Available online at www.sciencedirect.com

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Differences in durations, adverse events, and outcomes of in-hospital cardiopulmonary resuscitation between day-time and night-time: An observational cohort study

Wataru Takayama[a,*], *Akira Endo*[a], *Hazuki Koguchi*[a], *Kiyoshi Murata*[b], *Yasuhiro Otomo*[a]

[a] *Trauma and Acute Critical Care Medical Center, Tokyo Medical and Dental University Hospital of Medicine, 1-5-45, Yushima, Bunkyo-ku, Tokyo, Japan*

[b] *The Shock Trauma and Emergency Medical Center, Matsudo City Hospital, 4005, Kamihongo, Matsudo, Chiba, Japan*

Abstract

Background: Although patients with out-of-hospital cardiac arrest (OHCA) have a lower survival rate during night-time than during day-time, the cause of this difference remains unclear. We aimed to assess CPR parameters according to time period based on in-hospital cardiopulmonary resuscitation (IHCPR) duration and the frequency of iatrogenic chest injuries among OHCA patients.

Methods: This two-centre observational cohort study evaluated non-traumatic OHCA patients who were transferred between 2013–2016. These patients were categorised according to whether they received day-time treatment (07:00–22:59) or night-time treatment (23:00–06:59). Differences in IHCPR duration, CPR-related chest injuries, return of spontaneous circulation, and survivals to emergency department and hospital discharge were compared using a generalised estimating equation model adjusted for pre-hospital confounders. Sensitivity analysis was also performed using a propensity score matching method.

Results: Among 1254 patients (day-time: 948, night-time: 306), the night-time patients had a significantly shorter IHCPR duration (27.8 min vs. 23.6 min, adjusted difference: −5.1 min, 95% confidence interval [CI]: −6.7, −3.4), a higher incidence of chest injuries (40.4% vs. 67.0%, adjusted odds ratio [AOR]: 1.27, 95% CI: 1.20, 1.35), and a lower rate of return of spontaneous circulation (38.4% vs. 26.5%, AOR: 0.93, 95% CI: 0.88, 0.98). No significant differences were observed in the rates of survival to emergency department and hospital discharge. The propensity score-matched analysis revealed similar results.

Conclusions: Patients who underwent night-time treatment for OHCA had an increased risk of CPR-related chest injuries despite their shorter resuscitation duration. Further studies are needed to clarify the underlying mechanism(s).

Introduction

The survival rate after out-of-hospital cardiac arrest (OHCA) has improved because of the spread of bystander cardiopulmonary resuscitation (CPR) and automated external defibrillator use. However, OHCA remains a major public health issue throughout the world,[1] and Japan has approximately 120,000 OHCA cases that are transported annually.[2,3] Patients who receive night-time treatment for OHCA have a lower survival rate than patients who are treated

* Corresponding author at: Tokyo Medical and Dental University, Department of Emergency and Disaster Medicine, 1-5-45, Yushima, Bunkyo-ku, Tokyo, 113-0034, Japan.

E-mail address: tak2accm@tmd.ac.jp (W. Takayama).

https://doi.org/10.1016/j.resuscitation.2019.01.023

Received 22 June 2018; Received in revised form 29 November 2018; Accepted 19 January 2019

0300-9572/

during day-time, with this difference being potentially attributed to the decreased frequencies of witnessed cardiac arrest and bystander CPR.[4] Furthermore, reduced quality of treatment (e.g., because of fewer staff who are tired and less motivated) may explain the lower survival rate after night-time treatment.[5] However, few reports have examined CPR quality according to treatment time period.[6]

Quantitative evaluation of CPR quality and healthcare providers' fatigue is challenging, especially in the clinical setting. However, fatigued healthcare providers may provide CPR of shorter duration with lower quality, which may increase the incidence of iatrogenic chest injuries. Thus, the present study aimed to evaluate the quality of manual chest compressions based on CPR duration and the frequency of iatrogenic chest injuries, according to night-time or day-time treatment, among patients with OHCA.

Methods

Study design and setting

This observational cohort study evaluated patients with OHCA between April 2013 and March 2016 (three fiscal years). The patients were transferred to two Japanese tertiary critical care centres: the Tokyo Medical and Dental University Hospital of Medicine or the Matsudo City Hospital. Each hospital receives approximately 150 patients with OHCA each year. Both hospitals provided a similar staffing, relative to patient admissions, during daytime ($>$2 board-certified emergency physicians, 3 medical interns, and 3 nurses) and night-time (1 board-certified emergency physician, 3 medical interns, and 2 nurses). Furthermore, procedures and medications in both hospitals were equally available for weekdays and weekends when they were required. Pre-hospital factors were also similar between weekdays and weekends because the Japanese EMS system provides a constant quality of prehospital care (even on holidays). During the study period, in-hospital and out-of-hospital CPR were performed in accordance with the 2010 American Heart Association Guidelines for CPR and Emergency Cardiovascular Care.

This study complied with the principles of the 1964 Declaration of Helsinki and its later amendments. The study's protocol was approved by the ethics committees of the Tokyo Medical and Dental University Hospital of Medicine (M2017-182) and the Matsudo City Hospital (29-15). All patient data were retrospectively collected from electronic medical charts, and were subsequently anonymised before the statistical analyses.

Study population

This study included consecutive patients who were transferred because of OHCA to the Tokyo Medical and Dental University Hospital of Medicine or the Matsudo City Hospital between April 1, 2013 and March 31, 2016. We excluded patients who were $<$18 years old, who had do-not-attempt-resuscitation orders, who had trauma-related cardiac arrest, who had received open-chest CPR, or who had missing or insufficient data regarding the study variables (i.e., lack of information regarding patient age, CPR duration, witnessed status, or initial rhythm). In addition, patients were excluded if they had received CPR using an automated chest compression device, regardless of setting, as this study aimed to understand the quality of manual CPR performed by emergency medical staff. Based on the hospitals' shift schedules and the results of previous studies,[7,8] we divided the included patients according to whether they were admitted to the emergency department (ED) during day-time (07:00–22:59) or night-time (23:00–06:59).

Data collection

The patients' medical records were searched to collect data regarding age, sex, ED admission time, whether the OHCA was witnessed, whether bystander CPR or defibrillation had been performed before the paramedics' arrival, location of cardiac arrest, shockable rhythm status, the cause of the cardiac arrest, in-hospital CPR (IHCPR) duration, out-of-hospital CPR (OHCPR) duration, and statuses at ED and hospital discharge (i.e., survived or deceased). We also collected data regarding CPR-related chest injuries from the patients' medical records and computed tomography (CT) findings. Both hospitals had a policy of routinely performing CT after CPR to identify the cause of the cardiac arrest in non-traumatic cases. The radiological findings were interpreted by $\geq$2 board-certified emergency physicians and 1 radiologist.

Definitions and outcome measures

Cases of OHCA were defined as cardiac arrest that occurred out-of-hospital, with the patient being unresponsive to stimulation, gasping or not breathing, and having carotid arteries that were not palpable for a maximum assessment interval of 10 s.[9] The OHCPR duration was defined as the interval from EMS dispatch to ED arrival in cases with bystander CPR,[5] or as the interval from EMS arrival at the scene to ED arrival in cases without bystander CPR. The IHCPR duration was defined as the interval from the ED arrival to the termination of resuscitation or the return of spontaneous circulation (ROSC).[10] In this study, ROSC was defined as return of spontaneous circulation that lasted at least 5 min. We defined CPR-related chest injuries as rib fractures, sternum fractures, or pneumothorax. The study outcomes were defined as the IHCPR duration, the frequency of CPR-related chest injuries, the rate of ROSC, and the rates of survival to ED and hospital discharge.

Statistical analysis

Categorical variables were reported as number (percentage), while continuous variables were reported as mean (standard deviation) or median (interquartile range) as appropriate. The normality of continuous variables' distributions was tested using the Kolmogorov–Smirnov test. Multivariate mixed-effects analysis using a cluster-weighted generalised estimating equation (GEE) model was performed to determine whether the time of treatment was associated with the study outcomes. In this model, the fixed-effect variables were defined as age, sex, witnessed status, bystander CPR status, initial rhythm (shockable or not), the cause of cardiac arrest, and OHCPR duration, while the treating hospital's unique identifier was incorporated as a random-effect variable. However, the variables of bystander CPR, location of cardiac arrest, and bystander defibrillation were not incorporated into the GEE model considering the issue of multicollinearity. Those variables were selected based on clinical judgement and findings from previous reports.[4,11–13]

We also performed sensitivity analysis using a propensity score matching method to create matched groups of day-time and night-time patients. The propensity scores were calculated using logistic regression analysis that included the variables from the mixed effect model. The nearest neighbour method was used with a calliper of 0.25 (i.e., the largest allowable difference in the propensity scores of matched participants was 25%) to match the logit-transformed propensity scores 1:1 between the day-time and night-time groups. The absolute standardised mean difference was used to assess the matching balance for the different variables between the two groups, and the matching was considered acceptable at values of <0.1. Inter-group comparisons of the outcomes among the propensity score-matched subjects were performed using the χ^2 test.

All statistical analyses were performed using R software (version 3.4.1; R Foundation for Statistical Computing, Vienna, Austria) and a commander module that incorporates frequently used biostatistical functions. Differences were considered statistically significant at two-sided p-values of <0.05.

Table 1 – Baseline characteristics.

	Day-time N = 948	Night-time N = 306
Age in years, median (IQR)	72 (59–82)	67 (51–81)
Female sex, n (%)	320 (33.8)	97 (31.7)
Witnessed, n (%)	365 (38.5)	82 (26.8)
Bystander CPR, n (%)	298 (31.4)	61 (19.9)
Bystander defibrillation, n (%)	210 (22.2)	39 (12.7)
Arrest in a public location, n (%)	686 (72.4)	146 (47.7)
Shockable initial rhythm, n (%)	140 (14.8)	40 (13.1)
Cardiogenic shock, n (%)	139 (14.7)	30 (9.8)
OHCPR duration in min, median (IQR)	26 (20–34)	28 (22–38)

OHCPR, out-of-hospital cardiopulmonary resuscitation; IQR, interquartile range.

Results

The patient selection process identified 1254 patients with non-traumatic OHCA, including 948 day-time cases (75.6%) and 306 night-time cases (24.4%) (**Supplemental Fig. S1**). The numbers of OHCA cases according to admission times are shown in Fig. 1. The baseline characteristics of the two groups are summarised in Table 1. The day-time OHCA cases involved older patients (mean age: 69.0 years, standard deviation: 16.6 years) than the night-time group. However, the night-time group had relatively lower rates of witnessed OHCA, bystander CPR, defibrillation, and public cardiac arrest, as well as a relatively longer duration of OHCPR. Despite the longer OHCPR duration, the night-time group had a significantly shorter total duration of CPR (median [interquartile range]: 58 min [42–68 min] vs. 55 min [45–64 min], $p = 0.042$).

The associations among IHCPR duration, CPR-related chest injuries, and the rate of ROSC are shown in Fig. 2. Although the night-time group had a shorter IHCPR duration, these patients also had a higher incidence of chest injuries and a lower ROSC rate. The results of the univariate and multivariate analyses are summarised in Table 2. Relative to the day-time group, the night-time group had a significantly shorter IHCPR duration (27.8 min vs. 23.6 min, adjusted difference: −5.1 min, 95% confidence interval [CI]: −6.7, −3.4 min) and a higher incidence of chest injuries (40.4% vs. 67.0%, adjusted odds ratio [AOR]: 1.27, 95% CI: 1.20, 1.35). Although the night-time group had a significantly lower ROSC rate (38.4% vs. 26.5%, AOR: 0.93, 95% CI: 0.88, 0.98), there were no significant differences in the rates of survival to ED or hospital discharge.

The propensity score matching created 297 matched pairs, whose baseline characteristics are shown in Table 3. The absolute standardised mean difference values for each variable were <0.1, which indicated that a well-matched balance had been achieved. As with the multivariate analysis, the propensity score-matched group of night-time patients had a significantly shorter IHCPR duration, a higher incidence of chest injuries, and a lower ROSC rate (Table 4).

Discussion

This cohort study evaluated CPR parameters (IHCPR duration and CPR-related chest injuries) according to the time of treatment among 1,254 patients with OHCA. Several recent retrospective studies have also suggested that night-time treatment of OHCA is associated with poorer outcomes than day-time treatment,[14–17] although the underlying mechanism(s) remain unclear. Some reports have attributed this difference to fewer staff who were fatigued and not motivated during night-time shifts.[4,5]

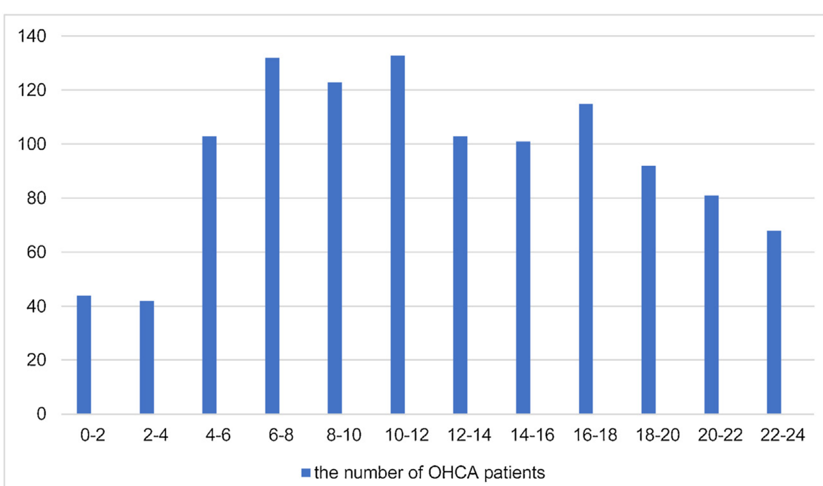

Fig. 1 – The number of OHCA patients transported during each 2-h time period.
The horizontal axis shows the 2-h time periods and the bars indicate the number of patients transported during each period. OHCA, out-of-hospital cardiac arrest.

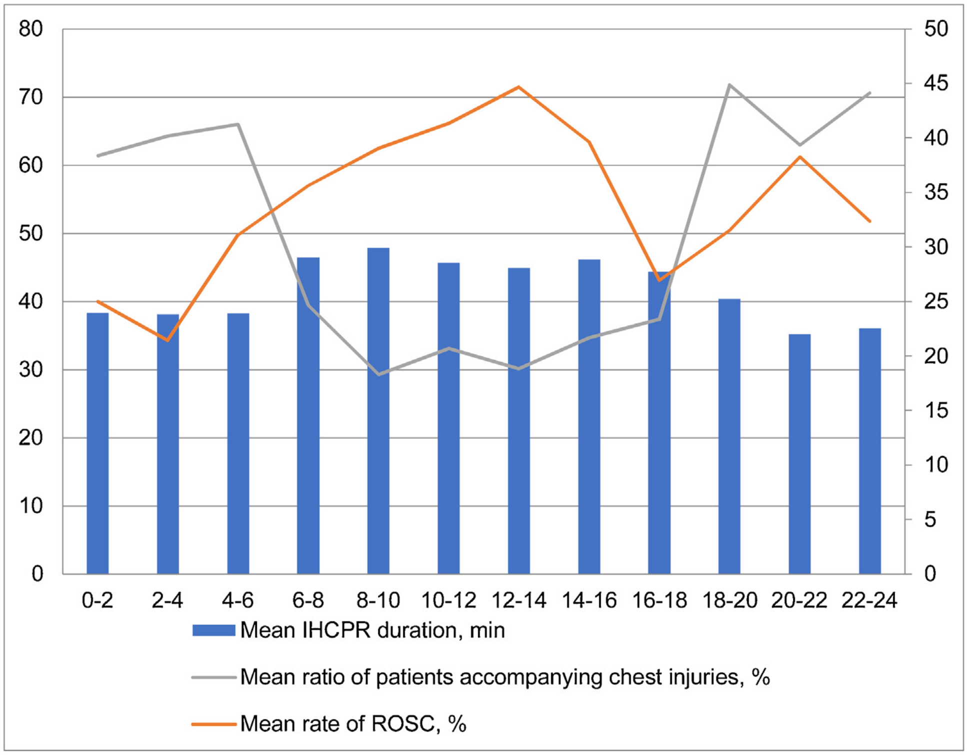

Fig. 2 – The associations between IHCPR duration, injuries caused by chest compressions, and the rate of ROSC. The horizontal axis shows the 2-h time periods. The bars indicate the mean duration of IHCPR. The grey line indicates the proportion of chest injuries and the orange line indicates the rate of ROSC. IHCPR, in-hospital cardiopulmonary resuscitation; ROSC, recovery of spontaneous circulation.

Table 2 – Multivariate analysis of outcomes using a generalised estimating equation.

	Day-time N = 948	Night-time N = 306	Unadjusted odds ratio [95% CI]	Unadjusted difference [95% CI]	Adjusted odds ratio [95% CI]	Adjusted difference [95% CI]	p-Value
IHCPR duration, min (SD)	27.8 (13.7)	23.6 (11.2)	–	−4.2 [−5.9, −2.5]	–	−5.1 [−6.7, −3.4]	<0.001
Chest injuries, n (%)	383 (40.4)	205 (67.0)	1.30 [1.23, 1.39]	–	1.27 [1.20, 1.35]	–	<0.001
ROSC, n (%)	364 (38.4)	81 (26.5)	0.89 [0.84, 0.94]	–	0.93 [0.88, 0.98]	–	0.003
Survival to ED discharge, n (%)	165 (17.4)	38 (12.4)	0.95 [0.91, 0.99]	–	0.98 [0.94, 1.02]	–	0.17
Survival to hospital discharge, n (%)	70 (7.4)	17 (5.6)	0.98 [0.95, 1.01]	–	1.00 [0.98, 1.03]	–	0.37

SD, standard deviation; ROSC, return of spontaneous circulation; ED, emergency department; CI, confidence interval.

Table 3 – Baseline characteristics of the propensity score-matched cohort

Baseline characteristics	Day-time N = 297	Night-time N = 297	p-Value	ASMD
Age in years, mean (SD)	65.4 (17.3)	65.8 (18.8)	0.82	0.02
Female sex, n (%)	88 (29.6)	94 (31.6)	0.66	0.04
Witnessed, n (%)	80 (26.9)	81 (27.3)	1.00	0.01
Bystander CPR, n (%)	72 (24.2)	61 (20.5)	0.33	0.09
Shockable initial rhythm, n (%)	38 (12.8)	40 (13.5)	0.90	0.02
Cardiogenic shock, n (%)	30 (10.1)	30 (10.1)	1.00	0.00
OHCPR time, mean (SD)	29.3 (10.0)	29.0 (10.9)	0.70	0.03
Treating hospital				
TMDU, n (%)	180 (60.6)	182 (61.3)	0.93	0.01

SD, standard deviation; OHCPR, out-of-hospital cardiopulmonary resuscitation; ASMD, absolute standardised mean difference; TMDU, Tokyo Medical and Dental University Hospital of Medicine.

It has also been reported that shorter duration of IHCPR is associated with a lower rate of survival to hospital discharge.[18] The present study revealed that, relative to day-time cases, night-time OHCA cases had shorter resuscitation durations but still had a higher incidence of CPR-related chest injuries, even after adjusting for the pre-hospital confounding factors. These results suggest that the quality of CPR, including chest compressions, may be lower during night-time than during day-time. Although a causal relationship between lower-quality CPR and the lower night-time ROSC rate could not be established, because of the study's design, it is reasonable to speculate that a shorter IHCPR duration could reduce the survival rate.

High-quality chest compression is an essential part of resuscitation, therefore, the ERC and AHA resuscitation guidelines emphasize its importance and recommend a compression depth as "at least 5 cm but not to exceed 6 cm".[9,19] However, high-quality CPR is physically demanding for the resuscitation team. During night-time, it might be difficult to maintain high-quality CPR (i.e., appropriate hand position, depth and rate) because of the limited number of medical staff, who are tired and less motivated. It has also been reported that deeper chest compressions increase chest injuries, especially when the depth exceeds 6 cm.[20] Thus, in this study, we hypothesised that CPR-related chest injuries and IHCPR duration might be useful surrogate outcomes for estimating CPR quality and the fatigue of the resuscitation team. In that context, the present study's findings indirectly suggest that night-time patients received lower-quality CPR with inappropriate depth of chest compressions, based on their higher incidence of CPR-related chest injuries.

The higher incidence of chest injuries might partially explain the lower rates of ROSC, as failure of thoracic compliance (e.g., because of fractured bones or pneumothorax) could interrupt the cycle of positive and negative pressure, which might result in ineffective chest compressions. In this study, the night-time group had a significant higher incidence of chest injuries and a lower ROSC rate than the day-time group. Although a causal relationship could not be established, it has been reported that chest injuries are a risk factor for a lower rate of ROSC.[13] Therefore, the higher rate of chest injuries could help explain the lower ROSC rate in the present study. Based on this perspective, alternative techniques, such as automated chest compression devices, might be useful for improving CPR quality, especially during night-time treatment, as they reportedly produce non-inferior outcomes (vs. chest compressions performed by well-trained healthcare providers) in terms of survival to ED discharge, survival to hospital discharge, and neurological outcomes after OHCA.[21] The ERC and AHA resuscitation guidelines also consider mechanical chest compressions acceptable for CPR in unstable settings (e.g., during transportation or coronary intervention).[22,23] However, the use of automated chest compression devices is also reportedly associated with an increased risk of chest injuries.[24,25] Further studies are needed to assess the efficacy of automated chest compression devices during night-time treatment.

In contrast with the findings of a previous multicentre study,[6] the present study failed to identify significant differences between the day-time and night-time groups in terms of survival to ED or hospital discharge, although day-time treatment was associated with a significantly higher incidence of ROSC. The relatively small sample size of the present study (vs. the previous study) might explain this discrepancy. Another potential explanation may be related to the Japanese EMS system, as there are restrictions on the decision to terminate resuscitation attempts in the field,[26–28] which might have lowered the in-hospital survival rates. For example, the in-hospital survival rate in the present study was 6.9%, which is lower than the previously reported rates.[7,29] Thus, a larger sample of Japanese patients (vs. patients in other countries) may be needed to detect significant differences in the survival rates.

The findings of the present study are strengthened by the fact that all patients underwent CT examinations, which allowed us to detect CPR-related chest injuries. Furthermore, the two hospitals had similar shift times and compositions of their resuscitation teams. However, the present study also has several limitations that should be considered when interpreting our findings. First, this was a two-centre observational cohort study, which limits the generalizability our findings and increases the risk of residual confounding, as we did not have access to OHCA-specific characteristics or detailed information regarding the patients' characteristics and comorbidities. Second, we were unable to evaluate the quality of pre-hospital CPR, as we did not have access to information regarding the bystanders' occupation (i.e., whether any were healthcare providers). Third, video records were not maintained, which precluded a direct evaluation of CPR quality parameters, such as depth, rhythm, and interruption time. Fourth, the detailed reason(s) for termination of resuscitation in the ED were not always available. Fifth, although Utstein has recommended defining ROSC as return of spontaneous circulation for $\geq$30 s,[30] the present study defined ROSC as return of spontaneous circulation for $\geq$5 min, based on the absence of clinical data for 30-s intervals in the hospitals' electronic medical record systems. Finally, many of the patients in the day-time group were not analysed due to the nature of the 1:1 propensity score matching, although both groups had well balanced background characteristics and received appropriate support. Despite these limitations, to the best of our knowledge, this is the first study to evaluate CPR parameters (i.e., IHCPR duration and CPR-related chest injuries) according to treatment time, although it

Table 4 – Outcomes after the propensity score matching

	Day-time N = 297	Night-time N = 297	Adjusted odds ratio [95% CI]	Adjusted difference [95% CI]	p-Value
IHCPR duration, min (SD)	28.8 (13.3)	23.6 (11.3)	-	−4.7 [−7.8, −2.9]	<0.001
Chest injuries, n (%)	120 (40.4)	197 (66.3)	3.51 [2.44, 5.09]	-	<0.001
ROSC, n (%)	103 (34.7)	81 (27.3)	0.64 [0.44, 0.94]	-	0.02
Survival to ED discharge, n (%)	42 (14.1)	38 (12.8)	0.67 [0.38, 1.17]	-	0.16
Survival to hospital discharge, n (%)	15 (5.1)	17 (5.7)	0.67 [0.27, 1.62]	-	0.38

SD, standard deviation; IHCPR, in-hospital cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; ED, emergency department; CI, confidence interval.

would be useful for prospective studies to validate our findings using direct evaluations of CPR quality (e.g., using video review or cardiac defibrillators with a CPR feedback system).

Conclusion

This two-centre observational cohort study revealed that OHCA patients who were treated at night-time had a significantly shorter duration of in-hospital resuscitation, a significantly higher incidence of CPR-related chest injuries, and a significantly lower rate of ROSC. Further studies are needed to clarify the underlying mechanism(s) for these findings.

Conflicts of interest

None.

Role of the funding source

None.

Acknowledgments

We thank all included patients and their families as well as the physicians, nurses, paramedics, and other staff for performing CPR and assistance with the data acquisition. In addition, we thank Dr. Ayako Yoshiyuki, Dr. Raira Nakamoto, Dr. Nao Urushibata, and Dr. Junichi Aiboshi for direct patient care and their review and feedback regarding our manuscript.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2019.01.023.

REFERENCES

1. Donoghue A, Hsieh TC, Myers S, Mak A, Sutton R, Nadkarni V. Videographic assessment of cardiopulmonary resuscitation quality in the pediatric emergency department. Resuscitation 2015;91:19–25.
2. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A. Nationwide public-access defibrillation in Japan. N Engl J Med 2010;362:994–1004.
3. Ambulance Service Planning Office of Fire and Disaster Management Agency of Japan. Effect of first aid for cardiopulmonary arrest [in Japanese]. (Accessed 24 May 2018, at https://www.fdma.go.jp/neuter/topics/kyukyukyujo_genkyo/h28/01_kyukyu.pdf).
4. Kuhn G. Circadian rhythm, shift work, and emergency medicine. Ann Emerg Med 2001;37:88–98.
5. Smith-Coggins R, Rosekind MR, Hurd S, Buccino KR. Relationship of day versus night sleep to physician performance and mood. Ann Emerg Med 1994;24:928–34.
6. Goldberger ZD, Chan PS, Berg RA, et al. Duration of resuscitation efforts and survival after in-hospital cardiac arrest: an observational study. Lancet 2012;380:1473–81.
7. Matsumura Y, Nakada TA, Shinozaki K, et al. Nighttime is associated with decreased survival and resuscitation efforts for out-of-hospital cardiac arrests: a prospective observational study. Crit Care 2016;20:141.
8. Karlsson LI, Wissenberg M, Fosbol EF, et al. Diurnal variations in incidence and outcome of out-of-hospital cardiac arrest including prior comorbidity and pharmacotherapy: a nationwide study in Denmark. Resuscitation 2014;85:1161–8.
9. Kleinman ME, Brennan EE, Goldberger ZD, et al. Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality. 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2015;132:S414–35.
10. Seung MK, You JS, Lee HS, Park YS, Chung SP, Park I. Comparison of complications secondary to cardiopulmonary resuscitation between out-of-hospital cardiac arrest and in-hospital cardiac arrest. Resuscitation 2016;98:64–72.
11. Krischer JP, Fine EG, Davis JH, Nagel EL. Complications of cardiac resuscitation. Chest 1987;92:287–91.
12. Hoke RS, Chamberlain D. Skeletal chest injuries secondary to cardiopulmonary resuscitation. Resuscitation 2004;63:327–38.
13. Kashiwagi Y, Sasakawa T, Tampo A, Kawata D, Nishiura T, Kokita N, et al. Computed tomography findings of complications resulting from cardiopulmonary resuscitation. Resuscitation 2015;88:86–91.
14. Wallace SK, Abella BS, Shofer FS, et al. Effect of time of day on prehospital care and outcomes after out-of-hospital cardiac arrest. Circulation 2013;127:1591–6.
15. Bagai A, McNally BF, Al-Khatib SM, et al. Temporal differences in out-of-hospital cardiac arrest incidence and survival. Circulation 2013;128:2595–602.
16. Koike S, Tanabe S, Ogawa T, et al. Effect of time and day of admission on 1-month survival and neurologically favourable 1-month survival in out-of-hospital cardiopulmonary arrest patients. Resuscitation 2011;82:863–8.
17. Brooks SC, Schmicker RH, Rea TD, et al. Out-of-hospital cardiac arrest frequency and survival: evidence for temporal variability. Resuscitation 2010;81:175–81.
18. Cha WC, Lee EJ, Hwang SS. 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.
19. Perkins GD, Handley AJ, Koster RW, et al. European Resuscitation Council Guidelines for Resuscitation 2015: section 2. Adult basic life support and automated external defibrillation. Resuscitation 2015;95:81–99.
20. Hellevuo H, Sainio M, Nevalainen R, et al. Deeper chest compression — more complications for cardiac arrest patients? Resuscitation 2013;84:760–5.
21. Bonnes JL, Brouwer MA, Navarese EP, et al. Manual cardiopulmonary resuscitation versus CPR including a mechanical chest compression device in out-of-hospital cardiac arrest: a comprehensive meta-analysis from randomized and observational studies. Ann Emerg Med 2016;67:349–60.
22. Truhlář A, Deakin CD, Soar J, et al. European Resuscitation Council Guidelines for Resuscitation 2015: section 4. Cardiac arrest in special circumstances. Resuscitation 2015;95:148–201.
23. Brooks SC, Anderson ML, Bruder E, et al. Part 6: alternative techniques and ancillary devices for cardiopulmonary resuscitation: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2015;132:S436–43.
24. Lardi C, Egger C, Larribau R, Niquille M, Mangin P, Fracasso T. Traumatic injuries after mechanical cardiopulmonary resuscitation (LUCAS 2): a forensic autopsy study. Int J Legal Med 2015;129:1035–42.
25. Smekal D, Lindgren E, Sandler H, Johansson J, Rubertsson S. CPR-related injuries after manual or mechanical chest compressions with the LUCAS™ device: a multicentre study of victims after unsuccessful resuscitation. Resuscitation 2014;85:1708–12.
26. Kajino K, Kitamura T, Iwami T, et al. Current termination of resuscitation (TOR) guidelines predict neurologically favorable outcome in Japan. Resuscitation 2013;84:54–9.

27. Goto Y, Maeda T, Goto YN. Termination-of-resuscitation rule for emergency department physicians treating out-of-hospital cardiac arrest patients: an observational cohort study. Crit Care 2013;17:R235.
28. Fukuda T, Ohashi N, Matsubara T, Doi K, Gunshin M, Ishii T. Applicability of the prehospital termination of resuscitation rule in an area dense with hospitals in Tokyo: a single-center, retrospective, observational study: is the pre hospital TOR rule applicable in Tokyo? Am J Emerg Med 2014;32:144–9.
29. Chan PS, McNally B, Tang F, Kellermann A, CARES Surveillance Group. Recent trends in survival from out-of-hospital cardiac arrest in the United States. Circulation 2014;130:1876–82.
30. 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 taskforce 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).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, Inter American Heart Foundation, Resuscitation Councils of Southern Africa). Circulation 2004;110:3385–97.