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Resuscitation

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Clinical paper

Three-year trends in out-of-hospital cardiac arrest across the world: Second report from the International Liaison Committee on Resuscitation (ILCOR)

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Abstract

Background: The International Liaison Committee on Resuscitation (ILCOR) Research and Registries Working Group previously reported data on systems of care and outcomes of out-of-hospital cardiac arrest (OHCA) in 2015 from 16 national and regional registries. To describe the temporal trends with updated data on OHCA, we report the characteristics of OHCA from 2015 through 2017.

Methods: We invited national and regional population-based OHCA registries for voluntary participation and included emergency medical services (EMS)-treated OHCA. We collected descriptive summary data of core elements of the latest Utstein style recommendation during 2016 and 2017 at each registry. For registries that participated in the previous 2015 report, we also extracted the 2015 data.

Results: Eleven national registries in North America, Europe, Asia, and Oceania, and 4 regional registries in Europe were included in this report. Across registries, the estimated annual incidence of EMS-treated OHCA was 30.0–97.1 individuals per 100,000 population in 2015, 36.4–97.3 in 2016, and 40.8–100.2 in 2017. The provision of bystander cardiopulmonary resuscitation (CPR) varied from 37.2% to 79.0% in 2015, from 2.9% to 78.4% in 2016, and from 4.1% to 80.3% in 2017. Survival to hospital discharge or 30-day survival for EMS-treated OHCA ranged from 5.2% to 15.7% in 2015, from 6.2% to 15.8% in 2016, and from 4.6% to 16.4% in 2017.

Conclusion: We observed an upward temporal trend in provision of bystander CPR in most registries. Although some registries showed favourable temporal trends in survival, less than half of registries in our study demonstrated such a trend.

Keywords: Out-of-hospital cardiac arrest, Utstein template, Epidemiology, Resuscitation, Registry

Introduction

Out-of-hospital cardiac arrest (OHCA) is a major public health burden worldwide. The estimated annual incidence of emergency medical services (EMS)-treated OHCA across nations in North America, Europe, Asia, and Oceania ranges from 28 to 244 per 100,000 population.[1–3] Survival after OHCA remains low across the geographic regions — 3.1% to 20.4% of patients who underwent resuscitation

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https://doi.org/10.1016/j.resuscitation.2023.109757

Received 26 December 2022; Received in Revised form 13 February 2023; Accepted 17 February 2023

treated by EMS providers survived to hospital discharge or for 30 days.[2,3]

A standardised template for reporting performance and outcomes of OHCA, Utstein style was initially developed at a conference at Utstein Abbey in Norway in 1990.[4–9] The International Liaison Committee on Resuscitation (ILCOR) was subsequently formed in 1992 and has updated the Utstein template for OHCA in 2004 and 2015.[10–13] The Utstein process and collaborations have globally contributed to better understanding of the epidemiology of OHCA, facilitating inter- and intra-system comparisons, identifying knowledge gaps, supporting clinical research, and improving systems of care.[5,7,8,14] As the ILCOR Research and Registries Working Group, we previously reported data on systems of care and outcomes of OHCA in 2015 from nine national and seven regional registries.[2] To describe the temporal trends with updated data on OHCA, this article reports the characteristics of OHCA from 2015 through 2017 from national and regional registries across the world.

Methods

Targeted registries

The ILCOR Research and Registries Working Group invited national and regional OHCA registries that participated previously and, through the ILCOR network extended the invitation to registries that were not included in the previous report via current participated registries' network.[2] Participation in this project was voluntary. We included population-based registries, which covered all cases with EMS-treated OHCA in each area. We defined a national registry as collecting data from the whole nation or multiple regions within one nation designed to represent the entire nation; other registries were designated as regional registries.[2]

Data collection

As previously reported, we conducted a survey to assess which core elements of the latest Utstein style recommendation for OHCA were collected by each registry.[2,10,11] Based on the availability of the data in the registries, we additionally collected descriptive summary data in 2016 and 2017 from each registry.

The elements of the collected summary data included system description (the total population of the covered area in each registry, proportion of the covered population among each nation's population, annual number of EMS-treated OHCA, number of dispatcher cardiopulmonary resuscitation [CPR] instruction episodes), patient variables (age, sex, number of bystander and EMS witnessed arrest, arrest location, bystander CPR, bystander automated external defibrillator [AED] use and shock delivery, first monitored shockable rhythm, and pathogenesis), process elements (response time [time from incoming call to EMS arrival on scene, time from incoming call to initiation of CPR by EMS providers, time from incoming call to the first shock delivery by EMS providers, time from incoming call to hospital arrival], number of cases with targeted temperature management [TTM], number of cases with drug [adrenaline and amiodarone] administration during resuscitation), and patient outcomes.[2] Patient outcomes were 30-day survival or survival to hospital discharge, and favourable functional outcome at hospital discharge or 30 days for both EMS-treated OHCA and bystander-witnessed shockable OHCA. Favourable functional outcome was defined as Cerebral Performance Category (CPC) score of 1 or 2, or modified Rankin Scale score $\leq$ 3 following the Utstein recommendation.[10,11] We used a secured electronic database, Research Electronic Data Capture (RED Cap) for data collection and data management.

Statistical analysis

We calculated the estimated annual incidence of EMS-treated OHCA at each registry, using the annual number of EMS-treated OHCAs as the numerator and the total population of the area covered as the denominator. When a registry collected types of bystander CPR, i.e., conventional CPR with rescue breathing or chest compression-only CPR, we presented the proportion of patients who received each type of bystander CPR among EMS-treated OHCAs in the registry.[2,10,11] When we calculated the proportion of those who received dispatcher CPR instruction and bystander responses (bystander CPR, bystander AED use and shock delivery), we excluded EMS-witnessed OHCA from the denominators as these patients do not have the opportunity to have these interventions.[2] Our definition of bystanders included anyone who started CPR or used an AED before EMS arrival and could include volunteer responders or off-duty clinicians (e.g., an off-duty paramedic). But we excluded professionals who used AED on duty (e.g., on-duty police, on-duty border patrol) before EMS arrival. For a registry that participated in the previous ILCOR Research and Registry report, we also showed the 2015 data in the registry for comparison.[2]

Results

Overall results

We obtained summary data of OHCA systems of care and outcomes from 2015 through 2017 from 15 national and regional OHCA registries across the world. As detailed below, we observed an upward temporal trend in the provision of bystander CPR in the majority of registries, with variations in the provision of bystander CPR across registries. Although some registries exhibited favourable temporal trends in survival, less than half of registries demonstrated such a trend from 2016 to 2017 for both all EMS-treated OHCA and bystander-witnessed shockable OHCA.

System of participated registries

Eleven national registries in North America, Europe, Asia and Oceania, and four regional registries in Europe were included (Table 1). The national registries covered 25.0% to 100% of the population of each nation in 2015, 9.1% to 100% in 2016, and 11.0% to 100% in 2017. Five national registries in 2015, six registries in 2016, and eight registries in 2017 covered the nation's whole population. The estimated annual incidence of EMS-treated OHCA was 30.0–97.1 individuals per 100,000 population in 2015, 36.4–97.3 individuals per 100,000 population in 2016 and 40.8–100.2 individuals per 100,000 population in 2017 (Fig. 1).

Dispatcher

The number of dispatcher CPR instruction events was available from three national and one regional registry in 2015, and collected from five national and two regional registries in 2016 and 2017. 12.2%-59.4% of OHCA in 2015, 13.7%-60.7% in 2016, and 20.5%-61.8% in 2017 received dispatcher CPR instructions (Table 1).

Table 1 – Summary data in Utstein core elements (system and dispatch).

Name of registries	Country	Total population of covered area of the registry			Proportion of population in covered area of the registry among the country's population			Annual number of treated resuscitaion			Annual number of dispatcher CPR instruction*, n (%)		
		2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
National/International Registries													
Cardiac Arrest Registry to Enhance Survival (CARES)	United States	85,000,000	88,673,688	102,631,321	25.0%	27.4%	31.5%	52,902	61,647	76,215	N/A	N/A	N/A
Danish Cardiac Arrest Registry	Denmark	5,627,235	5,707,251	5,748,769	100%	100%	100%	3647	5099	5345	N/A	N/A	N/A
Norwegian Cardiac Arrest Registry	Norway	4,793,741	5,220,143	5,295,619	93.0%	99.7%	100%	2320	2791	2772	N/A	1,374 (57.5)	1,453 (61.4)
Out-of-hospital Cardiac Arrest outcomes (OHCAO)	United Kingdom	54,646,932	50,032,458	50,359,436	83.9%	76.2%	76.3%	28,914	27,942	28,414	N/A	N/A	N/A
Australian Resuscitation Outcomes Consortium (Aus-ROC)	Australia	15,215,358	16,001,900	24,770,700	64.0%	68.0%	100%	7120	7701	10,964	N/A	N/A	N/A
Australian Resuscitation Outcomes Consortium (Aus-ROC)	New Zealand	4,663,700	4,767,600	4,859,500	100%	100%	100%	2305	2369	2556	N/A	N/A	N/A
Pan-Asian Resuscitation Outcomes Study (PAROS)	Singapore	5,535,002	5,607,283	5,612,253	100%	100%	100%	2322	2470	2807	1250 (59.2)	936 (42.2)	1,171 (45.8)
Korea OHCA registry (KOHCAR)	South Korea	51,069,375	51,230,704	51,112,971	97.0%	100%	100%	27,656	27,122	27,080	10,432 (40.5)	11,946 (47.4)	12,281 (49.4)
Utstein Japan	Japan	127,094,745	126,932,772	126,706,210	100%	100%	100%	123,421	123,554	127,018	67,488 (59.4)	69,055 (60.7)	72,396 (61.8)
Deutsches Reanimations register - German Resuscitation Registry	Germany	–	7,509,320	9,106,900	–	9.1%	11.0%	–	5214	6066	–	1,043 (47.7)	1,227 (46.0)
OHCAR	Ireland	4,635,400	4,747,976	4,747,976	100%	100%	100%	2150	2256	2200	N/A	N/A	N/A
Regional Registries													
Pavia Cardiac Arrest Registry (Pavia CARe)	Italy	547,435	547,946	547,251	1.0%	0.9%	0.9%	490	441	472	50 (12.2)	50 (13.7)	82 (20.5)
Ticino Registry of Cardiac Arrest	Switzerland	350,363	351,946	354,375	4.2%	4.2%	4.2%	247	221	244	N/A	115 (57.2)	107 (51.0)
Sudden Death Expertise Center registry (SDEC)	France	6,800,000	6,600,000	6,600,000	10.0%	10.0%	10.0%	2040	2403	2690	N/A	N/A	N/A
Utstein Bosnia and Herzegovina	Bosnia and Herzegovina	–	417,498	529,521	–	12.0%	15.0%	–	315	344	–	N/A	N/A

OHCA denotes out-of-hospital cardiac arrest, CPR; cardiopulmonary resuscitation, EMS; emergency medical services.

* We excluded EMS-witnessed OHCA from the denominators.

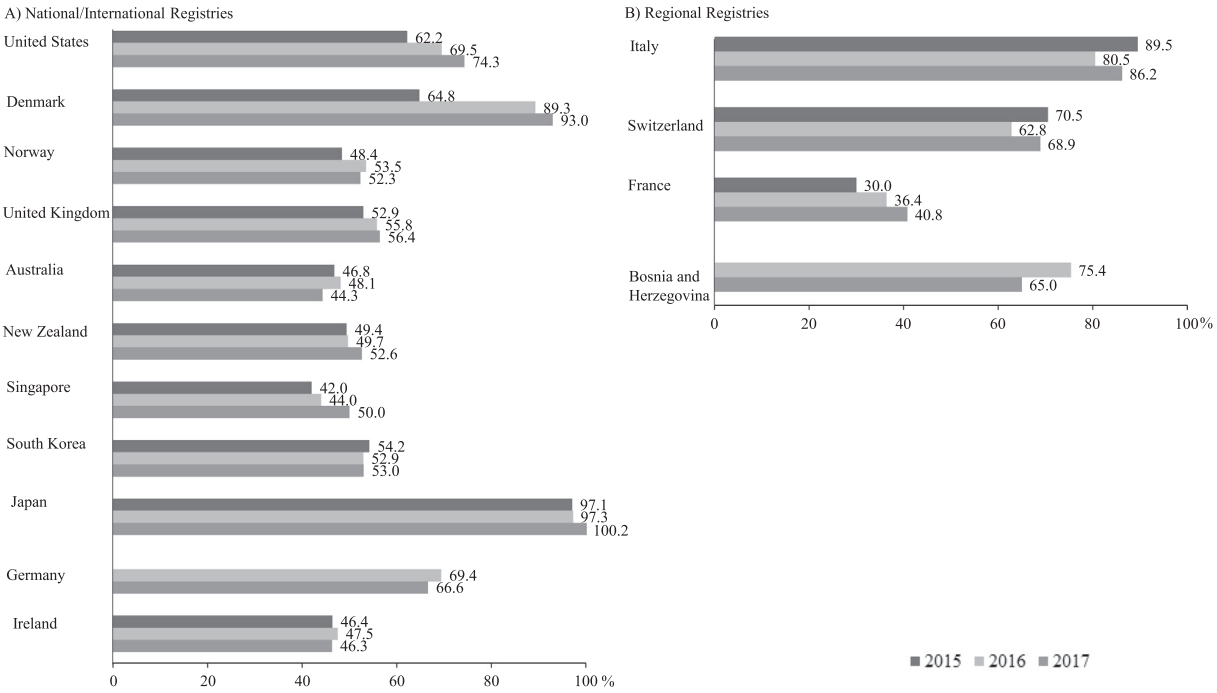

Fig. 1 – Temporal trend of estimated incidence of EMS treated OHCA per 100,000 population. A) National/International Registries, B) Regional Registries. EMS denoted emergency medical services; OHCA; out-of-hospital cardiac arrest.

Patient variables

Patient variables are described in Table 2 and Fig. 2. All 15 registries collected patient age and sex in 2016 and 2017. Location variable was available from 11 registries in 2015 and collected from 14 registries in 2016 and 2017. AED use was documented by nine registries in 2015 and by 10 registries in 2016 and 2017, and bystanders used an AED in 2.0% to 18.5% of OHCA in 2015, 0% to 19.4% in 2016 and 0% to 20.9% in 2017. Bystander AED shock delivery was available in 10 registries in 2015 and 13 in 2016 and 2017. 0.5% to 6.3% of OHCA in 2015, 0% to 8.8% in 2016, and 0% to 7.7% in 2017 received bystander AED shock delivery. First monitored shockable rhythm ranged from 6.5% to 36.5% of OHCA in 2015, from 6.6% to 34.7% in 2016, and from 6.5% to 35.8% in 2017. The majority of OHCAs were of medical origin in all registries. Bystander CPR was collected by 13 registries in 2015 and 15 in 2016 and 2017. Type of bystander CPR available was from three registries in 2015 and five in 2016 and 2017. The provision of bystander CPR varied from 37.2% to 79.0% in 2015, from 2.9% to 78.4% in 2016, and from 4.1% to 80.3% in 2017. The provision of bystander CPR increased in most areas, and five of 15 registries showed that bystander CPR was started in more than 70% of patients in 2017 (Fig. 2).

Process

Process elements are presented in Table 3. EMS response time was available in 11 registries in 2015 and 14 in 2016 and 2017.

Outcome

Patient outcomes are listed in Fig. 3.1, Fig. 3.2, and the supplemental table. Either survival to hospital discharge or 30-day survival for EMS-treated OHCA ranged from 5.2% to 15.7% in 2015, from 6.2% to 15.8% in 2016, and from 4.6% to 16.4% in 2017. Favourable functional outcome at hospital discharge or 30 days for EMS-treated OHCA ranged from 3.2% to 8.4% in 2015, from 3.9% to 12.7% in 2016, and from 3.2% to 15.6% in 2017. Either survival to hospital discharge or 30-day survival for bystander-witnessed shockable OHCA ranged from 20.5% to 43.6% in 2015, from 22.7% to 47.4% in 2016, and from 20.3% to 46.2% in 2017, and reached around 30% in most areas in 2017. The estimated incidence of either discharged alive or 30-day survival per 100,000 population was 1.0–3.8, 1.2–5.3, and 1.1–5.1 in 2015, 2016, and 2017, respectively (Supplementary data). Favourable functional outcome at hospital discharge or 30 days for bystander-witnessed shockable OHCA ranged from 14.3% to 29.9% in 2015, 16.6% to 42.1% in 2016, and, 15.9% to 37.0% in 2017, and reached over 30% in three areas in 2017.

Discussion

This ILCOR Research and Registries Working Group Report presents summary data of OHCA systems of care and outcomes from 2015 through 2017 at 15 national and regional OHCA registries worldwide. There was an upward temporal trend in the provision of bystander CPR in most, but not all, registries. Although some registries showed favourable temporal trends in survival, less than half of registries in our study demonstrated such a trend from 2016 to 2017 for both all EMS-treated OHCA and bystander-witnessed shockable OHCA.

For all EMS-treated OHCA, we observed a 2.5-fold difference (6.2% to 15.8%) in survival to hospital discharge or 30 day survival in 2016 and a 3.6-fold difference (4.6% to 16.4%) in the survival outcome in 2017. Similarly, for favourable functional outcome at hospital

Table 2 – Summary data for all EMS treated OHCA in Utstein core elements (patient).

Country	Age Median (IQR)			Male, n (%)			Witnessed arrest, n (%) Bystander witnessed			EMS witnessed		
	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
National/International Registries												
United States	64 (52, 77)	64 (52, 76)	64 (52, 76)	32,255 (61.0)	38,039 (61.7)	47,248 (62.0)	19,558 (37.0)	23,011 (37.3)	27,887 (36.6)	6,346 (12.0)	7,445 (12.1)	9,380 (12.3)
Denmark	73 (62, 82)	72 (62, 82)	73 (62, 82)	2,317 (63.5)	3,110 (63.6)	3,239 (63.1)	1,431 (45.0)	2,274 (50.4)	2.355 (49,1)	451 (12.7)	552 (10.9)	534 (10.0)
Norway	N/A	68 (56, 79)	69 (57, 79)	1,532 (66.7)	1,865 (66.8)	1,880 (67.8)	1,183 (51.5)	1,392 (49.9)	1,375 (49.6)	292 (12.7)	400 (14.3)	407 (14.7)
United Kingdom	72.6 (58.2, 82.7)	71.8 (57.2, 82.0)	71.5 (57.6, 81.8)	17,626 (63.3)	17,551 (62.8)	18,079 (63.6)	10,742 (46.6)	9,688 (46.6)	11,343 (48.8)	3,512 (15.2)	2,706 (13.0)	3,311 (14.3)
Australia	65 (48, 78)	65 (48, 78)	65 (49, 77)	4,863 (68.3)	5,239 (68.0)	7,381 (67.4)	2,687 (37.7)	3,137 (40.7)	4,538 (41.4)	1,081 (15.2)	1,164 (15.1)	1,663 (15.2)
New Zealand	66 (52, 77)	65 (52, 76)	65 (52, 76)	1,540 (66.8)	1,671 (70.5)	1,743 (68.1)	1,179 (51.1)	1,102 (46.5)	1,211 (47.4)	354 (15.4)	343 (14.5)	400 (15.7)
Singapore	67 (56, 77)	69 (56, 80)	70 (58, 82)	1,512 (65.1)	1,568 (63.5)	1,758 (62.6)	1,253 (54.0)	1,252 (50.7)	1,602 (57.1)	212 (9.1)	251 (10.2)	252 (9.0)
South Korea	69 (54, 79)	69 (54, 79)	69 (55, 80)	17,884 (64.7)	17,486 (64.5)	17,608 (65.0)	10,472 (37.9)	10,416 (38.4)	10,118 (37.4)	1,911 (6.9)	1934 (7.1)	2,227 (8.2)
Japan	79 (67, 86)	79 (68, 87)	80 (68, 87)	70,421 (57.1)	70,483 (57.0)	72,509 (57.1)	51,125 (41.4)	51,968 (42.1)	52,599 (41.4)	9,862 (8.0)	9,771 (7.9)	9,939 (7.8)
Germany	–	72 (61, 83)	72 (61, 83)	–	3,401 (65.2)	3,947 (65.1)	–	2,186 (41.9)	2,666 (43.9)	–	695 (13.3)	854 (14.1)
Ireland	67 (53, 78)	67 (52, 78)	68 (53, 79)	1,472 (68.5)	1,486 (65.9)	1,475 (67.0)	1,031 (48.0)	1,088 (48.2)	1,243 (56.5)	178 (8.3)	178 (7.9)	175 (8.0)
Regional Registries												
Italy	79 (66, 85)	76 (65, 84)	78 (64, 86)	297 (60.6)	259 (58.7)	290 (61.4)	276 (56.3)	249 (56.5)	278 (58.9)	79 (16.1)	76 (17.2)	72 (15.3)
Switzerland	74 (62, 83)	74 (62, 83)	72 (60, 80)	159 (64.4)	149 (67.4)	154 (63.1)	131 (53.0)	134 (60.6)	131 (53.7)	25 (10.1)	20 (9.0)	34 (13.9)
France	66 (54, 78)	65 (53, 78)	65 (52, 78)	1,344 (65.9)	1,665 (69.3)	1,768 (65.7)	1,274 (62.5)	1,698 (70.7)	1,891 (70.3)	251 (12.3)	325 (13.5)	363 (13.5)
Bosnia and Herzegovina	–	66 (57, 75)	64 (53, 75)	–	199 (63.2)	226 (65.7)	–	N/A	N/A	–	7 (2.2)	25 (7.3)

(*continued on next page*)

Table 2 (continued)

Country	Location, n (%)			AED use by bystander*, n (%)						First monitored shockable rhythm, n (%)			Pathogenesis, n (%)		
	Home/residence			AED use			Shock delivered						Medical		
	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
National/International Registries															
United States	36,733 (69.4)	42,221 (68.5)	53,240 (69.8)	2,866 (6.2)	3,511 (6.5)	4,589 (6.9)	893 (1.9)	1,049 (1.9)	1,199 (1.8)	10,594 (20.0)	12,217 (19.8)	14,019 (18.4)	45,243 (85.5)	51,763 (84.0)	62,171 (81.6)
Denmark	2,691 (75.2)	3,732 (73.5)	3,953 (74.2)	N/A	N/A	N/A	142 (4.6)	395 (8.8)	367 (7.7)	607 (17.6)	793 (16.3)	837 (16.3)	N/A	N/A	N/A
Norway	1,402 (61.0)	1,690 (60.6)	1,735 (62.6)	256 (12.8)	304 (12.7)	324 (13.7)	N/A	79 (3.3)	86 (3.6)	575 (25.0)	656 (23.5)	656 (23.7)	1659 (72.2)	2,387 (85.5)	2,389 (86.2)
United Kingdom	N/A	6,756 (77.5)	8,948 (72.3)	443 (2.5)	756 (4.0)	876 (4.5)	N/A	N/A	N/A	5,762 (21.3)	5,521 (20.5)	5,862 (20.9)	18,831 (92.3)	21,858 (92.1)	22,244 (91.3)
Australia	4,741 (66.6)	5,379 (69.8)	7,818 (71.3)	N/A	N/A	N/A	87 (1.6)	101 (1.7)	232 (2.5)	1,757 (24.7)	1,875 (24.3)	2,839 (25.9)	5,765 (81.0)	6,187 (80.3)	9,087 (82.9)
New Zealand	1,554 (67.4)	1,644 (69.4)	1,802 (70.5)	N/A	N/A	N/A	52 (2.7)	81 (4.0)	113 (5.2)	834 (36.5)	822 (34.7)	928 (36.3)	2,066 (89.6)	2,035 (85.9)	2,316 (90.5)
Singapore	1,649 (71.0)	1,828 (74.0)	2,110 (75.2)	90 (4.3)	110 (5.0)	178 (7.0)	34 (1.6)	41 (1.8)	69 (2.7)	377 (16.2)	432 (17.5)	419 (14.9)	2,211 (95.2)	2,349 (95.1)	2,688 (95.8)
South Korea	16,089 (58.2)	15,457 (57.0)	15,318 (56.6)	518 (2.0)	581 (2.3)	525 (2.1)	117 (0.5)	116 (0.5)	133 (0.5)	3,591 (13.0)	3,795 (14.0)	3,720 (13.7)	20,309 (73.4)	20,329 (75.0)	20,400 (75.3)
Japan	N/A	N/A	N/A	N/A	NA	NA	1,815 (1.6)	1,968 (1.7)	2,102 (1.8)	8,039 (6.5)	8,192 (6.6)	8,209 (6.5)	92,107 (74.6)	82,547 (66.8)	85,740 (67.5)
Germany	–	3,264 (62.6)	3,759 (62.0)	–	58 (2.7)	80 (3.0)	–	20 (0.9)	37 (1.4)	–	1,230 (23.6)	1,418 (23.4)	–	4,139 (79.4)	4,780 (78.8)
Ireland	1,483 (69.0)	1,514 (67.1)	1,508 (68.5)	334 (15.5)	386 (17.4)	423 (20.9)	131 (6.0)	134 (6.0)	132 (6.5)	450 (20.9)	501 (22.2)	440 (20.0)	1,898 (88.3)	1,944 (86.2)	1,900 (86.4)
Regional Registries															
Italy	393 (80.2)	360 (81.6)	360 (76.3)	9 (2.2)	8 (2.2)	17 (4.3)	4 (1.0)	5 (1.4)	6 (1.5)	84 (17.1)	83 (18.8)	91 (19.3)	461 (94.1)	410 (93.0)	436 (92.4)
Switzerland	167 (67.6)	158 (71.5)	150 (61.5)	41 (18.5)	39 (19.4)	40 (19.0)	14 (6.3)	13 (6.5)	13 (6.2)	45 (18.2)	47 (21.3)	63 (25.8)	198 (80.2)	193 (87.3)	209 (85.7)
France	1,511 (74.1)	1674 (69.7)	1894 (70.4)	35 (2.0)	56 (2.7)	51 (2.2)	N/A	N/A	N/A	552 (27.1)	569 (23.7)	606 (22.5)	N/A	1975 (82.2)	2136 (79.4)
Bosnia and Herzegovina	–	230 (73.0)	219 (63.7)	–	0	0	–	0	0	–	105 (33.3)	114 (33.1)	–	302 (95.9)	306 (89.0)

IQR denotes interquartile range; EMS: emergency medical services; AED: automated external defibrillator.

* We excluded EMS-witnessed OHCA from the denominators.

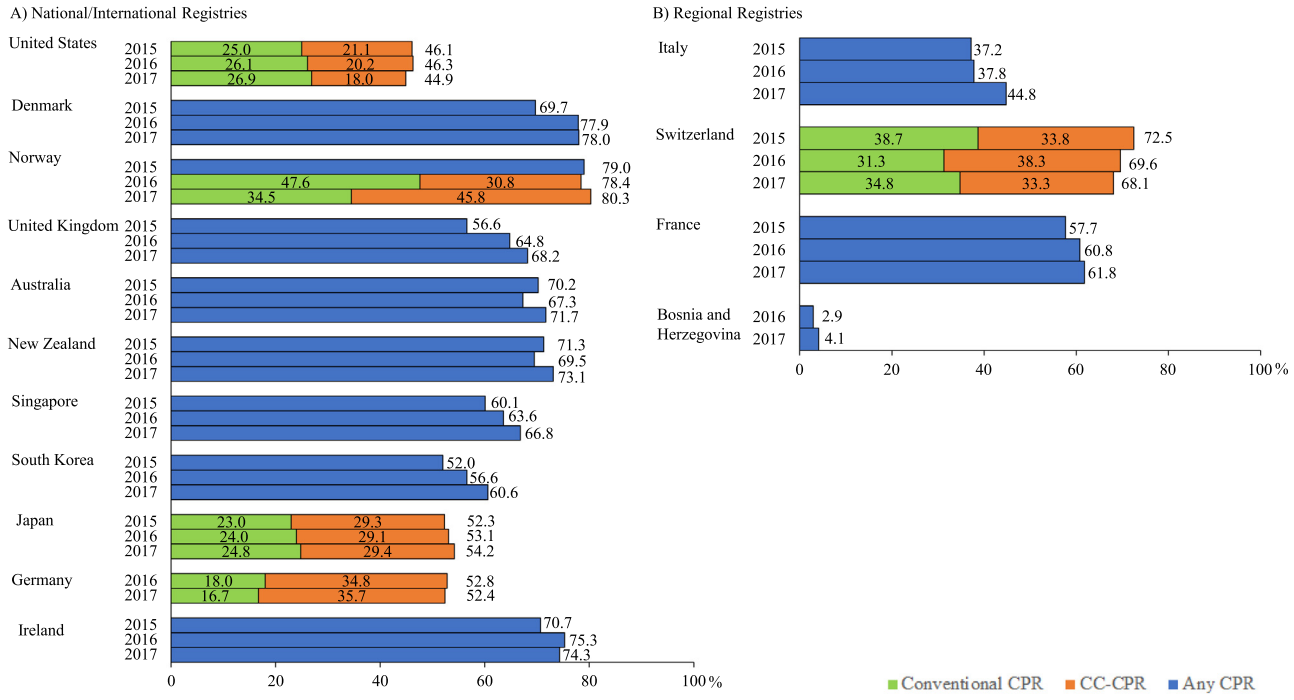

Fig. 2 – Temporal trend of bystander CPR among patients treated by EMS (we excluded EMS-witnessed OHCA from the denominators).
A) National/International Registries, B) Regional Registries.
CC-CPR denoted chest compression-only CPR, CPR; cardiopulmonary resuscitation, OHCA; out-of-hospital cardiac arrest, EMS; emergency medical services.

discharge or 30 days, we found a 3.3-fold difference (3.9% to 12.7%) in 2016 and a 4.9-fold difference (3.2% to 15.6%) in 2017. For bystander-witnessed shockable OHCA, we found a 2.1-fold difference (22.7% to 47.4%) in the survival outcome in 2016 and a 2.3-fold difference (20.3% to 46.2%) in 2017. For favourable functional outcome for bystander-witnessed shockable OHCA, there was a 2.5-fold difference (16.6% to 42.1%) in 2016 and a 2.3-fold difference (15.9% to 37.0%) in 2017. The Utstein template recommends bystander-witnessed shockable OHCA as a comparator group to measure EMS system efficacy because this group is less heterogeneous than all EMS-treated OHCAs.[10,11] In line with previous studies reporting that patient demographics, arrest characteristics, bystander and EMS responses, and hospital characteristics can partially explain the variation in patient outcomes after OHCA,[15–21] these factors could contribute to the outcome variation. Among patients for whom EMS providers were dispatched and confirmed OHCA (EMS-assessed OHCA), patients receiving resuscitation attempts vary widely across regions. For example, in Asia, 98.2% to 99.0% of EMS-assessed OHCA received resuscitation attempts by EMS providers,[22,23] while, in North America, Europe, and Oceania, 40.1% to 66.9% of EMS-assessed OHCA received resuscitation attempts, which may reflect differences in EMS systems, implementation of living wills, and culture across regions.[1,24,25] This difference in attempting resuscitation for EMS-assessed OHCAs may also be contributing to the regional variation in survival and favourable functional outcome. The discrepancies between the incidence of EMS treated OHCA and survival per 100,000 population observed in this study (e.g., high incidence of EMS treated OHCA and low incidence of survivors in Japan) might be partially explained by this difference of each regional EMS systems.

From 2016 to 2017, seven registries showed an increase in the survival from all EMS-treated OHCAs and eight registries showed a decrease. For bystander-witnessed shockable OHCA, seven registries showed an increase and seven registries showed a decrease in survival. Although previous studies showed improving temporal trends of patient outcomes after OHCA across multiple nations and regions,[26–34] less than half of registries in our study demonstrated an increase in survival from 2016 to 2017 for both all EMS-treated OHCA and bystander-witnessed shockable OHCA. Although the trend in a two-year period without accounting for confounders makes direct comparison difficult, the findings may imply an opportunity for further process improving interventions in each link of the *chain of survival*.

From 2016 to 2017, 11 registries showed an increase and four registries a decrease in the provision of bystander CPR. We observed a 27.0-fold difference in the provision of bystander CPR in 2016 (2.9% to 78.4%) and a 19.6-fold difference (4.1% to 80.3%) in 2017. Since some nations and regions showed a high incidence of provision of bystander CPR and AED use, there may be an opportunity to learn from these exemplars. System performance improvement with multifaceted interventions in training of bystander CPR and dispatchers was previously associated with increased provision of bystander CPR and improved patient outcomes.[35–37] Most recently, Taipei in Taiwan reported that provision of bystander CPR

Table 3 – Summary data for all EMS treated OHCA in Utstein core elements (process).

Country	Median Time from call to EMS arrival on scene, minute, median (IQR)			The time interval from incoming call to initiation of EMS CPR, minute, median (IQR)			Median Time from call to shock by EMS, minute, median (IQR)			The time interval from incoming call to hospital arrival*, minute, median (IQR)		
	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
National/International Registries												
United States	7.1 (5.1, 10.0)	7.1 (5.1, 10.0)	7.3 (5.3, 10.1)	N/A	N/A	N/A	N/A	N/A	N/A	40.0 (31.4, 51.0)	37.6 (30.0. 45.5)	38.3 (31.0. 46.4)
Denmark	N/A	7.0 (5.0, 10.0)	7.0 (5.0, 10.0)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Norway	9.0 (6.0, 14.0)	9.0 (7.0, 14.0)	9.0 (6.0, 13.0)	N/A	NA	NA	N/A	N/A	N/A	N/A	N/A	N/A
United Kingdom	6.1 (3.8, 9.3)	6.4 (4.0, 9.8)	6.5 (4.0, 10.0)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Australia	8.0 (6.0, 11.0)	8.0 (6.0, 11.0)	8.0 (6.0, 12.0)	N/A	N/A	N/A	N/A	N/A	N/A	65.0 (49.2, 88.2)	68.0 (52.0, 87.4)	61.0 (47.0, 82.0)
New Zealand	9.0 (7.0, 13.0)	8.0 (6.0, 12.2)	9.0 (6.9, 12.7)	N/A	NA	NA	N/A	N/A	N/A	58.0 (43.0, 79.0)	59.0 (45.0, 80.7)	62.0 (45.7, 85.3)
Singapore	9.0 (7.1, 11.5)	8.2 (6.4, 10,4)	8.3 (6.8, 10.3)	12.3 (10.1, 15.5)	12.0 (9.8, 15.4)	12.6 (10.1, 15.8)	16.6 (12.7, 23.9)	15.3 (12.1, 21.2)	15.6 (12.0, 21.7)	37.7 (33.0, 42.8)	38.2 (33.5, 43.2)	38.8 (33.8, 44.6)
South Korea	7.0 (5.0, 10.0)	7.0 (5.0,10.0)	7.0 (5.0, 10.0)	9 (6, 12)	9.0 (7.0, 13.0)	9.0 (7.0, 13.0)	10.0 (9.0, 14.0)	12.0 (9.0, 19.0)	12.0 (9.0, 19.0)	26.0 (21.0, 33.0)	28.0 (22.0, 36.0)	28.0 (23.0, 36.0)
Japan	7.0 (6.0, 9.0)	7.0 (6.0, 9.0)	7.0 (6.0, 9.0)	9.0 (7.0, 12.0)	9.0 (7.0, 12.0)	9.0 (7.0, 12.0)	12.0 (9.0, 20.0)	12.0 (9.0, 20.0)	12.0 (9.0, 20.0)	32.0 (26.0, 40.0)	32.0 (26.0, 40.0)	32.0 (26.0, 40.0)
Germany	–	7.0 (2.0, 9.0)	7.0 (2.0, 9.0)	–	8.0 (4.0, 12.0)	8.0 (4.0, 12.0)	–	11.0 (8.0, 14.0)	11.0 (8.0, 14.0)	–	63.0 (50.0, 76.0)	63.0 (50.0, 76.0)
Ireland	13.0 (9.0, 20.0)	13.0 (8.0, 19.0)	12.0 (8.0, 19.0)	NA	NA	NA	NA	NA	NA	51.0 (37.0, 70.0)	54.0 (40.0, 72.0)	56.0 (41.0, 79.0)
Regional Registries												
Italy	11.0 (8.0, 14.0)	10.0 (8.0, 13.0)	10.0 (8.0, 14.0)	13.0 (10, 21)	12.0 (9.0, 14.7)	11.0 (8.0, 15.0)	15.0 (11.0, 26.0)	15.0 (11.0, 25.5)	15.5 (11.0, 25.5)	66.0 (51.0, 87.0)	66.0 (51.0, 87.0)	69.5 (48.5, 87.0)
Switzerland	9.0 (6.0, 12.0)	9.0 (7.0, 13.0)	9.0 (7.0, 13.0)	N/A	10.0 (8.0,14.0)	10.0 (8.0,14.0)	11.0 (9.0, 15.0)	13.0 (10.0, 19.0)	14.0 (10.0, 18.0)	66.0 (49.0, 79.0)	59.0 (51.0, 81.0)	64.0 (49.0, 80.0)
France	N/A	10.0 (8.0, 13.0)	9.0 (7.0, 12.0)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bosnia and Herzegovina	–	14.5 (0, 29.0)	12.1 (0, 32.0)	–	14.5 (0, 29.0)	12.1 (0, 32.0)	–	14.5 (1.0, 30.0)	12.6 (1.0, 33.9)	–	29.5 (15.0, 74.0)	22.1 (17, 59.0)

Table 3 (continued)

Country	Total TTM, n (%)			Drugs given, n (%) Adrenaline			Amiodarone		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
National/International Registries									
United States	10,174 (19.2)	10,533 (17.1)	12,383 (16.2)	38,617 (73.0)	46,961 (76.2)	55,365 (72.6)	4,843 (9.2)	6,284 (10.2)	7,403 (9.7)
Denmark	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Norway	N/A	312 (11.2)	273 (9.8)	1,402 (61.0)	1,776 (63.6)	1,707 (61.6)	299 (13.0)	396 (14.2)	364 (13.1)
United Kingdom	N/A	N/A	N/A	17,125 (78.5)	15,003 (83.2)	15,761 (81.4)	2,116 (9.7)	2,019 (11.2)	1,928 (10.0)
Australia	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
New Zealand	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Singapore	133 (5.7)	125 (5.1)	128 (4.6)	1,866 (80.4)	1,499 (60.7)	1,522 (54.2)	27 (1.2)	0	0
South Korea	627 (2.3)	666 (2.5)	906 (3.3)	N/A	N/A	N/A	N/A	N/A	N/A
Japan	N/A	N/A	N/A	21,712 (17.6)	23,481 (19.0)	26,039 (20.5)	N/A	N/A	N/A
Germany	–	529 (10.1)	423 (7.0)	–	4,094 (78.5)	4,641 (76.5)	–	1,014 (19.4)	1,151 (19.0)
Ireland	N/A	N/A	N/A	1, 520 (70.7)	1, 578 (69.9)	1,622 (73.7)	222 (10.3)	271 (12.0)	261 (11.9)
Regional Registries									
Italy	N/A	N/A	N/A	223 (45.5)	204 (46.3)	205 (43.4)	43 (8.8)	41 (9.3)	38 (8.1)
Switzerland	N/A	N/A	N/A	205 (83.0)	139 (62.9)	150 (61.5)	36 (14.6)	19 (8.6)	30 (12.3)
France	271 (13.3)	370 (15.4)	332 (12.3)	1,522 (74.6)	1,749 (72.8)	1,962 (72.9)	241 (16.7)	280 (11.7)	334 (12.4)
Bosnia and Herzegovina	–	N/A	N/A	–	270 (85.7)	316 (91.9)	–	88 (27.9)	97 (28.2)

IQR denotes interquartile range; EMS: emergency medical services; CPR: cardiopulmonary resuscitation; TTM: targeted temperature management.

* Not in Utstein core element.

increased from 16.5% in 2008–2009 to 48.7% in 2016–2017, along with system-wide initiatives to optimise the community chain of survival. Survival to hospital discharge improved from 5.4% in 2008–2009 to 10.1% in 2016–2017. The system-wide initiatives include public-access AED implementation, web-based cardiac arrest registry development, public promotion of CPR and AED use, regionalised cardiac arrest care, and several other quality improvement initiatives.[38,39] This current knowledge highlights the importance of a scientific statement from the ILCOR and American Heart Association on the implementation of cardiac resuscitation systems of care that consist of interconnected community, EMS, and hospital efforts to measure and improve process and outcome of care for patients with cardiac arrest.[40,41] Recent studies have shown that smart phone activation of volunteer responders is associated with increased likelihood of receiving bystander CPR and AED shock delivery.[42,43] This innovative technology may increase the number of responding lay rescuers and be an essential tool to shorten the time to CPR and shock delivery.[44,45] Indeed, barriers for lay rescuers should also be identified and addressed to optimise the delivery of life-saving interventions.[46]

A critical step for any quality improvement programme to improve patient outcomes after OHCA is measuring and giving feedback on performance. Our results demonstrate that, to date, multiple national and regional OHCA registries are collecting data, using the standardised template. We intend to increase the number of participating registries and extend the scope to in-hospital cardiac arrest.

This report has several limitations. First, since we collected descriptive summary data, not patient-level data from each registry, our results have not been adjusted for confounders. Second, we relied on the data validation undertaken by each registry. As with all epidemiologic data, data integrity is a potential limitation. The varying incidences of OHCA may be due to differences in registration. The increase in both OHCA incidence and bystander CPR but unchanged frequency of shockable rhythm, as seen in Denmark and Singapore, may reflect increasing completeness of OHCA registration[47] or it might be due to a dilution effect since more bystander CPR could lead to a higher influx to the register. Third, although we attempted to include as many registries as possible, we were unable to include all population-based OHCA registries, and external validity to other regions and nations is a limitation. As we studied registries that have a dynamic denominator (e.g., growth of their population base) maximum of 3 years, it makes the determination of trends uncertain.

Conclusion

We observed an upward temporal trend in provision of bystander CPR in most OHCA registries. Although some registries showed favourable temporal trends in survival, less than half of registries in our study demonstrated such a trend. It appears there is opportunity for further process-improving interventions in each link of the chain of survival.

Conflict of interest

JPN is Editor-in-Chief, and GDP and JS are Editors of Resuscitation. The rest of authors report no conflicts of interest related specifically to this manuscript.

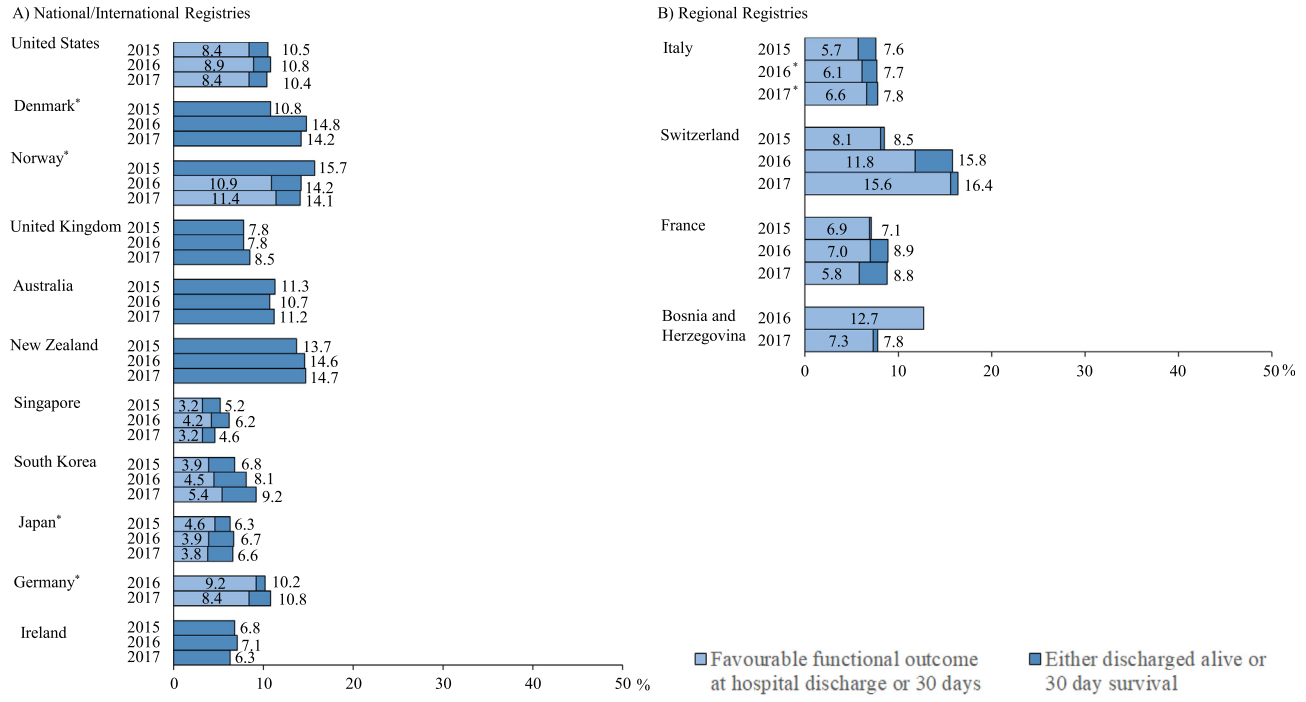

Fig. 3.1 – Temporal trend of survival and favourable functional outcome among all EMS treated OHCA including EMS witnessed.
A) National/International Registries, B) Regional Registries *Reported 30-day survival.
EMS denoted emergency medical services; OHCA; out-of-hospital cardiac arrest.

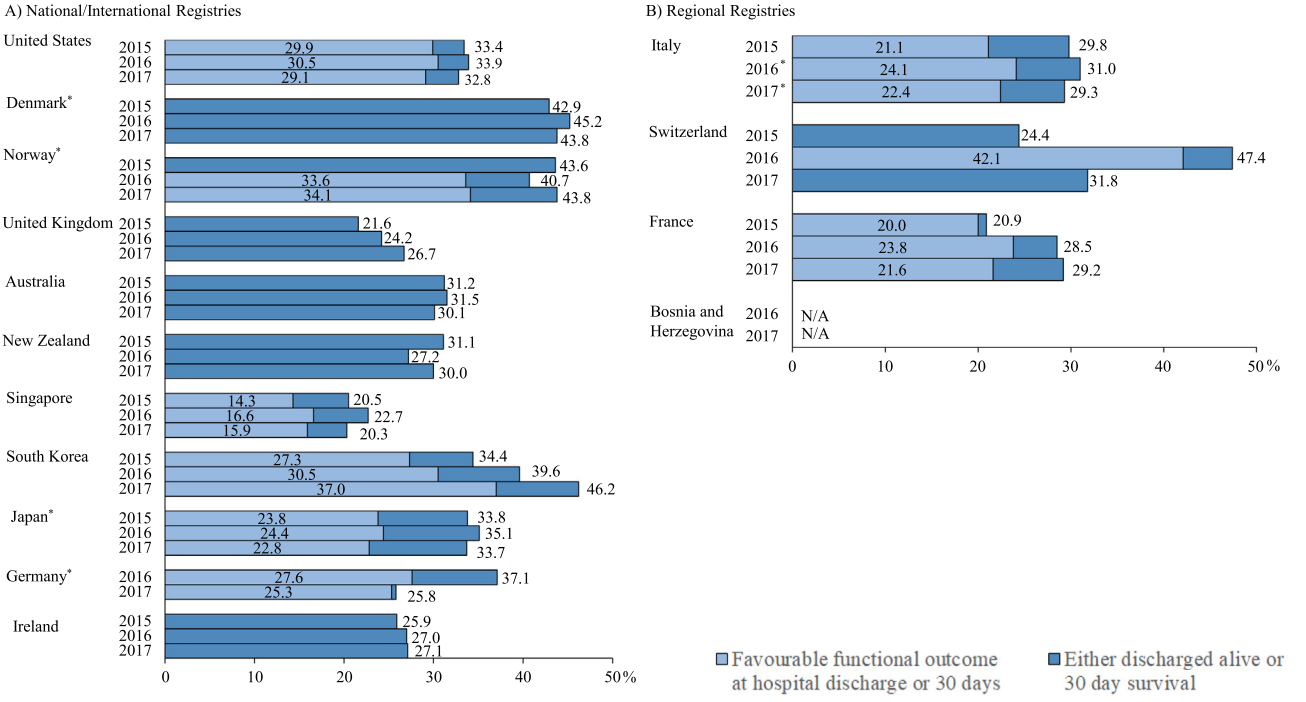

Fig. 3.2 – Temporal trend of survival and favourable functional outcome among shockable bystander witnessed excluding EMS witnessed.
A) National/International Registries, B) Regional Registries *Reported 30-day survival.
EMS denoted emergency medical services; OHCA; out-of-hospital cardiac arrest.

CRediT authorship contribution statement

Chika Nishiyama: Conceptualization, Methodology, Investigation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Tekeyuki Kiguchi:** Conceptualization, Methodology, Data curation, Resources, Writing – review & editing. **Masashi Okubo:** Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing. **Hajriz Alihodžić:** Investigation, Resources, Writing – review & editing. **Rabab Al-Araji:** Investigation, Resources, Writing – review & editing. **Enrico Baldi:** Methodology, Investigation, Resources, Writing – review & editing. **Frankie Beganton:** Investigation, Resources, Writing – review & editing. **Scott Booth:** Investigation, Resources, Writing – review & editing. **Janet Bray:** Methodology, Investigation, Resources, Writing – review & editing. **Erika Christensen:** Investigation, Resources, Writing – review & editing. **Ruggero Cresta:** Investigation, Resources, Writing – review & editing. **Judith Finn:** Methodology, Investigation, Resources, Writing – review & editing. **Jan-Thorsten Grasner:** Methodology, Investigation, Resources, Writing – review & editing. **Xavier Jouven:** Investigation, Resources, Writing – review & editing. **Karl B. Kern:** Methodology, Investigation, Resources, Writing – review & editing. **Ian Maconochie:** Methodology, Investigation, Resources, Writing – review & editing. **Siobhán Masterson:** Investigation, Resources, Writing – review & editing. **Bryan McNally:** Methodology, Investigation, Resources, Writing – review & editing. **Jerry P. Nolan:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Marcus Eng Hock Ong:** Methodology, Investigation, Resources, Writing – review & editing. **Gavin D. Perkins:** Methodology, Investigation, Resources, Writing – review & editing. **Jeong Ho Park:** Investigation, Resources, Writing – review & editing. **Patrick Ristau:** Investigation, Resources, Writing – review & editing. **Simone Savastano:** Investigation, Resources, Writing – review & editing. **Nur Shahidah:** Investigation, Resources, Writing – review & editing. **Sang Do Shin:** Investigation, Resources, Writing – review & editing. **Jasmeet Soar:** Methodology, Writing – review & editing, Supervision. **Ingvild Tjelmeland:** Methodology, Writing – review & editing, Supervision. **Martin O. Quinn:** Methodology, Writing – review & editing, Supervision. **Jan Wnent:** Methodology, Writing – review & editing, Supervision. **Myra H. Wyckoff:** Investigation, Resources, Writing – review & editing. **Taku Iwami:** Conceptualization, Methodology, Writing – review & editing, Funding acquisition, Project administration, Supervision.

Acknowledgement

We thank all who contribute participating registries for providing their valuable data. The authors would like to express their appreciation to the following for contributing valuable support: the ILCOR staff members, Bill Montgomery, Veronica Zamora, and Noelle Hutchins. We also thank Tatjana Jevtic from Emergency Medical Education Center of Canton of Sarajevo, Bosnia and Herzegovina to collect data set.

Financial Disclosure:

The authors have no financial relationships relevant to this manuscript to disclose.

Source of Funding

This manuscript received funding from the American Heart Association on behalf of ILCOR and a charge of Redcap was supported by Japan Resuscitation Council (JRC). Neither ILCOR nor JRC had no role in this study design, data collection, and analysis, or preparation of the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resuscitation.2023.109757.

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REFERENCES

1. Gräsner JT, Wnent J, Herlitz J, et al. Survival after out-of-hospital cardiac arrest in Europe - Results of the EuReCa TWO study. Resuscitation. 2020;148:218–26.
2. Kiguchi T, Okubo M, Nishiyama C, et al. Out-of-hospital cardiac arrest across the world: first report from the International Liaison Committee on Resuscitation (ILCOR). Resuscitation. 2020;152:39–49.
3. Virani SS, Alonso A, Aparicio HJ, et al. Heart Disease and Stroke Statistics-2021 Update: A Report From the American Heart Association. Circulation. 2021;143:e254–743.
4. Chamberlain D, Cummins RO. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the 'Utstein style'. European Resuscitation Council, American Heart Association, Heart and Stroke Foundation of Canada and Australian Resuscitation Council. Eur J Anaesthesiol. 1992;9:245–56.
5. Chamberlain DA, Cummins RO, Abramson NS, et al. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the 'Utstein style'. Prepared by a Task Force of Representatives from the European Resuscitation Council, American Heart Association, Heart and Stroke Foundation of Canada, Australian Resuscitation Council. Resuscitation. 1991;22:1–26.
6. Cummins RO, Chamberlain DA, Abramson NS, et al. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein Style. Task Force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. Ann Emerg Med. 1991;20:861–74.
7. Cummins RO, Chamberlain DA, Abramson NS, et al. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein Style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. Circulation. 1991;84:960–75.
8. Otto Q, Nolan JP, Chamberlain DA, Cummins RO, Soar J. Utstein Style for emergency care - the first 30 years. Resuscitation. 2021;163:16–25.
9. Perkins GD, Neumar R, Monsieurs KG, et al. The International Liaison Committee on Resuscitation-Review of the last 25 years and vision for the future. Resuscitation. 2017;121:104–16.
10. Perkins GD, Jacobs IG, Nadkarni VM, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care. Perioperative and Resuscitation. Circulation. 2015;132:1286–300.
11. Perkins GD, Jacobs IG, Nadkarni VM, et al. Cardiac Arrest and Cardiopulmonary Resuscitation Outcome Reports: Update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest: A Statement for Healthcare Professionals From a Task Force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care. Perioperative and Resuscitation. Resuscitation. 2015;96:328–40.
12. Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). Circulation. 2004;110:3385–97.
13. Jacobs I, Nadkarni V, Bahr J, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa). Resuscitation. 2004;63:233–49.
14. Nishiyama C, Brown SP, May S, et al. Apples to apples or apples to oranges? International variation in reporting of process and outcome of care for out-of-hospital cardiac arrest. Resuscitation. 2014;85:1599–609.
15. Callaway CW, Schmicker R, Kampmeyer M, et al. Receiving hospital characteristics associated with survival after out-of-hospital cardiac arrest. Resuscitation. 2010;81:524–9.
16. Carr BG, Kahn JM, Merchant RM, Kramer AA, Neumar RW. Inter-hospital variability in post-cardiac arrest mortality. Resuscitation. 2009;80:30–4.
17. Dyson K, Brown SP, May S, et al. International variation in survival after out-of-hospital cardiac arrest: a validation study of the Utstein template. Resuscitation. 2019;138:168–81.
18. Girotra S, van Diepen S, Nallamothu BK, et al. Regional variation in out-of-hospital cardiac arrest survival in the United States. Circulation. 2016;133:2159–68.
19. Okubo M, Schmicker RH, Wallace DJ, et al. Variation in survival after out-of-hospital cardiac arrest between emergency medical services agencies. JAMA Cardiol. 2018;3:989–99.
20. Rea TD, Cook AJ, Stiell IG, et al. Predicting survival after out-of-hospital cardiac arrest: role of the Utstein data elements. Ann Emerg Med. 2010;55:249–57.
21. Koyama S, Gibo K, Yamaguchi Y, Okubo M. Variation in survival after out-of-hospital cardiac arrest between receiving hospitals in Japan: an observational study. BMJ Open. 2019;9: e033919.
22. Okubo M, Kiyohara K, Iwami T, Callaway CW, Kitamura T. Nationwide and regional trends in survival from out-of-hospital cardiac arrest in Japan: A 10-year cohort study from 2005 to 2014. Resuscitation. 2017;115:120–8.
23. Ong ME, Shin SD, De Souza NN, et al. Outcomes for out-of-hospital cardiac arrests across 7 countries in Asia: The Pan Asian Resuscitation Outcomes Study (PAROS). Resuscitation. 2015;96:100–8.
24. Bray J, Howell S, Ball S, et al. The epidemiology of out-of-hospital cardiac arrest in Australia and New Zealand: a binational report from

the Australasian Resuscitation Outcomes Consortium (Aus-ROC). Resuscitation. 2022;172:74–83.
25. Daya MR, Schmicker RH, Zive DM, et al. Out-of-hospital cardiac arrest survival improving over time: Results from the Resuscitation Outcomes Consortium (ROC). Resuscitation. 2015;91:108–15.
26. Blom MT, Beesems SG, Homma PC, et al. Improved survival after out-of-hospital cardiac arrest and use of automated external defibrillators. Circulation. 2014;130:1868–75.
27. Buick JE, Drennan IR, Scales DC, et al. Improving temporal trends in survival and neurological outcomes after out-of-hospital cardiac arrest. Circ Cardiovasc Qual Outcomes. 2018;11:e003561.
28. Chan PS, McNally B, Tang F, Kellermann A. Recent trends in survival from out-of-hospital cardiac arrest in the United States. Circulation. 2014;130:1876–82.
29. Fothergill RT, Watson LR, Chamberlain D, Virdi GK, Moore FP, Whitbread M. Increases in survival from out-of-hospital cardiac arrest: a five year study. Resuscitation. 2013;84:1089–92.
30. Grunau B, Kawano T, Dick W, et al. Trends in care processes and survival following prehospital resuscitation improvement initiatives for out-of-hospital cardiac arrest in British Columbia, 2006–2016. Resuscitation. 2018;125:118–25.
31. Kitamura T, Iwami T, Kawamura T, et al. Nationwide improvements in survival from out-of-hospital cardiac arrest in Japan. Circulation. 2012;126:2834–43.
32. Ro YS, Shin SD, Song KJ, et al. A trend in epidemiology and outcomes of out-of-hospital cardiac arrest by urbanization level: a nationwide observational study from 2006 to 2010 in South Korea. Resuscitation. 2013;84:547–57.
33. van Diepen S, Girotra S, Abella BS, et al. Multistate 5-year initiative to improve care for out-of-hospital cardiac arrest: primary results from the HeartRescue Project. J Am Heart Assoc. 2017;6:e005716.
34. Okubo M, Atkinson EJ, Hess EP, White RD. Improving trend in ventricular fibrillation/pulseless ventricular tachycardia out-of-hospital cardiac arrest in Rochester, Minnesota: A 26-year observational study from 1991 to 2016. Resuscitation. 2017;120:31–7.
35. Del Rios M, Weber J, Pugach O, et al. Large urban center improves out-of-hospital cardiac arrest survival. Resuscitation. 2019;139:234–40.
36. Wissenberg M, Lippert FK, Folke F, et al. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. JAMA. 2013;310:1377–84.
37. Ko YC, Hsieh MJ, Ma MH, Bigham B, Bhanji F, Greif R. The effect of system performance improvement on patients with cardiac arrest: A systematic review. Resuscitation. 2020;157:156–65.
38. Lin HY, Chien YC, Lee BC, et al. Outcomes of out-of-hospital cardiac arrests after a decade of system-wide initiatives optimising community chain of survival in Taipei city. Resuscitation. 2022;172:149–58.
39. Huebinger R, Wang HE. Cardiac arrest systems of care; shining in the spotlight. Resuscitation. 2022;172:159–61.
40. McCarthy JJ, Carr B, Sasson C, et al. Out-of-hospital cardiac arrest resuscitation systems of care: A Scientific Statement From the American Heart Association. Circulation. 2018;137:e645–60.
41. Greif R, Bhanji F, Bigham BL, et al. Education, Implementation, and Teams: 2020 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation. 2020;142:S222–83.
42. Stieglis R, Zijlstra JA, Riedijk F, et al. Alert system-supported lay defibrillation and basic life-support for cardiac arrest at home. Eur Heart J. 2022;43:1465–74.
43. Andelius L, Malta Hansen C, Lippert FK, et al. Smartphone activation of citizen responders to facilitate defibrillation in out-of-hospital cardiac arrest. J Am Coll Cardiol. 2020;76:43–53.
44. Brooks SC, Clegg GR, Bray J, et al. Optimizing outcomes after out-of-hospital cardiac arrest with innovative approaches to public-access defibrillation: a scientific statement from the International Liaison Committee on Resuscitation. Resuscitation. 2022;172:204–28.
45. Berglund E, Hollenberg J, Jonsson M, et al. Effect of Smartphone Dispatch of Volunteer Responders on Automated External Defibrillators and Out-of-Hospital Cardiac Arrests: The SAMBA Randomized Clinical Trial. JAMA Cardiol. 2023;8:81–8.
46. Dainty KN, Colquitt B, Bhanji F, et al. Understanding the importance of the lay responder experience in out-of-hospital cardiac arrest: A Scientific Statement From the American Heart Association. Circulation. 2022;145:e852–67.
47. Jensen TW, Blomberg SN, Folke F, et al. The National Danish Cardiac Arrest Registry for Out-of-Hospital Cardiac Arrest - A Registry in Transformation. Clin Epidemiol. 2022;14:949–57.