BMC Anesthesiology

CrossMark

Association between cardiopulmonary resuscitation duration and one-month neurological outcomes for out-of-hospital cardiac arrest: a prospective cohort study

Masahiro Kashiura[1*] , Yuichi Hamabe[1], Akiko Akashi[1], Atsushi Sakurai[2], Yoshio Tahara[3], Naohiro Yonemoto[4], Ken Nagao[5], Arino Yaguchi[6], Naoto Morimura[7] and on behalf of the SOS-KANTO 2012 Study Group

Abstract

Background: The duration of cardiopulmonary resuscitation (CPR) is an important factor associated with the outcomes for an out-of-hospital cardiac arrest. However, the appropriate CPR duration remains unclear considering pre- and in-hospital settings. The present study aimed to evaluate the relationship between the CPR duration (including both the pre- and in-hospital duration) and neurologically favorable outcomes 1-month after cardiac arrest.

Methods: Data were utilized from a prospective multi-center cohort study of out-of-hospital cardiac arrest patients transported to 67 emergency hospitals between January 2012 and March 2013 in the Kanto area of Japan. A total of 3,353 patients with out-of-hospital cardiac arrest (age ≥18 years) who underwent CPR by emergency medical service personnel and achieved the return of spontaneous circulation in a pre- or in-hospital setting were analyzed. The primary outcome was a 1-month favorable neurological outcome. Logistic regression analysis was performed to estimate the influence of cardiopulmonary resuscitation duration. The CPR duration that achieved a cumulative proportion >99% of cases with a 1-month neurologically favorable outcome was determined.

Results: Of the 3,353 eligible cases, pre-hospital return of spontaneous circulation was obtained in 1,692 cases (50.5%). A total of 279 (8.3%) cases had a 1-month neurologically favorable outcome. The CPR duration was significantly and inversely associated with 1-month neurologically favorable outcomes with adjustment for pre- and in-hospital confounders (adjusted odds ratio: 0.911, per minute, 95% CI: 0.892–0.929, $p < 0.001$). After 30 min of CPR, the probability of a 1-month neurologically favorable outcome decreased from 8.3 to 0.7%. At 45 min of CPR, the cumulative proportion for a 1-month neurologically favorable outcome reached >99%.

Conclusions: The CPR duration was independently and inversely associated with 1-month neurologically favorable outcomes after out-of-hospital cardiac arrest. The CPR duration required to achieve return of spontaneous circulation in >99% of out-of-hospital cardiac arrest patients with a 1-month favorable neurological outcome was 45 min, considering both pre- and in-hospital settings.

Keywords: Cardiopulmonary resuscitation, Emergency medical services, Out-of-hospital cardiac arrest, Patient outcome assessment

* Correspondence: kashiura@me.com
[1]Tertiary Emergency Medical Center, Tokyo Metropolitan Bokutoh Hospital,
4-23-15 Kotobashi, Sumida-ku, Tokyo 130-8575, Japan
Full list of author information is available at the end of the article

Kashiura *et al. BMC Anesthesiology* (2017) 17:59

Page 2 of 8

Background

Out-of-hospital cardiac arrest (OHCA) is an important public health problem worldwide. Approximately 330,000 individuals in the United States and 275,000 individuals in Europe experience OHCA each year [1]. The survival rate for OHCA remains poor, at approximately 10% [1, 2]. The cardiopulmonary resuscitation (CPR) duration is independently and inversely associated with favorable neurological outcomes and survival [3, 4]. The optimal pre-hospital CPR duration for OHCA has been reported to be 35–48 min, after which the probability of survival falls to <1% [5, 6].

The CPR duration is probably the most important factor in the termination of resuscitation for OHCA. However, the 2010 CPR guidelines for the termination of resuscitation do not include the optimal CPR duration [7–9]. In every emergency medical service (EMS) system, patients suffering from OHCA are declared dead in the field by EMS personnel after a prescribed CPR duration has been exceeded (often 30 min) [10]. Therefore, it is very important to estimate how long CPR should be continued. However, most prior studies have focused on CPR duration in a pre-hospital setting and do not include CPR duration in a hospital setting. In urban areas, most OHCA patients are transported to emergency hospitals within the timeframe of the reported optimal pre-hospital CPR duration. Therefore, an optimal CPR duration that includes in-hospital circumstances is needed [5, 6, 11, 12]. In addition, the confounding factors both outside and inside the hospital should be assessed.

The aim of the present study was to evaluate the relationship between CPR duration (including both pre- and in-hospital settings) and neurologically favorable outcomes 1-month after cardiac arrest, adjusting for out-of-hospital and in-hospital confounders, using data from the Survey of Survivors after Cardiac Arrest, collected in the Kanto Area of Japan in 2012 (SOS-KANTO 2012).

Methods

Study design and setting

The SOS-KANTO 2012 is a prospective, multi-center observational study of patients with OHCA who were transported to 67 emergency hospitals in the Kanto area of Japan. The study was conducted between January 2012 and March 2013. The design and data collection methods for the SOS-KANTO 2012 have been reported in detail in previous studies [13–15]. The Kanto region consists of primarily urban areas, including the capital (Tokyo).

Japanese emergency medical service system

The Japanese EMS system has been explained in several previous studies [13, 16]. Briefly, the EMS system is operated by each municipal government and is supervised by the Fire and Disaster Management Agency of Japan. All EMS personnel are trained to perform CPR according to the Japanese resuscitation guidelines produced by the Japan Resuscitation Council based on a statement from the International Liaison Committee on Resuscitation. The ambulance crew consists of three EMS personnel, including at least one emergency lifesaving technician (ELST). ELSTs can perform several resuscitative methods under the supervision of an online medical control, including the operation of a semi-automated external defibrillator and insertion of a supraglottic airway device. Specially trained ELSTs have been able to perform endotracheal intubation since 2004, and have been able to administer adrenaline intravenously under the supervision of an online medical control since 2006. EMS personnel in Japan are not legally permitted to terminate resuscitation in the field and all OHCA patients are transported to hospitals, except in cases where death is certain [17].

Participants

All OHCA patients transported by EMS personnel to participating institutions during the study period were eligible for inclusion in the SOS-KANTO 2012 [13]. The present study included adult OHCA patients (18 years of age or older) who underwent CPR by EMS personnel and had a return of spontaneous circulation (ROSC) in either the pre- or in-hospital setting. Of these, cases with the initial resuscitation performed inside the hospital or missing data for onset location were excluded. In addition, cases with an unknown outcome were excluded.

Data collection and definition

The EMS personnel collected pre-hospital information based on the Utstein-style template, including age, sex, witnessed arrest, bystander CPR, time interval, initial rhythm monitored, and pre-hospital management (intravenous adrenaline administration, advanced airway management, and shock delivery) [18]. Physicians collected data regarding in-hospital treatments (drug administration, shock delivery, targeted temperature management, coronary angiography, percutaneous coronary intervention, and use of circulatory assist devices) and outcomes. CPR duration was defined as the period from the initiation of CPR by EMS personnel to a ROSC.

Outcome measurements

The primary end point was 1-month survival with a neurologically favorable outcome after cardiac arrest, defined as a Glasgow-Pittsburgh cerebral-performance category of 1 (good performance) or 2 (moderate disability) on a five-category scale [19]. The other Glasgow-Pittsburgh categories, including 3 (severe disability), 4

Kashiura *et al. BMC Anesthesiology* (2017) 17:59

Page 3 of 8

(vegetative state), and 5 (death), were defined as a 1-month neurologically unfavorable outcome. The secondary endpoint was 1-month survival after cardiac arrest.

Statistical analysis

Descriptive statistics were calculated for all variables of interest. Continuous variables are reported using median and interquartile ranges, whereas categorical variables are summarized using counts and percentages. A multivariate logistic regression analysis for 1-month neurologically favorable outcomes and survival was performed, controlling for the following pre-determined potential confounding factors: age, sex, initial cardiac rhythm (ventricular fibrillation, pulseless ventricular tachycardia, pulseless electrical activity, or asystole), witness, bystander CPR (layperson-initiated or EMS-personnel-initiated), time interval from the call to response, pre-hospital ROSC, cardiac etiology of arrest, pre-hospital managements (shock delivery [layperson or EMS personnel], adrenaline administration, and advanced airway management), and in-hospital managements (anti-arrhythmic drug administration, targeted temperature management, coronary angiography, and use of circulatory assist devices [extracorporeal membrane oxygenation or intra-aortic balloon pumping]). Crude and adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated using CPR duration as both an ordinal and continuous variable. As an ordinal variable, CPR duration was classified into 5 categories: 0–10, 11–20, 21–30, 31–40, and ≥41 min. All reported p values are two-tailed, and values less than 0.05 were considered statistically significant.

The dynamic probability of either 1-month favorable neurologic outcome or 1-month survival was described as a function of CPR duration and defined by the proportion of the remaining patients with 1-month neurologically favorable outcomes and 1-month survival relative to all eligible patients, respectively. In addition, the cumulative proportion curves for 1-month neurologically favorable outcomes and 1-month survival after cardiac arrest against the CPR duration were described. CPR guidelines recommend the false positive rate of a diagnostic test for prognostication to be close to 0% [20, 21]. Therefore, the CPR duration achieving a cumulative proportion >99% of those with a 1-month survival and 1-month neurologically favorable outcome was determined as in prior studies [5, 22]. Statistical analyses were performed using IBM SPSS for Mac Version 23.0 (IBM Corp., Armonk, NY).
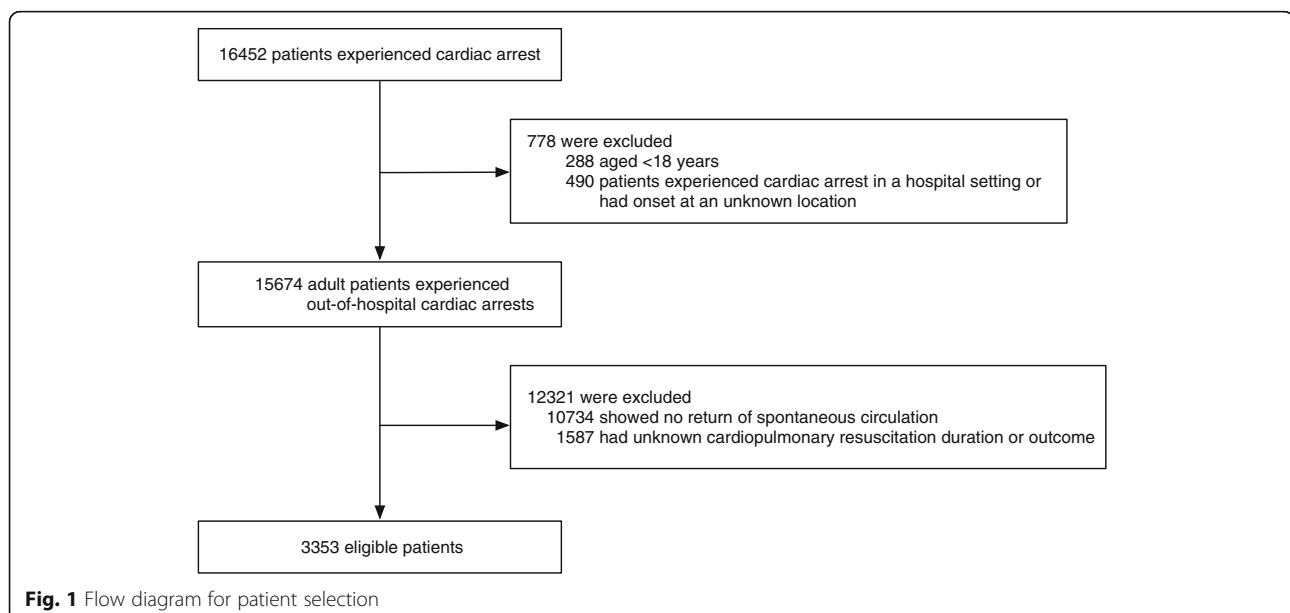
Results

Patient enrollment

During the study period, a total of 16,452 patients with cardiac arrest were registered in the SOS-KANTO 2012. Among the 15,674 adult OHCA cases, 10,734 never obtained a ROSC in or out of the hospital. After excluding cases with unknown CPR duration or outcome, 3,353 cases were finally enrolled in the present study (Fig. 1).

The characteristics and outcomes of the enrolled patients

The patient characteristics and outcomes are shown in Table 1. The median CPR duration was 30.0 min (interquartile range, 20.0–38.0 min). Pre-hospital ROSC was obtained in 1,692 cases (50.5%), and 1,661 cases (49.5%) obtained a ROSC in the hospital. A total of 514 (15.3%) and 279 (8.3%) cases had a 1-month survival and 1-month neurologically favorable survival, respectively.

Fig. 1 Flow diagram for patient selection

Kashiura *et al. BMC Anesthesiology* (2017) 17:59

Page 4 of 8

Table 1 Baseline characteristics and outcomes of participants according to 1-month neurological outcomes

Characteristics	Total (*n* = 3353)	1-month neurologically favorable outcome (*n* = 279)	1-month neurologically unfavorable outcome (*n* = 3074)
Pre-hospital variables			
Age (years)	75.0 [63.0–83.0]	63.0 [53.5–71.0]	76.0 [64.0–84.0]
Male	2087 (62.2)	212 (76.0)	1875 (61.0)
Bystander CPR			
No bystander involvement	2021 (60.3)	134 (48.0)	1887 (61.4)
Layperson-initiated	870 (25.9)	80 (28.7)	790 (25.7)
EMS-personnel-initiated	462 (13.8)	65 (23.3)	397 (12.9)
Witness	2258 (67.3)	229 (82.1)	2029 (66.0)
Pre-hospital defibrillation (layperson or EMS personnel)	668 (19.9)	193 (69.2)	475 (15.5)
Advanced airway management	1651 (49.2)	73 (26.2)	1578 (51.3)
Initial shockable rhythm	492 (14.7)	184 (65.9)	308 (10.0)
Initial cardiac rhythm			
Ventricular fibrillation	483 (14.4)	182 (65.2)	301 (9.8)
Pulseless ventricular tachycardia	9 (0.3)	2 (0.7)	7 (0.2)
Pulseless electrical activity	1355 (40.4)	84 (30.1)	1271 (41.3)
Asystole	1506 (44.9)	11 (3.9)	1495 (48.6)
Pre-hospital adrenaline administration	812 (24.2)	28 (10.0)	784 (25.5)
Pre-hospital ROSC	1692 (50.5)	202 (72.4)	1490 (48.5)
Cardiac etiology of arrest	1573 (46.9)	227 (81.4)	1346 (43.8)
In-hospital variables			
In-hospital ROSC	1661 (49.5)	77 (27.6)	1584 (51.5)
Antiarrhythmic drug administration	325 (9.7)	65 (23.3)	260 (8.5)
Coronary angiography	415 (12.4)	173 (62.0)	242 (7.9)
Targeted temperature management	707 (21.1)	168 (60.2)	539 (17.5)
Circulatory assist device	249 (7.4)	64 (22.9)	185 (6.0)
Time intervals			
Call to response (min)	7.0 [5.0–9.0]	7.0 [5.0–8.0]	7.0 [5.0–9.0]
CPR to Arrival (min)	22.0 [16.0–27.0]	21.0 [15.0–27.0]	22.0 [16.0–27.0]
CPR duration (min)	30.0 [20.0–38.0]	9.0 [5.0–16.0]	31.0 [22.0–39.0]
Outcomes			
Survival to admission	2298 (68.5)	279 (100.0)	2020 (65.7)
1-month CPC grade			
CPC 1	217 (6.5)	217 (77.8)	0 (0.0)
CPC 2	62 (1.8)	62 (22.2)	0 (0.0)
CPC 3	94 (2.8)	0 (0.0)	94 (3.1)
CPC 4	141 (4.2)	0 (0.0)	141 (4.6)
CPC 5	2831 (84.4)	0 (0.0)	2831 (92.1)

Data are shown as medians [interquartile ranges] for continuous variables and numbers (percent) for categorical values
CPC cerebral-performance category, *CPR* cardiopulmonary resuscitation, *EMS* emergency medical service, *ROSC* return of spontaneous circulation

The results of the multiple logistic regression analysis

The crude and adjusted ORs of a 1-month neurologically favorable outcome and survival in terms of the CPR duration (as both an ordinal and continuous variable) are shown in Table 2. The CPR duration was significantly and inversely associated with 1-month neurologically favorable outcomes and survival (adjusted OR: 0.911, per minute, 95% CI: 0.892–0.929, $p < 0.001$ for a neurologically favorable outcome; adjusted OR: 0.925, per minute, 95% CI: 0.912–0.938, $p < 0.001$ for survival). With CPR

Kashiura *et al. BMC Anesthesiology* (2017) 17:59

Page 5 of 8

Table 2 Multivariate logistic regression analysis of 1-month survival and 1-month neurologically favorable outcomes in terms of CPR duration

Variables	1-month neurologically favorable outcome		1-month survival	
	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)
CPR duration (continuous variable), per minute	0.873 (0.861–0.886), $p < 0.001$	0.911 (0.892–0.929), $p < 0.001$	0.903 (0.894–0.911), $p < 0.001$	0.925 (0.912–0.938), $p < 0.001$
CPR duration (ordinal variable)				
0 to 10 min $n = 372$ (11.1%)	Reference	Reference	Reference	Reference
11 to 20 min $n = 530$ (15.8%)	0.241 (0.175–0.331), $p < 0.001$	0.402 (0.261–0.619), $p < 0.001$	0.259 (0.195–0.344), $p < 0.001$	0.287 (0.196–0.419), $p < 0.001$
21 to 30 min $n = 837$ (25.0%)	0.044 (0.028–0.068), $p < 0.001$	0.107 (0.059–0.195), $p < 0.001$	0.074 (0.054–101), $p < 0.001$	0.110 (0.070–0.172), $p < 0.001$
31 to 40 min $n = 1006$ (30.0%)	0.023 (0.013–0.039), $p < 0.001$	0.090 (0.045–0.181), $p < 0.001$	0.043 (0.030–0.060), $p < 0.001$	0.090 (0.055–0.146), $p < 0.001$
≥41 min $n = 608$ (18.1%)	0.016 (0.008–0.036), $p < 0.001$	0.044 (0.017–0.112), $p < 0.001$	0.030 (0.019–0.047), $p < 0.001$	0.043 (0.023–0.079), $p < 0.001$

Adjusted odds ratios were calculated controlling for the following factors: age, sex, initial cardiac rhythm, witness, bystander CPR, time interval from the call to response, pre-hospital return-of-spontaneous circulation, etiology of arrest, pre-hospital managements, and in-hospital managements
CI confidence interval, *CPR* cardiopulmonary resuscitation

duration specified as an ordinal variable, the ORs for a 1-month neurologically favorable outcome and survival decreased stepwise.
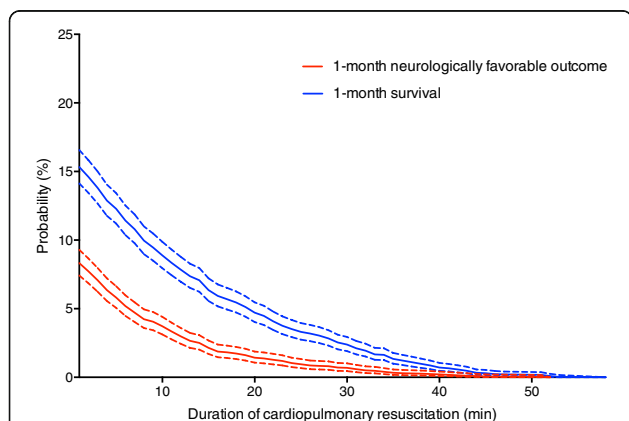
The dynamic probability of either a 1-month favorable neurologic outcome or 1-month survival

The dynamic probability curves for a 1-month neurologically favorable outcome and 1-month survival against the CPR duration are shown in Fig. 2. After 30 min of CPR, the probability of a 1-month neurologically favorable outcome decreased from 8.3% (95% CI: 7.4–9.3%) to 0.7% (95% CI: 0.4–1.0%), and decreased from 15.3% (95% CI: 14.1–16.6%) to 2.4% (95% CI 1.9–2.9%) for

survival. None of the patients who received CPR for more than 52 min survived.

The cumulative proportion of a 1-month neurologically favorable survival in terms of CPR duration

The cumulative proportion curves for 1-month survival and 1-month survival with a favorable neurological outcome against the CPR duration are shown in Fig. 3. For 1-month neurologically favorable outcomes, the cumulative proportion reached >99% at 45 min of CPR (99.3%, 95% CI: 99.1–99.5%). For 1-month survival, the cumulative proportion reached >99% at 52 min of CPR (99.4%, 95% CI: 99.3–99.5%).

Fig. 2 The dynamic probability of either a 1-month favorable neurologic outcome or 1-month survival relative to all patients against the duration of cardiopulmonary resuscitation. The short-dashed lines reflect the 95% confidence interval
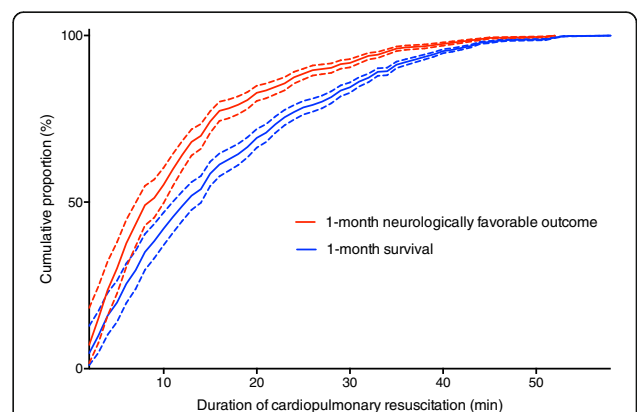
Fig. 3 Cumulative proportion of 1-month neurologically favorable outcomes and survival against the duration of cardiopulmonary resuscitation. The short-dashed lines reflect the 95% confidence interval

Discussion

Using data from a prospective multi-center observational study, the present study demonstrated that CPR duration, including pre- and in-hospital CPR, was inversely associated with 1-month survival and neurologically favorable outcomes after OHCA, with adjustment for pre- and in-hospital confounders. In addition, the cumulative proportion of a 1-month neurological favorable outcome fell to 1% at 45 min of CPR.

CPR duration, namely ischemic time, is associated with hypo-hemodynamics and low base excess after a ROSC, which has been suggested to lead to a poor outcome [23–26]. Several studies have investigated the influence of CPR duration on survival or neurological outcomes in OHCA patients [5, 6, 11, 12, 27]. Previous studies have reported that a pre-hospital CPR duration of 26–48 min achieves a 99% cumulative proportion for neurologically favorable outcomes [5, 6, 11, 12]. In addition, the probability of survival rapidly decreases with each minute of CPR [27]. These results are consistent with those of the present study.

However, previous studies defined CPR duration in terms of CPR performed by EMS personnel in an out-of-hospital setting. Few data are available which consider both pre- and in-hospital CPR durations [27]. In population-dense areas, many patients suffering from OHCA are transported to emergency hospitals before the CPR duration has reached 30 min [28]. In the present study, the median duration of CPR to hospital arrival was 22 min, and about half of the patients achieved a ROSC in the hospital. Therefore, estimating the critical CPR duration must include consideration of pre- and in-hospital settings. Moreover, while many previous studies adjusted for pre-hospital confounders, in-hospital factors were left unadjusted [5, 6, 11, 12].

The decision to terminate resuscitation is more challenging than that for other interventions. It has been argued that a success rate of <1% still justifies the resuscitation effort [22]. Therefore, termination of resuscitation could be permissible after the CPR duration has reached the time associated with a cumulative proportion >99% for 1-month neurologically favorable outcomes or 1-month survival. Given the results of the present study, CPR could reasonably be continued for a total of 45 or 52 min, considering both the pre- and in-hospital CPR duration.

Furthermore, CPR duration is a very important factor in the consideration of advanced therapy. In advanced therapies, such as extracorporeal assisted CPR, CPR duration should be considered as a component of the protocol [4, 27, 29, 30]. For example, Reynolds et al. showed that the optimal time for considering an alternative method to conventional CPR is within 15 min [27]. In the present study, the probability of a 1-month neurologically favorable outcome rapidly decreased from 8.3 to 0.7% after 30 min of CPR. Therefore, advanced therapies should be introduced as soon as possible. Moreover, to estimate the effectiveness of these therapies, CPR duration should be taken into account.

There are several limitations in the present study. Firstly, the present study was an observational study; therefore, we could not adjust for unmeasured confounders, and resuscitation efforts might not have been conducted consistently in all OHCA patients. Secondly, we could not divide the CPR duration into out-of-hospital and in-hospital durations. In-hospital CPR duration could be a potential confounder; however, we could not include in-hospital CPR duration in the analysis because of multi-collinearity. Thirdly, the SOS-KANTO 2012 was not a population-based study; it was conducted only at certain hospitals in the Kanto area of Japan. For example, the results of the present study are substantially conditioned by the call-to-response time. The observed call-to-response time of 7 min in the present study is the same as that in a nationwide study conducted in Japan [5], which may limit the generalizability of the results from these studies to other countries. Fourthly, this study excluded pediatric patients; therefore, the relevance of our findings to this population is unclear. Finally, the effect of CPR duration should be reevaluated as innovations for the pre- and in-hospital management of OHCA progress in the future.

Conclusion

CPR duration was independently and inversely associated with 1-month survival and 1-month neurologically favorable outcomes after OHCA. The CPR duration required to achieve a ROSC in >99% of OHCA patients with a 1-month favorable neurological outcome was 45 min, considering both pre- and in-hospital settings.

Key messages

- Longer CPR duration is independently and inversely associated with 1-month survival and neurologically favorable outcomes with adjustment for pre- and in-hospital confounders.
- The cumulative proportion of 1-month neurological favorable outcomes fell to 1% at 45 min of CPR.

Kashiura *et al. BMC Anesthesiology* (2017) 17:59

Page 7 of 8

SOS-KANTO 2012 steering council

Yokohama City University Medical Center, Kanagawa, Japan (president: Naoto Morimura MD); Nihon University School of Medicine, Tokyo Japan (Director, Atsushi Sakurai MD); National Cerebral and Cardiovascular Center Hospital (Director, Yoshio Tahara MD); Tokyo Women's Medical University Hospital, Tokyo, Japan (Arino Yaguchi MD); Nihon University Surugadai Hospital, Tokyo, Japan (Ken Nagao MD); Nippon Medical School Hospital, Tokyo, Japan (Tagami Takashi MD); Japanese Red Cross Maebashi Hospital, Gunma, Japan (Dai Miyazaki MD); National Disaster Medical Center, Tokyo, Japan (Tomoko Ogasawara MD); Keio University Hospital, Tokyo, Japan (Kei Hayashida MD, Masaru Suzuki MD); Tokai University School of Medicine, Kanagawa, Japan (Mari Amino MD); Kimitsu Chuo Hospital, Chiba, Japan (Nobuya Kitamura MD); Juntendo University Nerima Hospital, Tokyo, Japan (Tomohisa Nomura MD); Tokyo Metropolitan Children's Medical Centre, Tokyo, Japan (Naoki Shimizu MD); Tokyo Metropolitan Bokutoh Hospital, Tokyo, Japan (Akiko Akashi MD); National Center of Neurology and Psychiatry (Naohiro Yonemoto DPH).

SOS-KANTO 2012 Study Group

Tokai University School of Medicine (Sadaki Inokuchi MD); St. Marianna University School of Medicine, Yokohama Seibu Hospital (Yoshihiro Masui MD); Koto Hospital (Kunihisa Miura MD); Saitama Medical Center Advanced Tertiary Medical Center (Haruhiko Tsutsumi MD); Kawasaki Municipal Hospital Emergency & Critical Care Center (Kiyotsugu Takuma MD); Yokohama Municipal Citizen's Hospital (Ishihara Atsushi MD); Japanese Red Cross Maebashi Hospital (Minoru Nakano MD); Juntendo University Urayasu Hospital (Hiroshi Tanaka MD); Dokkyo Medical University Koshigaya Hospital (Keiichi Ikegami MD); Hachioji Medical Center of Tokyo Medical University (Takao Arai MD); Tokyo Women's Medical University Hospital (Arino Yaguchi MD); Kimitsu Chuo Hospital (Nobuya Kitamura MD); Chiba University Graduate School of Medicine (Shigeto Oda MD); Saiseikai Utsunomiya Hospital (Kenji Kobayashi MD); Mito Saiseikai General Hospital (Takayuki Suda MD); Dokkyo Medical University (Kazuyuki Ono MD); Yokohama City University Medical Center (Naoto Morimura MD); National Hospital Organization Yokohama Medical Center (Ryosuke Furuya MD); National Disaster Medical Center (Yuichi Koido MD); Yamanashi Prefectural Central Hospital (Fumiaki Iwase MD); Surugadai Nihon University Hospital (Ken Nagao MD); Yokohama Rosai Hospital (Shigeru Kanesaka MD); Showa General Hospital (Yasusei Okada MD); Nippon Medical School Tamanagayama Hospital (Kyoko Unemoto MD); Tokyo Women's Medical University Yachiyo Medical Center (Tomohito Sadahiro MD); Awa Regional Medical Center (Masayuki Iyanaga MD); Todachuo General Hospital (Asaki Muraoka MD); Japanese Red Cross Medical Center (Munehiro Hayashi MD); St. Luke's International Hospital (Shinichi Ishimatsu MD); Showa University School of Medicine (Yasufumi Miyake MD); Totsuka Kyoritsu Hospital 1 (Hideo Yokokawa MD); St. Marianna University School of Medicine (Yasuaki Koyama MD); National Hospital Organization Mito Medical Center (Asuka Tsuchiya MD); Tokyo Metropolitan Tama Medical Center (Tetsuya Kashiyama MD); Showa University Fujigaoka Hospital (Munetaka Hayashi MD); Gunma University Graduate School of Medicine (Kiyohiro Oshima MD); Saitama Red Cross Hospital (Kazuya Kiyota MD); Tokyo Metropolitan Bokutoh Hospital (Yuichi Hamabe MD); Nippon Medical School Hospital (Hiroyuki Yokota MD); Keio University Hospital (Shingo Hori MD); Chiba Emergency Medical Center (Shin Inaba MD); Teikyo University School of Medicine (Tetsuya Sakamoto MD); Japanese Red Cross Musashino Hospital (Naoshige Harada MD); National Center for Global Health and Medicine Hospital (Akio Kimura MD); Tokyo Metropolitan Police Hospital (Masayuki Kanai MD); Medical Hospital of Tokyo Medical and Dental University (Yasuhiro Otomo MD); Juntendo University Nerima Hospital (Manabu Sugita MD); Nihon University School of Medicine (Kosaku Kinoshita MD); Toho University Ohashi Medical Center (Takatoshi Sakurai MD); Saiseikai Yokohamashi Tobu Hospital (Mitsuhide Kitano MD); Nippon Medical School Musashikosugi Hospital (Kiyoshi Matsuda MD); Tokyo Rosai Hospital (Kotaro Tanaka MD); Toho University Omori Medical Center (Katsunori Yoshihara MD); Hiratsuka city Hospital (Kikuo Yoh MD); Yokosuka Kyosai Hospital (Junichi Suzuki MD); Saiseikai Yokohamashi Nambu Hospital (Hiroshi Toyoda MD); Nippon Medical School Chiba Hokusoh Hospital (Kunihiro Mashiko MD); Tokyo Metropolitan Children's Medical Centre (Naoki Shimizu MD); National Medical Center for Children and Mothers (Takashi Muguruma MD); Chiba Aoba Municipal Hospital (Tadanaga Shimada MD); Kuki General Hospital (Yoshiro Kobe MD); Matsudo City Hospital (Tomohisa Shoko MD); Japanese Red Cross Narita Hospital (Kazuya Nakanishi MD); Tokyo Bay Urayasu/Ichikawa Medical Center (Takashi Shiga MD); NTT Medical Center Tokyo (Takefumi Yamamoto MD); Tokyo Saiseikai Central Hospital (Kazuhiko Sekine MD); Fuji Heavy Industries Health Insurance Society OTA Memorial Hospital (Shinichi Izuka MD). (http://www.jaam-kanto.jp/sos_kanto.html).

Availability of data and materials
Not applicable.

Authors' contributions
MK contributed to the study conception and design, data acquisition, statistical analysis and interpretation, and drafting of the manuscript. YH and AA contributed to the conception and design of the study, and data interpretation. AS, YT, NY, KN, AY, and NM contributed to the study design and data acquisition. All authors critically revised the manuscript for important intellectual content, provided intellectual input to the study and manuscript, and read and approved the final manuscript.

Competing interests
All authors that participated in the current study are members of the Japanese Association for Acute Medicine of Kanto. We declare that we have no competing interest associated with the present study.

Consent for publication
Not applicable. No individual patient data will be reported.

Ethics approval and consent to participate
The SOS-KANTO 2012 study was approved by the institutional review boards of all participating institutions listed below in SOS-KANTO 2012 Study Group, with a waiver for informed consent in order to protect participant anonymity.

Publisher's Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Author details
[1]Tertiary Emergency Medical Center, Tokyo Metropolitan Bokutoh Hospital, 4-23-15 Kotobashi, Sumida-ku, Tokyo 130-8575, Japan. [2]Nihon University School of Medicine, Tokyo, Japan. [3]National Cerebral and Cardiovascular Center Hospital, Osaka, Japan. [4]Kyoto University School of Public Health, Kyoto, Japan. [5]Nihon University Surugadai Hospital, Tokyo, Japan. [6]Tokyo Women's Medical University Hospital, Tokyo, Japan. [7]Yokohama City University Medical Center, Kanagawa, Japan.

References
1. Berdowski J, Berg RA, Tijssen JGP, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. Resuscitation. 2010;81:1479–87.
2. Sasson C, Rogers MAM, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes. 2010;3:63–81.
3. Shih CL, Lu TC, Jerng JS, Lin CC, Liu YP, Chen WJ, et al. A web-based Utstein style registry system of in-hospital cardiopulmonary resuscitation in Taiwan. Resuscitation. 2007;72:394–403.
4. Chen YS, Lin JW, Yu HY, Ko WJ, Jerng JS, Chang WT, et al. Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis. Lancet. 2008;372:554–61.
5. Goto Y, Funada A, Goto Y. Relationship between the duration of cardiopulmonary resuscitation and favorable neurological outcomes after

Kashiura *et al. BMC Anesthesiology* (2017) 17:59

Page 8 of 8

out-of-hospital cardiac arrest: a prospective, nationwide, population-based cohort study. J Am Heart Assoc. 2016;4:e002819.

6. Grunau B, Reynolds JC, Scheuermeyer FX, Stenstrom R, Pennington S, Cheung C, et al. Comparing the prognosis of those with initial shockable and non-shockable rhythms with increasing durations of resuscitation: Informing minimum durations of resuscitation. Resuscitation. 2016;101:50–6.

7. Morrison LJ, Kierzek G, Diekema DS, Sayre MR, Silvers SM, Idris AH, et al. Part 3: ethics: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2010;122:S665–75.

8. Mancini ME, Diekema DS, Hoadley TA, Kadlec KD, Leveille MH, McGowan JE, et al. Part 3: Ethical Issues: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2015;132:S383–96.

9. Kashiura M, SOS-KANTO 2012 Study Group. Is it possible to terminate resuscitation in accordance with the termination of resuscitation rule? J Thorac Dis. 2016;8:E1435–7.

10. Atkins DL. Doing the same thing over and over, yet expecting different results. Circulation. 2013;128:2465–7.

11. Nehme Z, Andrew E, Bernard S, Smith K. Impact of cardiopulmonary resuscitation duration on survival from paramedic witnessed out-of-hospital cardiac arrests: An observational study. Resuscitation. 2016;100:25–31.

12. Arima T, Nagata O, Sakaida K, Miura T, Kakuchi H, Ikeda K, et al. Relationship between duration of prehospital resuscitation and favorable prognosis in ventricular fibrillation. Am J Emerg Med. 2015;33:677–81.

13. SOS-KANTO 2012 study group. Changes in pre- and in-hospital management and outcomes for out-of-hospital cardiac arrest between 2002 and 2012 in Kanto, Japan: the SOS-KANTO 2012 Study. Acute Med Surg. 2015;2:225–33.

14. Kitamura N, Nakada T-A, Shinozaki K, Tahara Y, Sakurai A, Yonemoto N, et al. Subsequent shock deliveries are associated with increased favorable neurological outcomes in cardiac arrest patients who had initially non-shockable rhythms. Crit Care. 2015;19:322.

15. Kashiura M, Hamabe Y, Akashi A, Sakurai A, Tahara Y, Yonemoto N, et al. Applying the termination of resuscitation rules to out-of-hospital cardiac arrests of both cardiac and non-cardiac etiologies: a prospective cohort study. Crit Care. 2016;20:49.

16. Kajino K, Kitamura T, Iwami T, Ong MEH, Hiraide A, Shimazu T, et al. Current termination of resuscitation (TOR) guidelines predict neurologically favorable outcome in Japan. Resuscitation. 2013;84:54–9.

17. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A, et al. Nationwide public-access defibrillation in Japan. N Engl J Med. 2010;362:994–1004.

18. Perkins GD, Jacobs IG, Nadkarni VM, Berg RA, Bhanji F, Biarent D, 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.

19. Cummins RO, Chamberlain DA, Abramson NS, Allen M, Baskett PJ, Becker L, 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.

20. Callaway CW, Donnino MW, Fink EL, Geocadin RG, Golan E, Kern KB, et al. Part 8: Post-Cardiac Arrest Care: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation. 2015;132:S465–82.

21. Sandroni C, Cariou A, Cavallaro F, Cronberg T, Friberg H, Hoedemaekers C, et al. Prognostication in comatose survivors of cardiac arrest: An advisory statement from the European Resuscitation Council and the European Society of Intensive Care Medicine. Resuscitation. 2014;85:1779–89.

22. Bossaert LL, Perkins GD, Askitopoulou H, Raffay VI, Greif R, Haywood KL, et al. European Resuscitation Council Guidelines for Resuscitation 2015: Section 11. The ethics of resuscitation and end-of-life decisions. Resuscitation. 2015; 95:302–11.

23. Abramson NS, Safar P, Detre KM, Kelsey SF, Monroe J, Reinmuth O, et al. Neurologic recovery after cardiac arrest: effect of duration of ischemia. Brain Resuscitation Clinical Trial I Study Group. Crit Care Med. 1985;13:930–1.

24. Takasu A, Sakamoto T, Okada Y. Arterial base excess after CPR: the relationship to CPR duration and the characteristics related to outcome. Resuscitation. 2007;73:394–9.

25. Menegazzi JJ, Ramos R, Wang HE, Callaway CW. Post-resuscitation hemodynamics and relationship to the duration of ventricular fibrillation. Resuscitation. 2008;78:355–8.

26. Komatsu T, Kinoshita K, Sakurai A, Moriya T, Yamaguchi J, Sugita A, et al. Shorter time until return of spontaneous circulation is the only independent factor for a good neurological outcome in patients with postcardiac arrest syndrome. Emerg Med J. 2013;31:549–55.

27. Reynolds JC, Frisch A, Rittenberger JC, Callaway CW. Duration of resuscitation efforts and functional outcome after out-of-hospital cardiac arrest: when should we change to novel therapies? Circulation. 2013;128:2488–94.

28. Cha WC, Lee EJ, Hwang S-S. The duration of cardiopulmonary resuscitation in emergency departments after out-of-hospital cardiac arrest is associated with the outcome: A nationwide observational study. Resuscitation. 2015;96:323–7.

29. Mosca MS, Narotsky DL, Mochari-Greenberger H, Liao M, Mongero L, Beck J, et al. Duration of conventional cardiopulmonary resuscitation prior to extracorporeal cardiopulmonary resuscitation and survival among adult cardiac arrest patients. Perfusion. 2016;31:200–6.

30. Kim SJ, Jung JS, Park JH, Park JS, Hong YS, Lee SW. An optimal transition time to extracorporeal cardiopulmonary resuscitation for predicting good neurological outcome in patients with out-of-hospital cardiac arrest: a propensity-matched study. Crit Care. 2014;18:535.