assessment of the public health benefit of improving resuscitation. For example, if survival from all-rhythm cardiac arrest could be improved from 10% to 15%, an additional 15,000 persons would survive cardiac arrest. This improvement would require additional efforts and resources, but evidence indicates that this increase in survival could be achieved through the enhanced links of early recognition, early CPR, early defibrillation, and early advanced care [40–43].

The incidence estimates are somewhat lower, while the survival estimates are somewhat greater, compared to a similar systematic study of U.S. communities [2]. These differences may reflect intercontinental disparity such as publication bias or true variation in risk, care, or outcome. Efforts to understand these differences across continents or even communities may provide a better understanding of how to improve care and outcomes. Registries involving multiple communities that use standardized review and data collection provide one approach for consideration.

This study has limitations. Many of the studies were not designed to assess the incidence of EMS-treated cardiac arrest treated by the EMS and thus reports of population size and total number of arrests may not have been a primary focus. Another consideration is that when calculating incidence, the numerator includes primarily adults while the denominator includes the entire population. In addition, although the study includes a heterogeneous set of communities, the communities were not randomly selected. More developed EMS-systems with more resources to publish reports on their experience with cardiac arrest may also have a greater ability to provide better care such that the survival figures may overestimate population-based survival. Finally, the incidence estimates pertain to arrest treated by the EMS and do not include the considerable public health mortality burden of those not receiving EMS treatment [44,45].

The results from this investigation provide a framework to evaluate potential public health benefits of improving outcomes from cardiac arrest. Given the typically low survival from cardiac arrest along with the survival differences across individual communities, such improvements appear feasible.

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