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Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies☆,☆☆

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ABSTRACT

Aim: The aim of this investigation was to estimate and contrast the global incidence and outcome of out-of-hospital cardiac arrest (OHCA) to provide a better understanding of the variability in risk and survival of OHCA.
Methods: We conducted a review of published English-language articles about incidence of OHCA, available through MEDLINE and EmBase. For studies including adult patients and both adult and paediatric patients, we used Utstein data reporting guidelines to calculate, summarize and compare incidences per 100,000 person-years of attended OHCAs, treated OHCAs, treated OHCAs with a cardiac cause, treated OHCA with ventricular fibrillation (VF), and survival-to-hospital discharge rates following OHCA.
Results: Sixty-seven studies from Europe, North America, Asia or Australia met inclusion criteria. The weighted incidence estimate was significantly higher in studies including adults than in those including adults and paediatrics for treated OHCAs (62.3 vs 34.7; $P<0.001$); and for treated OHCAs with a cardiac cause (54.6 vs 40.8; $P=0.004$). Neither survival to discharge rates nor VF survival to discharge rates differed statistically significant among studies. The incidence of treated OHCAs was higher in North America (54.6) than in Europe (35.0), Asia (28.3), and Australia (44.0) ($P<0.001$). In Asia, the percentage of VF and survival to discharge rates were lower (11% and 2%, respectively) than those in Europe (35% and 9%, respectively), North America (28% and 6%, respectively), or Australia (40% and 11%, respectively) ($P<0.001$, $P<0.001$).
Conclusions: OHCA incidence and outcome varies greatly around the globe. A better understanding of the variability is fundamental to improving OHCA prevention and resuscitation.

1. Introduction

Survival rates from out-of-hospital cardiac arrest (OHCA) vary greatly among studies and regions. Interestingly, Becker et al. observed a direct relationship between the incidence of OHCA and survival rates.[1] However, it is also possible that the variability in incidence and survival rates is simply related to differences in definitions of OHCA.

In order for these studies to be comparable, they need to use the same definitions of the numerator (cardiac arrest) and denominator (population at risk during a specific period of time). The definition of incidence is the number of new cases per unit of person-time at risk. However, the definition of an OHCA could be all patients who die outside of a hospital, only patients who die suddenly, only those attended by emergency medical services (EMS) personnel, only those for whom resuscitation efforts were attempted, only those with a presumed cardiac cause (i.e., no evidence of a non-cardiac cause), only those with witnessed arrests, or only those with witnessed ventricular fibrillation (VF). In addition, the denominator may include all people in a region, only adults, or only children. Also,

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☆☆ This review includes information on resuscitation questions developed through the C2010 Consensus on Science and Treatment Recommendations process, managed by the International Liaison Committee on Resuscitation (http://www.americanheart.org/ILCOR). The questions were developed by ILCOR Task Forces, using strict conflict of interest guidelines. In general, each question was assigned to two experts to complete a detailed structured review of the literature, and complete a detailed worksheet. Worksheets are discussed at ILCOR meetings to reach consensus and will be published in 2010 as the Consensus on Science and Treatment Recommendations (CoSTR). The conclusions published in the final CoSTR consensus document may differ from the conclusions of in this review because the CoSTR consensus will reflect input from other worksheet authors and discussants at the conference, and will take into consideration implementation and feasibility issues as well as new relevant research.

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the best approach to estimating incidence depends on the intent of the investigation and certainly could vary depending on whether the focus was epidemiology (risk factors) versus health services (resuscitation).

The goal of this review is to better understand the global and continental burden and variability of OHCA. The investigation provides the underpinnings for understanding the potential for public health benefit with improvements in OHCA prevention and resuscitation.

2. Materials and methods

2.1. Literature search

On 18 December 2009, we (investigators) conducted a MEDLINE and EmBase search for "out-of-hospital," or "pre hospital," and "heart arrest," "cardiopulmonary resuscitation," or "sudden cardiac death," limited to publications in English and in humans (Fig. 1). Additional keywords "vital statistics," "incidence," "epidemiology," or "Utstein" resulted in 1391 articles for review. An additional 185 articles were reviewed from the original 2726, based on the search terms "Middle East," "Asia," "South America," "Africa," or "Australia," to ensure global coverage.

2.2. Selection of articles

We analyzed the abstracts of these 1576 articles. We ultimately included articles for further analysis if they reported consecutive OHCA cases in a circumscribed geographically defined (adult) population of more than 50,000 during a period of at least 6 months. Data collection took place during or after the year 1990. We excluded studies that were paediatric only, subgroup reports and reviews. If multiple articles were found that described the same region, the most recently published paper was included, unless the older article was more complete in reporting incidence data of the Utstein template,[2] or included a larger set of patients. References of selected articles were crosschecked for other relevant studies. Authors were contacted when a publication could not be obtained.

The resultant 130 articles were screened for completeness of data. Articles were excluded from further consideration if no information was provided on the size of the study population or if there were inconsistencies in either the number of OHCA cases or the size of the study population. The data from 67 articles were ultimately included in these analyses; 20 with only adults, 47 with both children and adults.

2.3. Data extraction

From each article, we extracted the size of the population at risk, the study duration and the number of OHCA cases. We specifically focused on four OHCA patient groups: (1) EMS attended OHCAs, (2) OHCA treated by EMS personnel, (3) EMS treated OHCAs of cardiac aetiology, (4) EMS treated OHCAs with VF, as per Utstein guidelines for reporting cardiac arrest and resuscitation data.[2] Cardiac aetiology was based on the operational definition of the particular study.

When available, we report the incidence of OHCA by the census population, the percentage of patients who had VF as initial rhythm, and patients who survived until discharge. Some articles reported on more than one study area.

2.4. Calculation of incidence

Most of the articles did not report their incidence of OHCA, but provided information from which it could be calculated – study population, study duration and OHCA cases. We thereby calculated the incidence per 100,000 person-years. Fig. 2 shows the incidence of OHCA can be calculated at several levels; this example demonstrates that the incidence decreases when descending the Utstein template's patient selection. We calculated the incidence at four levels of the Utstein template: EMS attended OHCA, EMS treated OHCA, EMS treated OHCA of presumed cardiac aetiology and EMS treated OHCA with VF.

2.5. Statistical analysis

Incidences describing adult population only and populations with both adults and children were calculated and averaged separately. The population published in the article was corrected for the adult census population of the area at the time of the study if the adult population was not described (for European areas, http://epp.eurostat.ec.europa.eu/; for North American areas, http://www.census.gov/; for Asian areas, http://www.e-stat.go.jp/; for Australian areas, http://www.censusdata.abs.gov.au). Incidence estimates of individual communities were weighted and averaged according to the size of the study population. The percentage of OHCA cases treated by the EMS was calculated by dividing the number of cases that were resuscitated by the number of patients in OHCA attended by EMS. Sensitivity analyses were computed by: (1) estimate weighted according to the person-years; (2) the median.

Comparisons between continents were analyzed with weighted ANOVA and a post hoc Scheffe correction. The incidence estimates of adult-only and adult plus paediatric studies were compared with a weighted unpaired Student's *t*-test. To address potential secular trends over time, we evaluated the relationship of the average year of the study with incidence, percentage of EMS treated OHCA cases, and percentage of VF using weighted multivariable linear regression analysis. The relationship between survival-to-hospital discharge and incidence, percentage of EMS treated OHCA cases, and percentage of VF was also tested using weighted multivariable linear regression analysis. We evaluated goodness of fit using the coefficient of determination of the model (R).

3. Results

We found 30 studies performed in Europe, 24 in North America, 7 in Asia and 6 in Australia. Table 1 shows the incidences and survival rates presented per area.

3.1. Incidence estimates

Table 2 shows the average crude incidence per 100,000 person-years of OHCA, percentage of OHCAs treated by EMS, percentage of VF and survival rates for studies with only adults and for those with both children and adults. Only the incidence of EMS treated OHCA and of EMS treated OHCA of presumed cardiac cause differed significantly between adult-only studies and adult plus paediatric studies. Table 3 shows the summary estimates were consistent across the various statistical approaches.

The percentage of VF decreased over the past 20 years ($R = -0.34$; $P = 0.001$), while the incidences and the average (VF) survival to discharge did not change demonstrably; however, the variability among studies was great, potentially obscuring secular changes. Survival was negatively associated with the percentage of EMS treated OHCA ($R = -0.50$; $P < 0.001$), and positively associated with the percentage of patients with VF as initial rhythm ($R = 0.51$; $P < 0.001$) and VF–OHCA incidence ($R = 0.47$; $P < 0.001$); there was a trend for the association between survival and the incidence of EMS treated OHCA of presumed cardiac aetiology ($R = -0.21$; $P = 0.09$), but not for the other OHCA incidences.

Table 1
Incidences, percentage of survival and percentage of VF per study area. All incidence rates are per 100,000 person-years.

Setting	Study data collection	Study time span (months)	Study population	Age included	Incidence EMS attended OHCA	Incidence EMS treated OHCA	Incidence EMS treated OHCA, cardiac cause	Incidence EMS treated OHCA, cardiac cause, VF	%VF	% survival to discharge	% survival to discharge, VF
Europe											
Vienna, Austria[5]	1995–1996	24	1,508,120	All			49.7	13.4	27%	19.5%	
East Bohemian region, Czech Republic[20]	2002–2004	29	1,236,000	All	24.0	19.2	18.7	7.4	41%	9.5%	14%
Copenhagen, Denmark[21]	2004–2007	30	593,000	All	73.8	53.4	28.3	4.5	34%	11%	29%
London, England[22]	1997–1998	12	8,000,000	All			47.0				
Nottinghamshire, England[23]	1991–1994	48	1,000,000	All	155.7	52.4	38.7	18.2		6%	12%
Estonia[24]	1999–2002	48	1,370,000	All	80.0	38.5	25.9				
Helsinki, Finland[25]	1994	12	516,000	All	173.6	66.7	49.4				
Tampere, Finland[26]	2004–2005	12	203,000	All	94.1	45.8	35.5	13.8	30%	13%	32%
Saint-Etienne, France[27]	1991–1992	12	571,191	All	66.5	41.0	19.8	7.9		3%	8%
Bonn, Germany[28]	1989–1992	48	240,000	All	62.7	55.2	48.3	21.9	43%	16%	23%
Dachau, Germany[29]	2000–2006	72	134,019	All	101.2	67.0	51.2	16.3		11%	28%
Heidelberg, Germany[30]	1992–1994	36	330,000	All	76.3	51.7	34.1	10.7	31%	14%	34%
Stralsund, north-east Germany[3]	1984–1988, 1991–1997	144	67,800	All			42.8	15.9	40%	7%	
Forli, Italia[31]	1994–2004	126	138,510[a]	≥18	111.3	68.6	58.0				
Piacenza region, Italy[32]	1999–2001	22.8	173,114	All		107.6		20.4	19%	6%	33%
Pordenone province, Italy[33]	2003–2004	13	290,229	All	166.0	78.6	61.7	12.4	20%	10%	41%
Belfast, Ireland[34]	2003–2004	12	337,672	All	79.6[b]		74.1	22.2	27%	7%	
Kaunas City, Lithuania[35]	2005	12	360,627	All		20.0	17.2	9.2	53%		27%
Amsterdam, The Netherlands[36]	1995–1997	27	1,300,000	All	57.6	43.9	35.8	22.0	63%	9%	43%
Maastricht, The Netherlands[37]	1991–1994	48	132,762	20–75			44.6	24.1	58%	6%	23%
Rotterdam, The Netherlands[38]	1988–1994	84	598,694	All			21.4	14.4	67%	31%	39%
Oslo, Norway[39]	2003–2007	36	436,265[a]	≥18		70.1	48.5	2.4	34%		3%
Ostfold County, Norway[40]	1997	12	241,151	All		70.5	67.6	26.1	39%	13%	32%
Trondheim, Norway[41]	1990–1994	48	154,000	All		85.6	71.8	27.9	57%	13%	
Katowice, Poland[42]	2001–2002	12	338,000	All	114.8	55.6	43.5	26.0	44%	10%	15%
Edinburgh, Scotland[43]	1991	12	659,545[a]	≥13			45.0	24.3	41%	13%	23%
Glasgow, Scotland[43]	1991	12	171,290[a]	≥13			92.9	31.5	32%	8%	19%
Ljubljana, Slovenia[44]	1995–1997	36	397,306	All	81.0	38.1	28.3	10.2	36%	6%	12%
Maribor, Slovenia[45]	1998–2007	108	158,800[a]	≥18	82.1	55.1	36.9	22.1	35%	22%	
70% of Sweden[46]	1992–2005	168	8,900,000	All		31.0	21.3	9.6	29%	6%	14%
South Glamorgan, Wales[47]	1989–1992	81.85	400,000	All		35.0	26.9	9.7	28%	7%	
North America											
Edmonton, Alberta Canada[48]	2002	12	616,741	All			55.3	16.7	30%	9%	26%
Provincial average British Colombia, Canada[48]	2002	12	3,282,061	All			59.4	15.8	27%		
Vancouver, Canada[49]	2006–2007	12	2,779,373	All	85.4[b]		58.8	17.2	29%	10%	25%
provincial average Nova Scotia, Canada[48]	2002	12	899,942	All			52.9	15.0	28%	6%	19%
Ottawa Ontario Canada[49]	2006–2007	12	4,030,696	All	73.6[b]		45.6	10.6	23%	5%	15%
Toronto, Ontario Canada[49]	2006–2007	12	5,627,021	All	91.6[b]		53.2	10.9	21%	6%	16%
Provincial average Ontario Canada[48]	2002	12	2,352,473	All			59.3	17.7	30%	5%	13%
Montreal Metro, Quebec Canada[48]	2002	12	2,140,000	All			52.6	14.2	27%	4%	11%
Alabama[49]	2006–2007	12	644,701	All	110.9[b]		41.4	10.1		3%	8%
Alachua County, FL[50]	1998	12	211,403	All	79.0	72.8	68.6	25.1	37%	4%	
Allegheny County, PE[51]	1990–1995	61	145,000	All		70.5		28.1	45%		
Arizona[52]	2005–2006	15	5,500,000	All		21.6	16.1	4.8	30%	3%	9%
Dallas[49]	2006–2007	12	1,989,357	All	123.8[b]		63.6	9.8	15%	5%	10%
Delaware County, IN[53]	1995–1996	24	89,866[a]	≥18			72.3	22.3	31%	0.8%	3%
Detroit, MI[54]	2002	6	654,550[a]	≥18	113.3[b]		148.8	15.6	11%	5%	4%
Hamilton County, IN[53]	1995–1996	24	109,123[a]	≥18			39.9	17.0	43%	3%	8%
Houston, TX[55]	1989–1990	24	1,305,000[a]	≥18			92.1	37.3	41%	8%	15%

Table 1 (*Continued*)

Setting	Study data collection	Study time span (months)	Study population	Age included	Incidence EMS attended OHCA	Incidence EMS treated OHCA	Incidence EMS treated OHCA, cardiac cause	Incidence EMS treated OHCA, cardiac cause, VF	%VF	% survival to discharge	% survival to discharge, VF
Howard County, IN[53]	1995–1996	24	63,275[a]	≥18			49.0	19.0	39%	10%	17%
Iowa[49]	2006–2007	12	1,015,347	All	101.2[b]		55.6	13.3	24%	11%	23%
Kansas City, MO[56]	2003–2007	48	350,848[a]	≥18		141.4	108.2	24.6	32%	6%	
King County WA[49]	2006–2007	12	1,666,978	All			70.2	17.8	25%	16%	40%
Los Angeles, CA[57]	2000–2001	12	2,569,000[a]	≥18		78.7	66.2			1%	
Memphis, TE[58]	1989–1992	39	440,053[a]	≥18			74.7				
Miami-Dade County, FL[7]	1997–2001	49	1,181,612	All			15.3	5.9	38%	7%	14%
Three southeastern Michigan counties[59]	1991–1994	48	1,065,400[a]	≥18		46.1		18.2	49%		12%
Milwaukee, WI[49]	2006–2007	12	940,164	All			85.2	17.6	21%	10%	26%
Multnomah County, OR[60]	2002–2003	12	660,486	All			35.9	14.8	41%	12%	24%
New York City, NY[61]	1986–1993	96	97,024[a]	≥18		62.0	52.3			2%	
Oakland County, MI[62]	1989–1993	54	763,000[a]	≥19			82.3	16.7	62%	11%	
Olmsted County MN[63]	1995–2005	132	133,283	All	54.3	28.2	22.1				
Pittsburgh, PE[49]	2006–2007	12	935,967	All	130.0[b]		61.4	10.9	18%	7%	22%
Portland, OR[49]	2006–2007	12	1,751,119	All	75.4[b]		45.3	14.2	31%	11%	23%
Rochester, MN[64]	1991–2008	216	58,938[a]	≥18		57.6	42.8	24.1	56%	25%	42%
Rochester, NY[65]	1998–2001	48	158,180[a]	≥18	186.0	150.1	96.6	27.7	32%	7%	10%
Salt Lake City, UT[66]	1992–1994	36	122,240[a]	≥18			87.8	45.3	52%	8%	8%
San Diego, CA[67]	2001–2002	18	1,300,000	All			58.5	17.5	30%	4%	5%
San Francisco, CA[6]	1992–1993	10.4	653,059[a]	≥18			82.2	24.2	20%	6%	15%
Town of Colonie, NY[68]	1994	12	76,500	All		104.6	95.4	35.3	55%	12%	
Tucson, AZ[69]	1988–1993	72	312,910[a]	≥18			35.4	18.5	52%	7%	12%
Asia											
Akita, Japan[70]	1995–1998	36	316,000	All	98.4	67.3	26.2				
Izumo, Japan[70]	1998–1999	24	128,000	All	52.3	31.3	15.6				
Okayama City, Japan[71]	2003–2004	12	647,879	All		56.0	27.6	5.1	11%	1%	6%
Osaka, Japan[72]	1998–2003	60	7,257,500[a]	≥18	67.1	64.6	37.8	3.27	9%	3%	
Otsu, Japan[70]	1997–1998	24	306,000	All	66.5	49.2	25.5				
Takatsuki City, Japan[73]	1999–2004	72	360,000	All		50.6		2.9	6%		
Yamaguchi, Japan[74]	2002–2008	72	142,000	All	83.1			2.5	6%	0.6%	19%
Singapore[75]	2001–2002	7	4,100,000	All	20.9	20.9	14.7	4.0	20%	0.9%	
Tai Pei, Taiwan[76]	1992–1993	10	2,700,000	All		28.4	24.6	1.38	6%	1%	
Australia											
Adelaide, Australia[77]	2005–2007	25	1,214,875[a]	≥18	128.2	55.3		15.9	29%		
Perth, Western Australia[78]	1996–1999	48	1,079,381	≥16	85.0	34.9	29.5	6.5		6%	10%
Queensland, Australia[79]	2000–2002	36	2,887,709[a]	≥18	102.0	53.5	39.8	15.8	46%	6%	
Sydney, Australia[80]	2004–2005	12	3,993,000	All			50.4	13.9	32%	13%	19%
Victoria, Australia[81]	2002–2003	24	3,587,963	≥17	125.1	55.2	46.4				
Auckland, New Zealand[82]	1991–1993	36	935,000	All		41.9	38.1	24.7	65%	13%	14%
South America											
No articles met the inclusion criteria											
Africa											
No articles met the inclusion criteria											

OHCA indicates out-of-hospital cardiac arrest; CPR indicates cardiopulmonary resuscitation; VF indicates ventricular fibrillation.

[a] The population published in the article has been corrected for the adult census population of the area at the time of the study.

[b] Presumed cardiac cause only.

3.2. Comparisons between continents

Fig. 3 and Table 4 show incidence and survival rates per continent. The incidence of EMS attended OHCA was lower in Asia (52.5) than in Europe (86.4), North America (98.1), and Australia (112.9) ($P < 0.001$). The incidence of EMS treated OHCA of presumed cardiac aetiology was higher in North America (54.6) than in Europe (35.0), Asia (28.3), and Australia (44.0) ($P < 0.001$). The incidence of EMS treated OHCA with VF was lower in Asia (3.2) than in Europe (12.8), North America (14.0), and Australia (14.9) ($P < 0.001$). The percentage of EMS treated OHCA was higher in Asia (96%) than in Australia (46%), Europe (60%), and North America (58%) ($P < 0.001$). Both the percentage of VF and survival to discharge rates were lower in Asia (11% and 2%, respectively) than those in Europe (35% and 9%, respectively), North America (28% and 6%, respectively), and Australia (40% and 11%, respectively) ($P < 0.001$, $P < 0.001$). Table 4 shows that the calculated incidences and percentages were consistent across the various methods used to calculate outcomes.

4. Discussion

In the present systematic overview of 67 studies and 178,440 OHCAs in a source population of over a 100 million people, we found substantially different incidences among the studies, with 10-fold variability in incidences of OHCA. The global average incidence was 55 adult OHCAs of presumed cardiac cause per 100,000 person-years. Of all OHCAs, 27% had VF as the initial rhythm. The average survival following adult OHCA was 7%. We did not find a

Table 2
Incidence estimates of out-of-hospital cardiac arrest, percentage of treated out-of-hospital cardiac arrest, of ventricular fibrillation and of survival for studies including adult and paediatric patients and studies including only adult patients.

	Adult and paediatric included		Adult-only included		*P*-value
	Mean	(SD)	Mean	(SD)	
Incidence EMS attended OHCA ($n=39$)	83.7	(37.2)	95.9	(30.5)	0.25
Incidence EMS treated OHCA ($n=48$)	34.7	(15.8)	62.3	(17.0)	<0.001
Incidence EMS treated OHCA, cardiac cause ($n=80$)	40.8	(17.5)	54.6	(26.0)	0.004
Incidence EMS treated OHCA, VF ($n=73$)	11.8	(5.7)	12.8	(10.6)	0.71
Percentage EMS treated OHCA ($n=39$)[a]	63.7	(17.3)	68.9	(25.6)	0.39
Percentage VF ($n=68$)	28.0	(10.8)	26.9	(19.4)	0.75
Percentage survival ($n=68$)	7.1	(4.7)	5.6	(4.1)	0.19
Percentage VF survival ($n=55$)	17.3	(8.5)	11.4	(6.0)	0.11

EMS indicates emergency medical services; OHCA indicates out-of-hospital cardiac arrest; CPR indicates cardiopulmonary resuscitation; VF indicates ventricular fibrillation. All incidence rates are per 100,000 person-years.

[a] Numerical discrepancies between the upper and lower part of the table can be explained by the fact that these parts are based on different sets of studies. All estimates are weighed according to the population size.

relation between OHCA incidence rates and survival. The incidence of resuscitations with presumed cardiac cause was the highest in North America. Asia had the lowest percentages of VF, the lowest survival to discharge rate and the highest percentage of EMS treated OHCA.

4.1. Differences between studies

Although true variation in incidence may exist among the investigated populations, differences in EMS system, research methodology, and case definition may also lead to artificial differences between studies. The role of the EMS system in incidence rate variability is illustrated by Kentsch et al., who described a four-fold increase in incidence rates in Stralsund, Germany, between 1984–1988 and 1991–1997.[3] The authors specifically related this increase to a marked improvement in the telecommunication network, which had significantly shortened the time interval from collapse to ambulance arrival.

The involvement of bystanders may influence the incidence of resuscitations as well. The reported incidence of OHCA with resuscitation efforts initiated in Vienna, Austria, was 16.5 per 100,000 person-years in 1990,[4] compared with 49.7 just five years later.[5] This observation could be explained by the reported tripling in bystander CPR rate. More frequent application of bystander CPR presumably increases the number of cases where EMS personnel will undertake resuscitation efforts.

The variation in incidence rate of resuscitations for presumed cardiac cause can also be attributed to variability of case definitions. We found that the definition for 'presumed cardiac cause' of the arrest varied from "nontraumatic normothermic cardiac arrests"[6] to "patients with loss of consciousness, not anticipated by prior clinical or hemodynamic status, in the absence of trauma or other exogenous influences as a definable precipitating event."[7] According to the Utstein template definition, a cardiac cause is presumed in the absence of evidence for non-cardiac causes.[2] Therefore, the cardiac aetiology category will greatly vary depending on the rigor of the efforts to identify other causes. Definitions of the cause of arrest would be more accurate by including information obtained at hospitals and by autopsy data. Yet, these data are often difficult to obtain.

As a consequence of these factors, estimating a population-based incidence determined from a handful of communities is challenging. However, the summary estimates of OHCA incidences varied little among the sensitivity analyses, implying the estimates are robust.

4.2. Differences between continents

When we compared incidence rates by continent, North America had the highest incidence of resuscitations for presumed cardiac cause. According to the World Health Organization, inhabitants of the U.S. are more obese than those of the other continents. An increased body mass index is a known risk factor for sudden cardiac death.[8]

Asia had the lowest percentage of VF and the lowest survival rates. A recent prospective computed tomography study from Japan showed that 16% of all nontraumatic OHCA was due to aneurismal subarachnoid hemorrhage.[9] Patients with aneurismal subarach-

Table 3
Sensitivity analyses of incidences of out-of-hospital cardiac arrest, percentage of treated out-of-hospital cardiac arrest, of ventricular fibrillation and of survival for studies including adult and paediatric patients and studies including only adult patients.

	Adult and paediatric included			Adult-only included		
	Primary estimate[a]	Estimate weighted according to person-years[b]	Median estimate[c]	Primary estimate[a]	Estimate weighted according to person-years[b]	Median estimate[c]
Incidence EMS attended OHCA	83.7	85.8	82.1	95.9	85.3	111.3
Incidence EMS treated OHCA	34.7	33.5	50.6	62.3	62.0	62.0
Incidence EMS treated OHCA, cardiac cause	40.8	39.6	43.5	54.6	47.8	58.0
Incidence EMS treated OHCA, VF	11.8	10.9	14.2	12.8	10.5	20.5
Percentage EMS treated OHCA	63.7	60.4	59.7	68.9	76.6	57.1
Percentage VF	28.0	30.4	30.0	26.9	23.5	38.7
Percentage survival to discharge	7.1	7.1	7.0	5.6	5.8	6.8
Percentage survival to discharge, VF	17.3	15.7	19.2	11.4	13.2	10.3

Incidence is per 100,000 person-years.

[a] Each community is weighted according to the size of the study population (mean estimates are also shown in Table 2).

[b] Each community is weighted according to the number of person-years.

[c] Each community is weighted according to the size of the study population.

Table 4
Sensitivity analyses of incidences of out-of-hospital cardiac arrest, percentage of treated out-of-hospital cardiac arrest, of ventricular fibrillation and of survival per continent.

	Europe			North America			Asia			Australia		
	Primary estimate[a]	Estimate weighted according to person-years[b]	Median estimate[c]	Primary estimate[a]	Estimate weighted according to person-years[b]	Median estimate[c]	Primary estimate[a]	Estimate weighted according to person-years[b]	Median estimate[c]	Primary estimate[a]	Estimate weighted according to person-years[b]	Median estimate[c]
Incidence EMS attended OHCA	86.4	87.4	81.6	98.1	96.5	101.2	52.5	65.4	66.8	112.9	108.9	113.6
Incidence EMS treated OHCA	40.6	34.4	54.2	47.3	53.1	70.6	45.9	59.4	49.8	51.1	49.7	53.5
Incidence EMS treated OHCA, cardiac cause	35.0	25.7	42.8	54.6	53.2	58.8	28.3	35.1	25.5	44.0	41.3	39.8
Incidence EMS treated OHCA, VF	12.8	10.7	15.9	14.0	15.0	17.2	3.2	3.2	3.1	14.9	14.7	15.8
Percentage EMS treated OHCA	60.3%	58.9%	61.2%	57.6%	58.4%	56.5%	95.7%	95.3%	74.0%	46.3%	46.7%	43.5%
Percentage VF	35.2%	31.6	35.5%	28.1%	33.0%	30.4%	11.2%	9.1%	7.4%	39.8%	37.0%	39.0%
Percentage survival to discharge	9.4%	7.6%	10.0%	6.3%	6.8%	6.8%	2.2%	3.0%	1.2%	10.7%	9.7%	12.8%
Percentage survival to discharge, VF	19.0%	15.7%	23.3%	15.9%	15.5%	14.6%	12.3%	13.6%	12.8%	16.6%	14.2%	13.9%

Incidence is per 100,000 person-years.
[a] Each community is weighted according to the size of the study population (mean estimates are also shown in Table 2).
[b] Each community is weighted according to the number of person-years.
[c] Each community is weighted according to the size of the study population.

noid hemorrhage were less likely to have VF as initial rhythm and were less likely to have return of spontaneous circulation before arrival to the hospital. Asia also had the highest percentage of EMS treated OHCA, which was negatively associated with survival. If the Asian countries started CPR more often on patients who had been "dead" for a long time, it is likely they would have encountered less VF and had lower survival rates. The lower thresholds in Asian EMS protocols for initiating resuscitation is likely to contribute to the differences in the incidence as well.

None of the articles from South America or Africa fit our inclusion criteria. Selection bias is likely because of unpublished data, abstracts, and presentations were not included. For a more complete view of the global incidence and survival of OHCA, it is important to include these continents as well.

4.3. Differences in survival

The striking variability in survival across studies underscores potential opportunities to make improvements. One of the main factors that influence survival rate was the percentage of patients that were in VF. Since VF deteriorates into asystole over time, shortening time to defibrillation could increase survival. Application of bystander AEDs allows defibrillation attempts prior to EMS arrival.[10] Bystander CPR slows down VF deterioration.[11] If the percentage of patients with VF as initial rhythm would be equal among communities, survival would equalize as well, as demonstrated by the similar survival among the VF cohorts between the continents.

We did not find a statistically significant relation between survival and the incidence of OHCA for all rhythms. Our findings are in contrast with a previous overview of 20 studies, which found that survival was inversely related to the incidence of resuscitations of presumed cardiac aetiology.[1] Our analysis included three times as many articles, and four times as many study areas. Although some of the included articles were the same, the majority of our articles are more recent. Many of the included studies, which were not available at the time of the previous overview, report low incidence rates and low survival rates. This explains why the inverse relation previously reported is no longer demonstrable.

The VF cohort in our study did show a significant relation between survival and the incidence of OHCA, while two other reviews of European studies[12] and U.S. studies[13] did not. The relation we found was mainly attributable to the Asian studies, which all published low survival rates and low VF incidences. In accordance with Rea et al. and Atwood et al., we did not find this association when we restricted our analysis to either U.S. or European studies (data not shown). This explains the discrepancy between our findings and those in the other reviews.

4.4. Differences in VF over time

As previously noted, the percentage of patients with VF as initial rhythm has decreased over time.[14–16] Some investigators have attributed the decline in VF to increased use of B-blockers.[17] A randomized animal study found that the drugs widely used in primary and secondary coronary artery disease prevention strategies shortened the duration of ventricular fibrillation.[18] Other researchers suggest that the increase in ICD implantation rates and thus the rates of ICD termination of VF may contribute to the lower incidence of VF OHCA.[19]

4.5. Recommendations

The results of this review underscore the importance of being explicit with regard to reporting the study population, those attended by EMS, those treated by EMS, those treated by EMS due to cardiac aetiology, and those treated by EMS with VF. Only when this

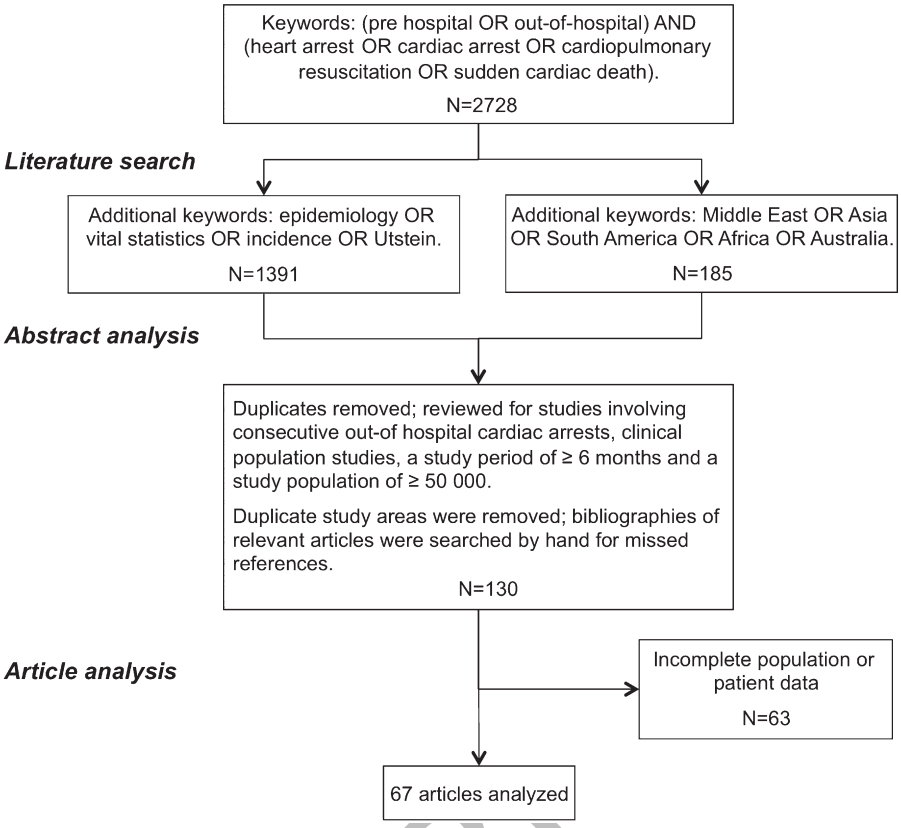

Fig. 1. Literature search strategy.

information is reported in a clear and concise manner can we fully understand the potential reasons for differences in incidence and outcome. Authors need to make clear whether they report the incidence of: (1) EMS attended OHCAs, (2) EMS treated OHCAs, (3) EMS treated OHCAs with cardiac cause and/or (4) EMS treated OHCAs with VF. The authors should also explicitly note their inclusion and exclusion criteria. They should report who decides if a patient in OHCA should be resuscitated and on what criteria that decision is based. Because the category of presumed cardiac cause is a diagnostic category by exclusion, authors should attempt to include

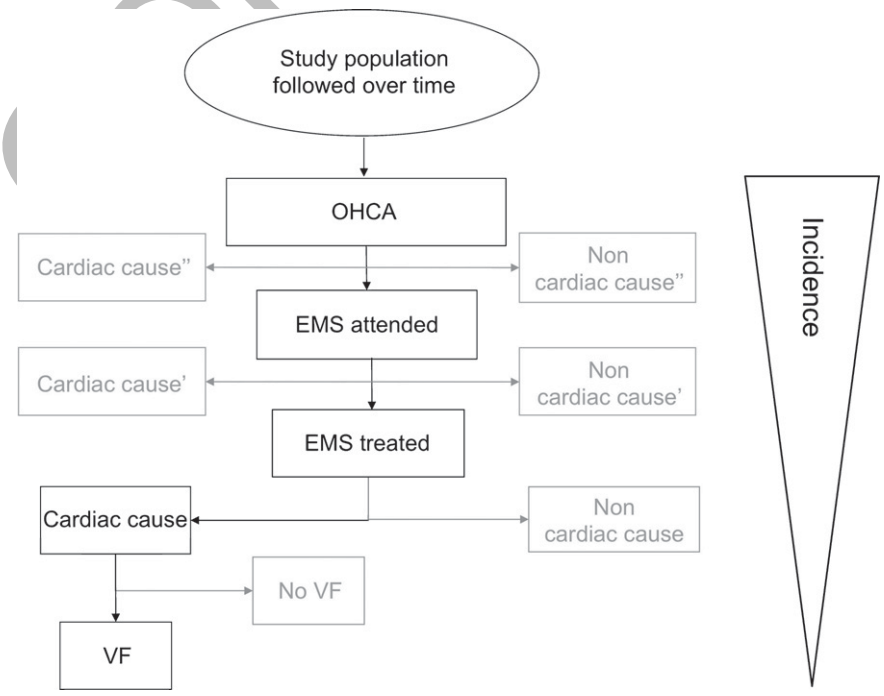

Fig. 2. Illustration of how the incidence decreases as the number of cases decrease at different levels of the Utstein template.

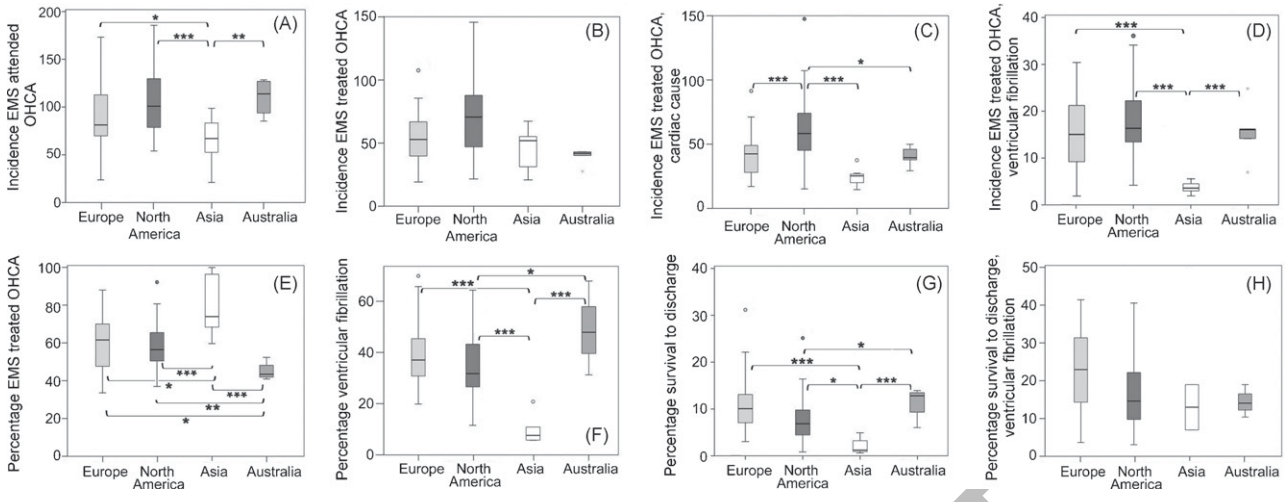

Fig. 3. Box and whisker plot of incidence rates and resuscitation characteristics in various continents. $^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$. OHCA indicates out-of-hospital cardiac arrest; CPR indicates cardiopulmonary resuscitation. (A)–(D) show incidence rates of EMS attended OHCA, of EMS treated OHCA, of EMS treated OHCA of presumed cardiac cause, and of EMS treated OHCA with VF as initial rhythm, respectively. (E)–(H) show the percentages of EMS treated OHCA, of VF as initial rhythm, of survival to discharge, and of survival to discharge for patients with VF as initial rhythm, respectively.

further information to support the diagnosis of "cardiac cause," when possible. Hospital-based diagnostic information and autopsy data would likely improve the accuracy, although such information is often difficult to obtain by EMS providers and resuscitation scientists. Finally, the denominator for calculated OHCA incidences should be the true population at risk.

5. Conclusions

There is a 10-fold global variation in reported OHCA incidences and outcome. This may reflect differences in methodology, in EMS systems, in case definitions, as well as true differences in risk and treatment. Uniform reporting practices with precise case definitions and clearly stated inclusion and exclusion criteria allow a more accurate and consistent estimate of the incidence of OHCA. To achieve this uniformity, researchers who report their experience on out-of-hospital cardiac arrest need to be thoughtful and exacting when following the Utstein template.

Conflict of interest statement

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