Improving Outcomes of Witnessed Out-of-Hospital Cardiac Arrest After Implementation of International Liaison Committee on Resuscitation 2010 Consensus: A Nationwide Prospective Observational Population-Based Study

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***Background*—**The International Liaison Committee on Resuscitation (ILCOR) periodically updates the consensus recommendations for cardiopulmonary resuscitation to improve the outcomes of out-of-hospital cardiac arrest (OHCA). However, little is known about the differences in outcomes of witnessed OHCA following the publication of the ILCOR 2010 and the ILCOR 2005 recommendations.

***Methods and Results*—**We enrolled 241 990 adults who experienced witnessed OHCA between 2007 and 2013 from a prospective, nation-wide, population-based cohort database in Japan. We compared neurologically favorable 1-month survival and 1-month survival rates post-OHCA by dividing the study period into 2 categories: the ILCOR 2005 period and ILCOR 2010 period. The associations between guideline periods and outcomes were estimated using multivariable logistic regression analysis and reported as adjusted odds ratio and 95% CI. Among 241 990 patients examined in this study, OHCA was witnessed in 44 706 patients (18%) by emergency medical service personnel and in 197 284 patients (82%) by citizens. Compared with the ILCOR 2005 period, the neurologically favorable 1-month survival rate improved from 4.6% to 5.2% (adjusted odds ratio, 1.54; 95% CI, 1.42–1.67; *P*<0.001), and the 1-month survival rate improved from 9.0% to 9.7% (adjusted odds ratio, 1.34; 95% CI, 1.27–1.42; *P*<0.001) in the ILCOR 2010 period. These improvements were also shown in patients receiving conventional versus compression-only cardiopulmonary resuscitation.

***Conclusions*—**Outcomes of witnessed OHCA were better in the ILCOR 2010 period than those in the ILCOR 2005 period. Our results can provide baseline data for many future prospective studies. **(*J Am Heart Assoc*. 2017;6:e004959. DOI: 10.1161/JAHA.116.004959.)**

Key Words: cardiopulmonary resuscitation • International Liaison Committee on Resuscitation • out-of-hospital cardiac arrest

Out-of-hospital cardiac arrest (OHCA) is an important health problem worldwide, affecting ≈300 000 in the United States, 250 000 in Europe, and 100 000 in Japan annually; however, its outcome remains poor despite recent advances in treatment strategies.[1–3] To improve outcomes post-OHCA, the International Liaison Committee on Resuscitation (ILCOR) was formed in 1992 to provide a forum for analysis and discussion of resuscitation research among principal resuscitation councils and international resuscitation experts. ILCOR develops the consensus on science with treatment recommendations for CPR and updates them periodically. ILCOR defers to the member Councils the development of Council-specific CPR Guidelines that take into consideration local factors, healthcare systems, training capabilities, and cost. Publication and implementation of the CPR guidelines based on the ILCOR 2005 consensus (updated from the ILCOR 2000 consensus) were associated with improvement in outcome from OHCA.[1,2] Thereafter, the updated ILCOR 2010 consensus (updated from the ILCOR 2005 consensus) emphasized the importance of: (1) changing the "A-B-C" (airway, breathing, chest compressions) sequence

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Clinical Perspective

What Is New?

- Comparing outcomes of witnessed out-of-hospital cardiac arrest following publication of the International Liaison Committee on Resuscitation (ILCOR) 2005 consensus recommendations to those following the ILCOR 2010 consensus recommendations using a nation-wide database is new.

What Are the Clinical Implications?

- Our results could be a very informative reference while assessing the impact of the updated ILCOR 2015 consensus recommendations.

to the "C-A-B" (chest compressions, airway, breathing) sequence; (2) educational training and monitoring of actual CPR performance to ensure provision of high-quality CPR; and (3) increased availability of publicly accessible automated external defibrillators (AEDs).[1,2]

However, even with the widespread dissemination of the ILCOR 2010 consensus recommendations, little is known about whether the changes implemented following this update were associated with changes in the outcome of witnessed OHCA. The objective of the present study was to compare outcomes of witnessed OHCA following publication of the ILCOR 2005 consensus recommendations plus the 2006 Japan CPR recommendations to the outcome from OHCA following the ILCOR 2010 consensus recommendations plus the 2010 Japan CPR recommendations, by using a prospective, nation-wide, Utstein-style data set from the Fire and Disaster Management Agency of Japan. It is important to identify whether the ILCOR 2010 consensus recommendations have influenced cardiac arrest survival at this time of the implementation of the ILCOR 2015 consensus.

Methods

Study Patients

Between 2007 and 2013, we enrolled 241 990 adult patients with OHCA witnessed by EMS personnel (n=44 706) or bystanders (n=197 284) with initial documented rhythm data from the All-Japan Utstein Registry (n=841 732; Figure 1). The All-Japan Utstein Registry is a prospective, nation-wide, population-based cohort database of all OHCA patients in Japan. The data set was collected from the standardized style used by the Utstein database.[3–6] Among 841 732 OHCA patients, we excluded pediatric patients younger than 18 years (n=12 850), patients without resuscitation attempts (n=13 659), patients missing cardiac origin data (n=3), patients without witnesses to OHCA (n=480 304) or information regarding bystander detail (n=65 098), patients without initial rhythm data (n=27 786), and patients without outcome information (n=42) to identify whether survival from OHCA changed during the 2 sampling periods. Finally, 241 990 patients with witnessed OHCA were enrolled and analyzed in this study (Figure 1). The ethics committee at Osaka University Graduate School of Medicine (Osaka, Japan) approved the study (Approval No. 16064), and the requirement of written informed consent was waived. The study was performed in accord with the Declaration of Helsinki.

Japanese CPR guidelines were developed and released by the Japan CPR Guideline Committee in October 2006 based on the ILCOR 2005 consensus. Thus, there was a 1-year delay between the publication of the 2005 ILCOR consensus recommendations and the publication of the 2006 Japan CPR guidelines. In October 2010, the Japan CPR guidelines were published simultaneously with the ILCOR 2010 consensus recommendations. Therefore, in this study, we assumed that CPR was performed based on the ILCOR 2005 consensus between 2007 and 2010 (ILCOR 2005 period group) and CPR was performed based on the ILCOR 2010 consensus between 2011 and 2013 (ILCOR 2010 period group), even though there might have been a crossover period between when the new guidelines were introduced and when complete implementation occurred.[7] Details of the Japanese EMS system have been described elsewhere.[5,6] We defined cardiac arrest as the cessation of cardiac mechanical activity confirmed by the absence of signs of circulation.[3,4] Diagnoses of cardiac or noncardiac origin were clinically made by physicians in collaboration with EMS personnel by excluding the possibility of noncardiac causes in accord with the Utstein-style international guidelines.[3–6] This means that the diagnosis of cardiac origin was made when there was no evidence of a noncardiac cause, and any other information regarding comorbidities or underlying conditions was not available.[3–6]

Japan has an area of ≈378 000 km^2, and its population was ≈127 million in 2013. There were 770 fire stations with dispatch centers in 2013; EMS is provided by municipal governments. EMS is available 24 hours per day, 365 days per year. When people call emergency services for an ambulance, it will be dispatched from the nearest fire station with 3 emergency providers, with at least 1 highly trained prehospital emergency care provider.

The All-Japan Utstein registry is a mandatory registry and includes data on all those with EMS-treated cardiac arrest in Japan.[5,6] EMS providers do not cease resuscitation in the field. Resuscitation is attempted for all patients in cardiac arrest unless death is obvious, such as in the case of

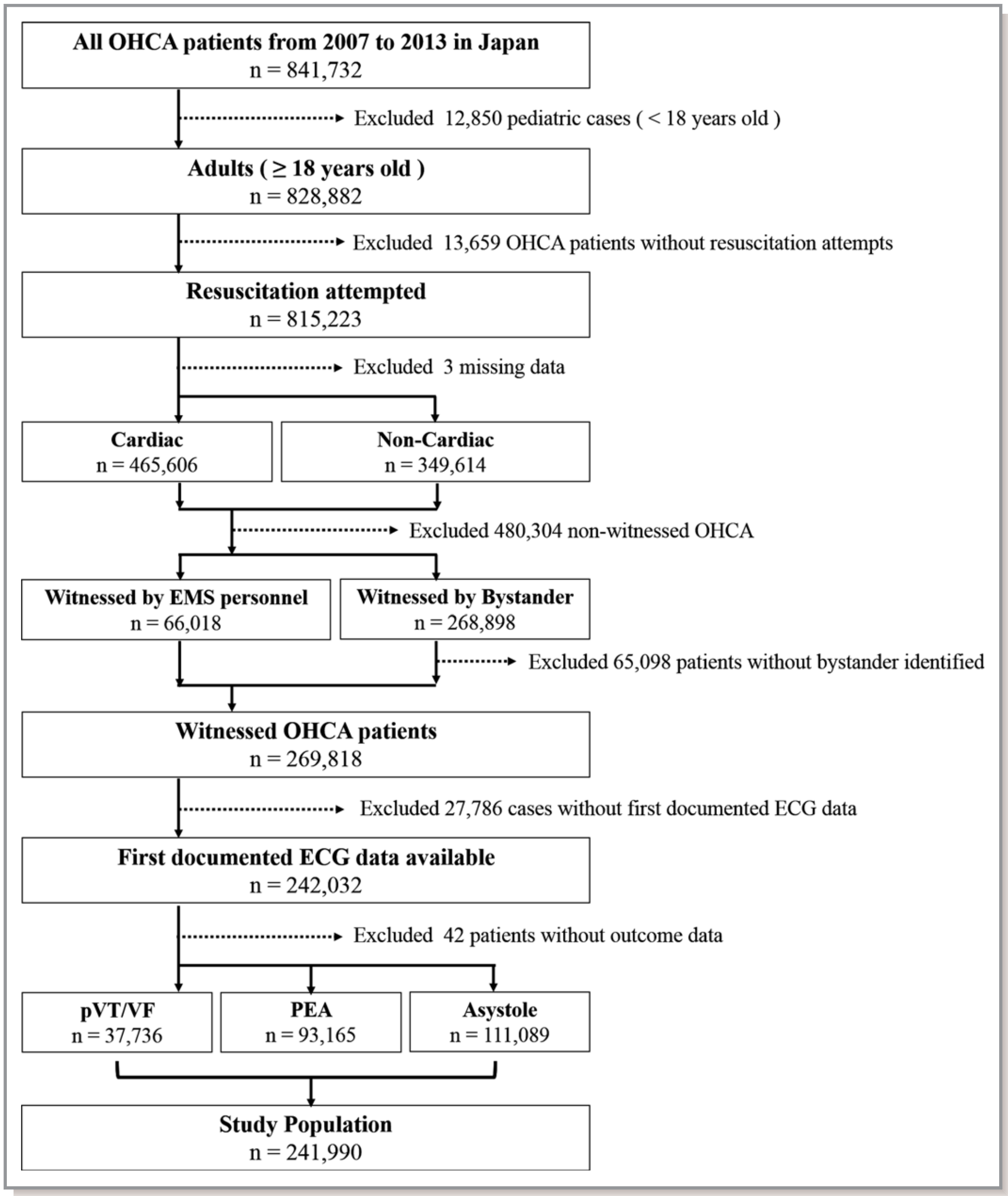

Figure 1. Patient selection flow. OHCA indicates out-of-hospital cardiac arrest; PEA, pulseless electrical activity; pVT/VF, pulseless ventricular tachycardia and ventricular fibrillation.

decapitation, incineration, decomposition, rigor mortis, or the presence of dependent cyanosis.[5,6]

Data Collection

We collected the following clinical data from the All-Japan Utstein Registry: age; sex; enrollment year; origin of arrest (cardiac or noncardiac); type of bystander based on the Utstein Style (family, passerby, friend, and colleague); type of CPR procedure including bystander AED use, which indicates that bystanders delivered shock using AED; first documented cardiac rhythm (shockable or nonshockable); EMS treatments before hospital arrival, such as administration of epinephrine and the use of advanced airway management devices; EMS response time (time from emergency call to first contact with a patient); and hospital arrival time (time from emergency call to patient arrival at a hospital). Both conventional and chest compression–only CPR were considered bystander CPR. The first documented rhythms were classified into 2 categories according to the ILCOR consensus. Those included shockable rhythms defined as pulseless ventricular tachycardia or ventricular fibrillation and nonshockable rhythms, including pulseless electrical activity or asystole, respectively. When bystanders delivered shocks using publicly accessible AEDs, the patient's first documented rhythm was regarded as shockable rhythm.

Outcomes

The primary outcome measure was neurologically favorable 1-month survival and the secondary outcomes were 1-month survival and prehospital return of spontaneous circulation (ROSC). Neurological outcome was determined at 1 month after successful resuscitation with the Glasgow–Pittsburg cerebral performance category system: category 1, good cerebral performance; category 2, moderate cerebral disability; category 3, severe cerebral disability; category 4, coma or vegetative state; and category 5, death. Glasgow–Pittsburg cerebral performance scale categories 1 and 2 were defined as neurologically favorable in this study.[3,4]

Statistical Analysis

Categorical data are presented as percentage (%), and continuous data are presented as medians (25th–75th percentiles). The chi-square test or Wilcoxon rank-sum test was used for comparisons of categorical and continuous data between groups, respectively. We divided our patients into 2 groups: ILCOR 2005 period and ILCOR 2010 period. Then, we evaluated and compared patient backgrounds and outcomes between the 2 groups. For comparisons of the type of bystander (citizen, which consisted of family, passerby, friend, and colleague) and type of CPR procedure (which consisted of conventional, compression-only, and respiratory-only), P values from the chi-square test for contingency table were evaluated. Outcomes associated with the ILCOR 2010 consensus guidelines period were compared to those associated with the ILCOR 2005 consensus guidelines period using a multivariable logistic regression model and presented as adjusted odds ratio (OR) and 95% CI. Adjusted covariates included: age; sex; enrollment year; cardiac versus noncardiac; type of bystander and CPR attempt by bystander, if appropriate; initial rhythm, if appropriate (shockable versus nonshockable); EMS treatments, including epinephrine and advanced airway management; EMS response time; and hospital arrival time; $P<0.05$ was considered statistically significant. To evaluate the differences among the maturation cycles of the guideline iterations, we performed a multivariable logistic regression analysis including a cross-product term between the version of ILCOR consensus and the maturation cycle of the guideline. Adjustments were performed similarly to those described for the above logistic regression model. We conducted all statistical analyses by using the R software package (version 3.1.0; R Development Core Team).

Results

Table 1 shows patient characteristics of the study population. Among 241 990 patients examined in this study, 44 706 patients (18%) had OHCA witnessed by EMS personnel and 197 284 patients (82%) had OHCA witnessed by citizens. Median age was older for those with OHCA during the ILCOR 2010 period than during the ILCOR 2005 period. Patients were more likely to be male during the ILCOR 2005 period. Among patients with OHCA witnessed by citizens, more than 80% of OHCA instances were witnessed by family members. Public AED use was more common during the ILCOR 2010 period. Patients received more-aggressive prehospital EMS treatments, such as epinephrine injection, during the ILCOR 2010 period than during the ILCOR 2005 period; however, this did not include advanced airway management device implantation in patients with OHCA witnessed by citizens. EMS response time and hospital arrival time was longer during the ILCOR 2010 period than during the ILCOR 2005 period.

Table 2 and Figure 2 show the changes in neurologically favorable 1-month survival, 1-month survival, and prehospital ROSC achievement rate from the ILCOR 2005 period to the ILCOR 2010 period. Neurologically favorable 1-month survival, 1-month survival, and prehospital ROSC rates improved significantly between these 2 study periods, from 4.6% to 5.2% (adjusted OR, 1.54; 95% CI, 1.42–1.67; $P<0.001$), from 9.0% to 9.7% (adjusted OR, 1.34; 95% CI, 1.27–1.42; $P<0.001$), and from 12.1% to 14.9% (adjusted OR, 1.38; 95% CI, 1.32–1.45; $P<0.001$), respectively. These improvements were also found in each subgroup, such as patients with OHCA witnessed by EMS personnel and citizens, or patients with or without shockable rhythms. For example, neurologically favorable 1-month survival, 1-month survival, and prehospital ROSC rates improved in patients with OHCA witnessed by EMS personnel from 6.9% to 7.7% (adjusted OR, 1.35; 95% CI, 1.16–1.58; $P<0.001$), from 11.7% to 12.5% (adjusted OR, 1.29; 95% CI, 1.15–1.45; $P<0.001$), and from 13.7% to 16.6% (adjusted OR, 1.29; 95% CI, 1.16–1.44; $P<0.001$), respectively. Significant ($P<0.05$) improvements in outcomes of citizen-witnessed OHCA occurred in every citizen category with the exception of 1-month survival for those with OHCA witnessed by a passerby, and prehospital ROSC for those with OHCA that was witnessed by a friend. In addition, the improvements in outcomes in the ILCOR 2010 period tended to be greater for patients with OHCA witnessed by citizens than by EMS, and it also tended to be greater for patients with shockable rhythm than for those with nonshockable rhythm. Furthermore, improvements in outcomes were common in each guideline maturation cycle (Table 3), and there were no obvious improvements in outcomes between patients who achieved prehospital ROSC in the ILCOR 2010 period and the ILCOR 2005 period (Figure 3).

Table 4 provides data on patients receiving conventional CPR versus chest compression–only CPR. Outcomes were better for patients receiving conventional CPR, across all outcomes and all time periods. Conventional CPR was

Table 1. Patient Characteristics

Parameters	Witnessed by EMS			Witnessed by Citizen		
	ILCOR 2005 (n=24 434)	ILCOR 2010 (n=20 272)	*P* Value	ILCOR 2005 (n=109 601)	ILCOR 2010 (n=87 683)	*P* Value
Age	75 (63, 84)	77 (64, 85)	<0.001	76 (64, 84)	77 (65, 85)	<0.001
Male	14 849 (60.8)	12 059 (59.5)	0.006	70 671 (64.5)	55 993 (63.8)	0.001
Enrollment						
2007	5583 (22.8)	…	…	26 362 (24.1)	…	…
2008	5761 (23.6)	…	…	26 832 (24.5)	…	…
2009	6216 (25.4)	…	…	27 047 (24.7)	…	…
2010	6874 (28.1)	…	…	29 360 (26.8)	…	…
2011	…	6779 (33.4)	…	…	29 645 (33.8)	…
2012	…	6699 (33.0)	…	…	29 200 (33.3)	…
2013	…	6794 (33.5)	…	…	28 838 (32.9)	…
Cardiac	13 125 (53.7)	11 337 (55.9)	<0.001	63 341 (57.8)	52 431 (59.8)	<0.001
Citizen-witnessed arrest						<0.001
Family	…	…	…	91 174 (83.2)	73 672 (84.0)	
Passerby	…	…	…	7801 (7.1)	6056 (6.9)	
Friend	…	…	…	5575 (5.1)	4059 (4.6)	
Colleague	…	…	…	5051 (4.6)	3896 (4.4)	
Perform CPR	…	…	…	44 098 (40.3)	36 202 (41.3)	<0.001
CPR procedure						<0.001
Conventional	…	…	…	10 425 (9.5)	4765 (5.4)	
Compression-only	…	…	…	32 997 (30.1)	31 130 (35.5)	
Respiratory-only	…	…	…	676 (0.6)	307 (0.4)	
Public AED	…	…	…	970 (2.2)*	1276 (3.5)*	<0.001
Shockable rhythm	3056 (12.5)	2345 (11.6)	0.002	18 134 (16.5)	14 201 (16.2)	0.037
EMS treatments						
Epinephrine	1578 (6.5)	2520 (12.4)	<0.001	15 563 (14.2)	21 229 (24.2)	<0.001
Advanced AWM	6826 (27.9)	5561 (27.4)	0.235	52 409 (47.8)	38 923 (44.4)	0.001
EMS response, min	8 (6, 10)	8 (6, 11)	<0.001	8 (6, 10)	8 (7, 11)	<0.001
Hospital arrival, min	32 (25, 41)	34 (27, 43)	<0.001	31 (25, 39)	33 (26, 41)	<0.001

Categorical data are presented as percentage (%) and continuous data are presented as medians (25th–75th percentiles). The variable citizen-witnessed arrest consisted of 4 subcategories of family, passerby, friend, and colleague. AED indicates automated external defibrillator; AWM, airway management; ILCOR, International Liaison Committee on Resuscitation.
*Denominators are numbers of patients who received CPR (numbers at the above row).

associated with significantly ($P<0.05$) better outcomes than chest compression–only CPR even after adjustments of patient backgrounds with the exception of neurologically favorable 1-month survival during early cycle.

Discussion

In the present study, we compared outcomes after OHCA by dividing study patients into 2 categories: ILCOR 2005 and ILCOR 2010 periods using the prospective, nation-wide Utstein-style data set in Japan by enrolling a total of 241 990 patients. The key findings of the present study are as follows: (1) clinical outcomes of patients with witnessed OHCA improved in the updated ILCOR 2010 period; (2) improvement in clinical outcomes was observed for patients with OHCA witnessed by both EMS personnel and citizens regardless of initial rhythm; (3) improved outcomes with the updated guidelines tended to be greater for patients with OHCA witnessed by citizens than for those by EMS; and (4) improved outcomes with the updated guidelines tended to be

Table 2. Associations of the ILCOR Update and Clinical Outcomes in the Entire Cohort

Parameters	Achieve Rate ILCOR 2005 Period	Achieve Rate ILCOR 2010 Period	Adjusted OR	95% CI	*P* Value
Neurologically favorable 1-month survival	4.6	5.2	1.54	1.42 to 1.67	<0.001
EMS-witnessed arrest	6.9	7.7	1.35	1.16 to 1.58	<0.001
Citizen-witnessed arrest	4.1	4.6	1.63	1.49 to 1.79	<0.001
Family	3.0	3.4	1.58	1.41 to 1.77	<0.001
Passerby	6.4	8.3	1.63	1.22 to 2.19	0.001
Friend	9.4	10.8	1.67	1.24 to 2.25	<0.001
Colleague	14.0	15.9	2.02	1.55 to 2.63	<0.001
Conventional CPR	7.8	10.9	2.66	2.03 to 3.50	<0.001
Compression-only CPR	5.2	6.0	1.76	1.50 to 20.6	<0.001
pVT/VF	20.6	23.6	1.58	1.42 to 1.75	<0.001
PEA/asystole	1.6	1.9	1.48	1.30 to 1.68	<0.001
One-month survival	9.0	9.7	1.34	1.27 to 1.42	<0.001
EMS-witnessed arrest	11.7	12.5	1.29	1.15 to 1.45	<0.001
Citizen-witnessed arrest	8.4	9.0	1.37	1.28 to 1.46	<0.001
Family	7.2	7.6	1.36	1.26 to 1.47	<0.001
Passerby	11.3	12.6	1.20	0.95 to 1.51	0.120
Friend	14.5	16.2	1.35	1.07 to 1.72	0.012
Colleague	19.6	21.7	1.67	1.32 to 2.11	<0.001
Conventional CPR	12.8	16.5	2.13	1.72 to 2.63	<0.001
Compression-only CPR	9.6	10.6	1.47	1.31 to 1.65	<0.001
pVT/VF	29.3	32.6	1.48	1.36 to 1.62	<0.001
PEA/asystole	5.2	5.5	1.24	1.15 to 1.34	<0.001
Prehospital ROSC	12.1	14.9	1.38	1.32 to 1.45	<0.001
EMS-witnessed arrest	13.7	16.6	1.29	1.16 to 1.44	<0.001
Citizen to witnessed arrest	11.8	14.6	1.42	1.34 to 1.50	<0.001
Family	10.9	13.6	1.42	1.33 to 1.51	<0.001
Passerby	12.6	16.0	1.43	1.16 to 1.77	<0.001
Friend	16.8	20.1	1.20	0.97 to 1.48	0.101
Colleague	20.8	24.3	1.64	1.33 to 20.4	<0.001
Conventional CPR	15.9	22.1	1.83	1.52 to 2.21	<0.001
Compression-only CPR	12.9	16.1	1.53	1.39 to 1.70	<0.001
pVT/VF	30.7	35.1	1.39	1.27 to 1.52	<0.001
PEA/asystole	8.6	11.3	1.36	1.28 to 1.44	<0.001

Adjusted OR of ILCOR 2010 vs ILCOR 2005 for neurologically favorable 1-month survival, 1-month survival, and prehospital ROSC. Adjusted covariates included age; sex; enrollment year; cardiac vs noncardiac; type of bystander and CPR attempt by bystander if appropriate; initial rhythm if appropriate (shockable vs nonshockable); EMS treatments, including epinephrine administration and advanced airway management; EMS response time; and hospital arrival time. The variable citizen-witnessed arrest included 4 subcategories: family, passerby, friend, and colleague. ILCOR indicates International Liaison Committee on Resuscitation; OR, odds ratio; PEA, pulseless electrical activity; pVT/VF, pulseless ventricular tachycardia/ventricular fibrillation; ROSC, return of spontaneous circulation.

greater for patients with shockable rhythm than with nonshockable rhythm. These findings may be the result of a variety of factors including changes with the updated ILCOR 2010 consensus, which emphasized the importance of chest compressions (described as the "C-A-B" sequence), educational training to improve the quality of CPR and use of publicly accessible AEDs, as well as other important changes such as increased bystander AED use, emphasis on high-

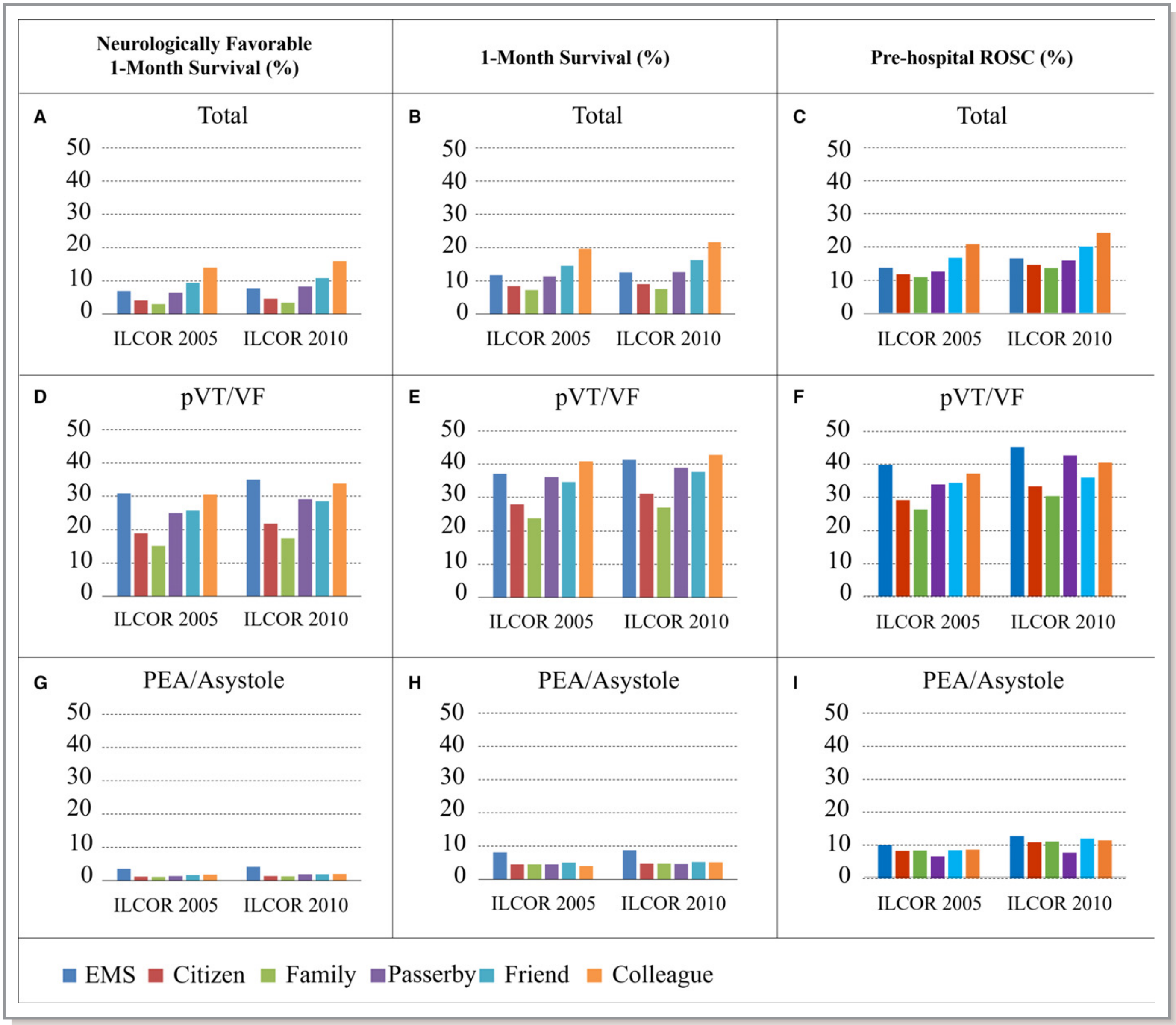

Figure 2. Clinical outcomes after OHCA in ILCOR 2005 and ILCOR 2010 guideline periods. Neurologically favorable 1-month survival (A, D, and G), 1-month survival (B, E and H), and prehospital ROSC achievement rate (C, F, and I) in the entire cohort, patients with shockable, and nonshockable rhythms, respectively. ILCOR indicates International Liaison Committee on Resuscitation; OHCA, out-of-hospital cardiac arrest; PEA, pulseless electrical activity; pVT/VF, pulseless ventricular tachycardia/ventricular fibrillation; ROSC, return of spontaneous circulation.

quality CPR, and improved advanced life support and postcardiac arrest care.

The ILCOR 2010 consensus recommended rearranging the order of CPR steps from the "A-B-C" sequence in the ILCOR 2005 consensus to the "C-A-B" sequence. In adults with sudden, witnessed OHCA, initial arterial oxygen content is high, so chest compressions (to create blood flow) are initially more important than ventilation in the first minutes of sudden arrest. Bystander attempts to administer rescue breaths will delay the onset of chest compressions, particularly if the bystander is not well trained in delivery of rescue breaths.[8–15] The change in CPR sequence likely contributed to the improved outcomes. For example, Marsch et al compared the "A-B-C" sequence with the "C-A-B" sequence for patients with cardiac arrest and showed that "C-A-B" was superior to "A-B-C" because of the earlier start of compressions and shorter time to completion of the resuscitation cycle.[16] In addition, because clinical outcomes of witnessed OHCA improved after the introduction of this novel "C-A-B" sequence in this study, this may suggest its validation for use in general populations.

In this study, neurologically favorable 1-month survival, 1-month survival, and prehospital ROSC rates were significantly ($P<0.05$) better in patients who received conventional CPR than

Table 3. Associations of the ILCOR Update and Clinical Outcomes During Implementation Cycles of the New Guidelines

Parameters	Adjusted OR	95% CI	*P* Value
Neurologically favorable 1-month survival			
Early cycle (2007 vs 2011)	1.38	1.27 to 1.49	<0.001
Early to middle cycle (2008 vs 2012)	1.39	1.28 to 1.51	<0.001
Middle cycle (2009 vs 2013)	1.29	1.20 to 1.39	<0.001
		P for interaction	0.337
One-month survival			
Early cycle (2007 vs 2011)	1.22	1.15 to 1.29	<0.001
Early to middle cycle (2008 vs 2012)	1.27	1.20 to 1.34	<0.001
Middle cycle (2009 vs 2013)	1.18	1.12 to 1.25	<0.001
		P for interaction	0.456
Prehospital ROSC			
Early cycle (2007 vs 2011)	1.22	1.16 to 1.28	<0.001
Early to middle cycle (2008 vs 2012)	1.26	1.20 to 1.32	<0.001
Middle cycle (2009 vs 2013)	1.22	1.17 to 1.28	<0.001
		P for interaction	0.765

Adjusted OR of ILCOR 2010 vs ILCOR 2005 for neurologically favorable 1-month survival, 1-month survival, and prehospital ROSC in each maturation cycle. Adjusted covariates included age; sex; cardiac vs noncardiac; type of bystander; initial rhythm; EMS treatments, including epinephrine administration and advanced airway management; EMS response time; and hospital arrival time. To evaluate the differences among the maturation cycles of the guideline iterations, we performed a multivariable logistic regression analysis including above-mentioned variables and a cross-product term between the version of ILCOR consensus and the maturation cycle of the guideline. ILCOR indicates International Liaison Committee on Resuscitation; OR, odds ratio; ROSC, return of spontaneous circulation.

in those who received chest compression–only CPR for all time periods, including maturation cycles with the exception of neurologically favorable 1-month survival during early cycle (Table 4). This finding is contrary to most of the published literature.[13,17–19] For example, a primary meta-analysis from 3 randomized, controlled trials indicated that survival to hospital was better with dispatcher-assisted compression-only CPR than with conventional CPR, whereas a secondary meta-analysis included 7 observational studies of bystander CPR showed no difference between the 2 CPR techniques.[19] An explanation for this discrepancy could be that rescuers who provided chest compression–only CPR may be less trained and thus quality of chest compression may be less effective than those provided by rescuers who were trained.

Regarding the emphasis on high-quality CPR, it is obvious that the provision of high-quality CPR by EMS personnel and citizens is indispensable. For example, significant increases in epinephrine administration and advanced airway management shown in this study might be the result of educational training of EMS personnel, and quality improvement initiatives might have contributed to the improved outcomes.[20,21] It is also reported that CPR education could lead to an improvement in outcomes post-OHCA with resuscitation attempts by citizens. However, our results indicate that there is potential room for further improvement, especially regarding educational training of citizens.

Outcomes of patients with OHCA witnessed by family members were the worst among all patients with OHCA witnessed by citizens, even though this situation was the most frequent one with an incidence greater than 80% (Table 1). Several reasons could explain this result. For example, if OHCA were witnessed by family members at home, then it could be difficult to perform high-quality, single-person CPR, particularly for any length of time. This situation could be one of the next to be targeted to enable further improvements in OHCA outcomes. Because the absolute increase in survival was still small in clinical settings, even with statistically significant improvements in outcomes, much effort is needed to further improve outcomes. For example, the estimated number of survivors with a 1-month favorable neurological outcome increased by 0.6% from the ILCOR 2005 period to the ILCOR 2010 period, which indicates that an absolute number of 210 additional survivors per year could be achieved for approximately every 35 000 witnessed adult OHCAs.

The CPR guidelines based on the ILCOR 2005 consensus and the ILCOR 2010 consensus categorize OHCA into 2 rhythm groups with different therapeutic algorithms according to the first documented rhythm.[1] With the ample evidence of high resuscitation rates for patients with shockable rhythm as compared with nonshockable rhythm, the ILCOR 2010 consensus emphasized the use of CPR plus the AED by the

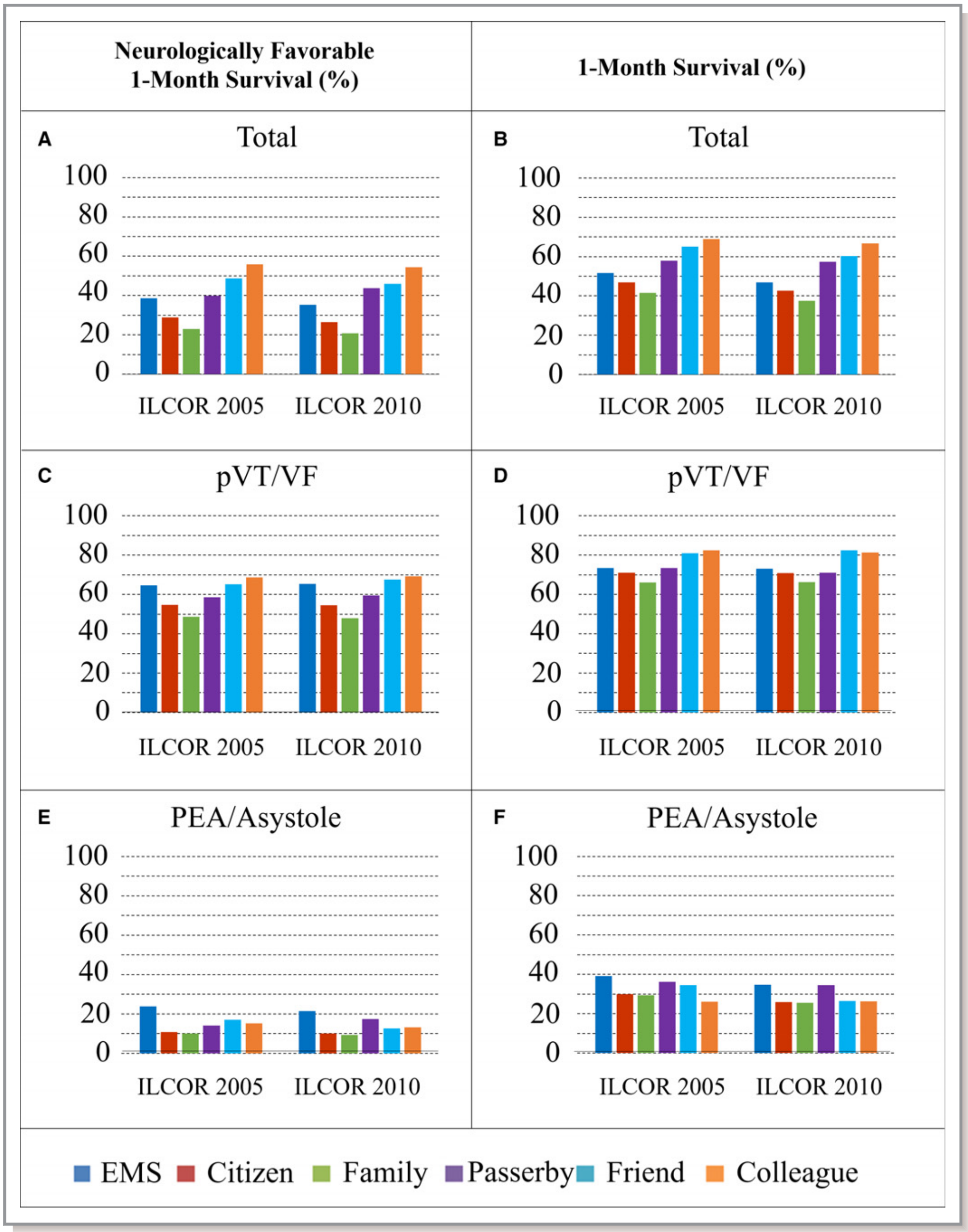

Figure 3. Clinical outcomes after OHCA patients who achieved prehospital ROSC in ILCOR 2005 and ILCOR 2010 guideline periods. Neurologically favorable 1-month survival (A, C, and E), 1-month survival (B, D and F) in the entire cohort, patients with shockable, and nonshockable rhythms, respectively. ILCOR indicates International Liaison Committee on Resuscitation; OHCA, out-of-hospital cardiac arrest; PEA, pulseless electrical activity; pVT/VF, pulseless ventricular tachycardia/ventricular fibrillation; ROSC, return of spontaneous circulation.

general public. Increased use of the public access AEDs might have also contributed to the improved outcomes in this study. In fact, publicly accessible AEDs have become widespread in Japan during the past 10 years.[5,22,23]

In October 2015, the ILCOR 2015 consensus was launched. With this update, the importance of high-quality CPR, especially by citizens, was re-emphasized with very specific goals of adequate chest compressions (rate of 100–120/min, depth of 5–6 cm), allowing sufficient recoil after each compression and minimal pauses in compressions. Ideally, CPR and the use of publicly accessible AEDs occur with the guidance of the EMS dispatcher.[24] The implementation of these very specific and objective guidelines is expected to further improve OHCA outcomes. In the future,

Table 4. Differences in Outcome Between Victims of OHCA Who Received Conventional CPR and Those Who Received Compression-Only CPR

Parameters	Conventional CPR	Compression-Only CPR	Adjusted OR	95% CI	*P* Value
Neurologically favorable 1-month survival					
Total population	8.8	5.6	0.79	0.73 to 0.86	<0.001
ILCOR 2005 period	7.8	5.2	0.81	0.74 to 0.90	<0.001
ILCOR 2010 period	10.9	6.0	0.75	0.66 to 0.85	<0.001
Early cycle (2007 vs 2011)	7.6	5.2	0.89	0.76 to 1.03	0.112
Early to middle cycle (2008 vs 2012)	8.7	5.4	0.83	0.72 to 0.97	0.015
Middle cycle (2009 vs 2013)	10.1	6.1	0.69	0.59 to 0.80	<0.001
One-month survival					
Total population	13.9	10.1	0.82	0.77 to 0.87	<0.001
ILCOR 2005 period	12.8	9.6	0.84	0.78 to 0.91	<0.001
ILCOR 2010 period	16.5	10.6	0.77	0.70 to 0.85	<0.001
Early cycle (2007 vs 2011)	13.1	9.5	0.82	0.74 to 0.92	<0.001
Early to middle cycle (2008 vs 2012)	13.4	9.8	0.88	0.78 to 0.99	0.028
Middle cycle (2009 vs 2013)	15.7	10.7	0.73	0.65 to 0.82	<0.001
Prehospital ROSC					
Total population	17.9	14.4	0.81	0.77 to 0.86	<0.001
ILCOR 2005 period	15.9	12.9	0.84	0.78 to 0.90	<0.001
ILCOR 2010 period	22.1	16.1	0.78	0.71 to 0.84	<0.001
Early cycle (2007 vs 2011)	16.4	13.2	0.80	0.72 to 0.88	<0.001
Early to middle cycle (2008 vs 2012)	18.0	14.1	0.83	0.75 to 0.92	<0.001
Middle cycle (2009 vs 2013)	19.3	15.7	0.80	0.73 to 0.89	<0.001

Adjusted OR of compression-only CPR vs conventional CPR for neurologically favorable 1-month survival, 1-month survival, and prehospital ROSC. Adjusted covariates included age; sex; enrollment year; cardiac vs noncardiac; type of bystander; initial rhythm; EMS treatments, including epinephrine administration and advanced airway management; EMS response time; and hospital arrival time. ILCOR indicates International Liaison Committee on Resuscitation; OR, odds ratio; ROSC, return of spontaneous circulation.

we will need to evaluate the impact of the implementation of the ILCOR 2015 consensus (updated from the ILCOR 2010 consensus). Because the results of the present study showed improvements needed after the implementation of the ILCOR 2010 consensus, an assessment after the publication of the ILCOR 2015 consensus could also provide physicians with important insights regarding further improvements needed. This study could be a very informative reference while assessing the impact of the updated ILCOR 2015 consensus. Finally, it will be critical to document how quickly EMS providers are being trained according to new recommendations to accurately assess the impact of the 2015 ILCOR recommendations.

Study Limitations

This study had some limitations. First, our data did not consider the potential various forms of in-hospital care, although the use of these treatments could be associated with the improved outcomes. Even though there were no obvious improvements in outcomes of patients who achieved prehospital ROSC in the present study, we speculated that this happened because patients with more-severe illnesses may have achieved prehospital ROSC in the ILCOR 2010 period as compared with the ILCOR 2005 period. In addition, the number of medical centers providing targeted temperature management, extracorporeal membrane oxygenation for resuscitation, or bundled postcardiac arrest care are unknown. Second, analysis of observational data could not adjust unmeasured confounding factors during the multivariable regression model. Third, there are no data regarding how quickly all EMS providers were retrained within the study period and no data regarding CPR quality assessment during resuscitations, even though there might have been a cross-over period between the time when the new guidelines were introduced and when complete implementation occurred.[7] Fourth, a significant proportion of 1-month survivors had poor neurological outcomes in the present study compared with other countries[25]; however, this phenomenon could be explained by differences in EMS systems between Western countries and Japan. In Japan, all OHCA patients who were treated by EMS personnel were transported to a hospital unless death was obvious. In comparison, the proportion of field termination of resuscitation is often at least 50% of all OHCA patients in other countries.[26] Fifth, because of the nature of epidemiological studies, validity and integrity are potential limitations of this study. Therefore, our data should be interpreted with consideration of these limitations. However, these potential sources of bias should be minimized by using the uniform data collection style used by the Utstein database.

Conclusions

Outcomes of witnessed OHCA were better in the ILCOR 2010 period than those in the ILCOR 2005 period. Our results can provide baseline data for many future prospective studies.

Author Contributions

Kaneko, Hara, Mizutani, Yoshiyama, Yokoi, Kabata, Shintani, and Kitamura meet the authorship criteria by contributing to the following: (1) conception, design, analysis and interpretation of data; (2) drafting of the manuscript or revising it critically for important intellectual content; and (3) final approval of the manuscript submitted.

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Disclosures

None.

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