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Clinical paper

Enhancing survival outcomes in developing emergency medical service system: Continuous quality improvement for out-of-hospital cardiac arrest

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Abstract

Introduction: Emergency Medical Service (EMS) providers are essential for out-of-hospital cardiac arrest (OHCA) survival, however implementing high-performance CPR guidelines in developing EMS settings presents challenges. This study assessed the impact of Continuous Quality Improvement (CQI) initiatives on OHCA outcomes in a hospital-based EMS agency in Bangkok, Thailand.

Methods: A before-and-after study design was utilized, utilizing data from a prospective OHCA registry spanning 2019 to 2023. CQI interventions included low-dose high-frequency training in advanced airway management, high-performance CPR, and post-debriefing with video recording (VDO). Data collection encompassed patient characteristics, EMS management, and survival outcomes. Quality CPR metrics were assessed using the mobile defibrillator and CPR code review software. Statistical analyses compared outcomes between the pre-intervention period in 2019 and the post-full CQI implementation period in 2023.

Results: Among enrolled OHCA patients, with 88 cases occurring in 2019 and 91 cases in 2023. The bystander CPR rate was similar between both groups (47.73% in 2023 vs 53.85%, $p = 0.413$). In 2023, there was a significantly higher rate of prehospital intubation (93.40% vs 70.45%, $p < 0.001$) compared to 2019. Prehospital return of spontaneous circulation (ROSC) improved from 30.68% to 49.45% ($p = 0.012$), with an adjusted odds ratio (aOR) of 2.16 (95% CI: 1.14–4.07). Survival to discharge increased significantly from 2.27% in 2019 to 7.69% in 2023 ($p = 0.27$), with an aOR of 3.81 (95% CI: 0.46–31.79).

Conclusion: Tailored CQI initiatives in a developing EMS setting were significantly associated with improved prehospital ROSC but showed an insignificant increase in survival to discharge.

Keywords: Out-of-hospital cardiac arrest, Continuous quality improvement, High-performance CPR

Introduction

Emergency Medical Service (EMS) providers are integral to the survival of out-of-hospital cardiac arrest (OHCA) patients. High-quality cardiopulmonary resuscitation (CPR), as delineated by the American Heart Association (AHA),[1] necessitates optimizing compression rate (100–120 compressions per minute) and depth (5–6 cm), minimizing interruptions, ensuring complete recoil, and delivering controlled ventilation. However, translating these guidelines into consistent practice poses challenges in real-world settings[2,3] marked by time constraints, stress, and environmental factors. Sustaining proficiency

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in CPR skills requires ongoing training and support, emphasizing the importance of comprehensive training programs and quality improvement initiatives for EMS providers.

Numerous CPR quality initiatives have been undertaken worldwide. For instance, Arizona EMS units implemented team-based scenario training and utilized real-time CPR feedback devices from 2010 to 2011, resulting in significant enhancements in CPR quality and survival rates.[4] Similarly, Victoria ambulance adopted a high-performance CPR protocol to optimize EMS provider positioning and communications, particularly aimed at minimizing interruptions, leading to notable improvements in survival rates as evidenced by a 2019 study.[5] Furthermore, in 2020, Victoria ambulance introduced post-resuscitation debriefing, which demonstrated the initiative's capacity to enhance CPR quality.[6]

Moreover, certain promising hospital initiatives hold potential for adaptation in prehospital care settings. Hospitals have employed low-dose, high-frequency CPR training, offering shorter but more frequent CPR training sessions, typically conducted around four times a year.[7] Results indicate improved knowledge, CPR skills, and self-efficacy in resuscitation.[8] However, the majority of recent quality CPR research has been conducted within developed EMS systems.[5–10]

To the best of our knowledge, the implementation of quality CPR initiatives in developing EMS systems has presented significant challenges. Our study sought to address this by introducing continuous quality improvement (CQI) initiatives specifically tailored for developing EMS systems and examining their impact on survival outcomes. The primary focus of our investigation involved comparing survival outcomes before (2019) and after (2023) the full implementation of CQI projects in our center.

Method

Study design, setting, and population

A before-and-after study was conducted to assess the impact of Continuous Quality Improvement (CQI) initiatives among out-of-hospital cardiac arrest (OHCA) patients, utilizing data from a prospective OHCA registry spanning the years 2019 to 2023. The year 2019 was designated as the control group, as CQI projects were implemented by the Emergency Medical Service (EMS) team starting in 2021. And we did not select data in COVID-19 era in 2020 as a control group to avoid confounding from the COVID-19 effect.[11] The study received approval from the Institutional Review Board (IRB) of the Faculty of Medicine Siriraj Hospital, Mahidol University (COA 864/2564(IRB2)).

The study was carried out within a single hospital-based EMS agency located in Bangkok, Thailand, which is part of the Bangkok EMS network.[12] The agency's coverage area encompassed 59.87 square kilometers (km^2), representing approximately 4% of Bangkok city, with a population of 353,000 individuals, also accounting for approximately 4% of the city's population. The population density within this coverage area was 5896 persons per km^2. The EMS system operated on a two-tier response system, with six volunteer-based EMS units serving as basic ambulances. These basic units provided basic life support and utilized automatic external defibrillators (AEDs), although the majority lacked AEDs due to limited funding and resources.[11]

Two advanced ambulances, one from a municipal-based EMS agency and another from the hospital-based EMS agency, served the coverage area. In the event of cardiac arrest, the Bangkok dispatch center activated dual dispatch for both basic and advanced ambulances, although the predominant response was from a single advanced unit. The population-to-advanced-ambulance ratio was approximately 176,500 persons per ambulance.[11] Each advanced ambulance team comprised two paramedics and three basic emergency medical technicians (EMT-B), providing advanced life support including prehospital intubation and drug administration per OHCA protocol. The OHCA protocol followed the American Heart Association Guidelines for Cardiopulmonary Resuscitation.[1] Mechanical CPR devices (Autopulse, Zoll®, MA, US) were utilized exclusively during patient transport. The site applied the universal termination of resuscitation criteria to withhold resuscitation. The investigating site also recruited emergency nurse practitioners (ENP) as paramedics since the scope of practice for prehospital emergency care in Thailand was similar between both professions.

In 2020, the EMS team introduced audio-visual teleconsultation for online medical direction between EMS providers and the EMS medical director. In 2021, the OHCA protocol was revised to exclude prehospital intubation in suspected COVID-19 cases during the pandemic, while maintaining other standardized OHCA management procedures. Real-time feedback devices via mobile defibrillators were implemented, and weekly OHCA case reviews utilizing CPR data and video (VDO) recordings from audio-visual teleconsultation sessions were initiated.

Subsequently, in 2022, the OHCA protocol was updated to include prehospital endotracheal intubation (ETI) with video laryngoscopy. Additionally, the EMS team implemented low-dose, high-frequency training for both CPR and prehospital airway management skills. Monthly training sessions were conducted, consisting of two-minute CPR sessions and ten-minute airway management sessions per provider.

In 2023, the high-performance CPR (HP-CPR) concept was integrated into the OHCA protocol, as outlined in Supplement 1. A half-day HP-CPR workshop was conducted, consisting of a one-hour didactic session followed by a two-hour simulation training session for EMS providers. Subsequently, monthly HP-CPR simulation training sessions, each lasting one hour, were implemented. Performance evaluation of HP-CPR, utilizing VDO recordings, CPR records, and the code review software, was established by EMS medical directors, as detailed in Supplement 2. Additionally, weekly OHCA reviews were consistently conducted to assess performance and facilitate debriefing sessions for providers. During these reviews, a substantial level of agreement was observed among two EMS medical directors and three paramedics regarding the performance assessment, particularly concerning data derived from VDO recordings.

In terms of human resource management, the site employed a full-time ENP who functioned as a paramedic, alongside two EMT-Bs in 2019. The majority of providers served in part-time capacities. By 2023, the EMS center successfully recruited an additional eight paramedics, comprising five ENPs and three paramedics, along with two new EMTs. The total number of full-time providers in 2023 was thirteen. Further details regarding the characteristics of EMS providers at the investigation site are provided in Supplement 3.

Data collection and quality control

The site developed the OHCA registry using variables and definitions from the Pan-Asian Resuscitation Outcome Study. The prospective OHCA registry was based on the Ustein template.[13] Data encompassing patient characteristics, community response, and EMS management were collected by EMS providers after end of resuscitation. Prehospital advanced airway included both endotracheal intubation and supraglottic airway devices. Subsequent emergency room management and in-hospital data, including survival outcomes, were collected by our paramedics and EMS medical directors via the electronic medical record.

Beginning in 2021, quality metrics pertaining to chest compressions were collected using the Zoll X-series mobile defibrillator (Zoll®, MA, US) and analyzed using the CPR code review software (Zoll RescueNet® Code Review, Zoll®, MA, US). Specifically, percentages of chest compression rate and depth conforming to standard recommendations were separately collected during the period spanning 2021–2022.

Transitioning to a web-based platform (Zoll RescueNet® Case Review, Zoll®, MA, US), a combination of percentages reflecting adherence to both recommended compression rate and depth, termed the percentage of chest compression quality, was collected from January 2023 onwards. Additionally, chest compression fraction data have been collected since 2021, with all chest compression measurements obtained exclusively manual CPR at the scene.

To ensure data integrity and accuracy, weekly OHCA case reviews were conducted to provide feedback to EMS providers and facilitate quality control measures within the OHCA registry. This iterative process of review and feedback served to enhance the reliability and validity of the collected data, thereby bolstering the robustness of our study findings.

Inclusion and exclusion criteria

The study encompassed adult non-traumatic out-of-hospital cardiac arrest (OHCA) patients who received resuscitation from our hospital-based EMS agency. Patients or their families who refused resuscitation upon the arrival of the ambulance team or had pre-existing Do Not Attempt Resuscitation (DNAR) orders were excluded from the study. Additionally, cases where initial chest compressions were administered by mechanical CPR devices were excluded. Furthermore, cardiac arrest patients who were transported from the scene to nearby hospitals other than our hospital were also excluded from the study due to difficulties encountered by the investigators in accessing in-hospital management and outcomes for these cases.

Outcome measurement

The primary outcome of the study was the percentage of survival to discharge in 2023 compared to that in 2019, while secondary outcomes included pre-hospital return of spontaneous circulation (ROSC) and survival to admission in 2023 compared to the corresponding data in 2019. Prehospital ROSC was defined as any ROSC occurring before patients arrived at the emergency department (ED). The investigation also assessed trends in improvements in survival outcomes. Quality CPR metrics comprised the percentage of chest compression rate within 100–120 compressions per minute (cpm), percentage of chest compression depth within 4–6 cm, and chest compression fraction (CCF). The study standardized the chest compression depth to at least 4 cm to account for the predominantly lesser chest wall depth observed in the Asian population compared to Western countries as indicated by the Singaporean CPR guideline.[14]

Statistical methods

Descriptive analyses of demographic data, clinical characteristics, prehospital management, and patient outcomes were conducted among all eligible EMS-treated OHCA patients. The prehospital intervals and quality of CPR metrics were presented as the median and interquartile range and compared by using non-parametric method (Kruskal-Wallis method). The comparison of categorical variables of survival outcomes between 2019 and 2023 was performed using either a Chi-square test or Fisher's exact test. Additionally, multiple logistic regression analysis adjusted for age, initial cardiac arrest rhythm, bystander CPR, and response time was employed to analyze OHCA outcomes between 2019 and 2023. We also analyzed subgroup witnessed and initial shockable rhythm cardiac arrest and adjusted for age, bystander CPR, and response time. Moreover, survival outcomes, particularly in the subgroup of witnessed cardiac arrest with initial shockable rhythm, were illustrated by year in a run chart, with the increase assessed using the Chi-square test for linear trend. A significance level of $p < 0.05$ was deemed statistically significant. Data analyses were conducted using PASW Statistics for Windows, version 18.0 (SPSS Inc., Chicago, IL, USA). Run charts for process indicators by quarter such as CCF and prehospital ROSC were depicted using QI Macro for Excel (KnowWare International, Denver, CO, USA).

Results

The study encompassed 796 adult non-traumatic OHCA patients who underwent resuscitation by the investigating site between 2019 and 2023. Of these, 189 patients were excluded due to transportation from the scene to other hospitals. Additionally, 179 patients who stated Do Not Attempt Resuscitation (DNAR) and 2 patients who received initial chest compressions from mechanical CPR devices were excluded. Consequently, a total of 426 patients were enrolled, and they were classified into respective groups based on the year of occurrence, as depicted in Fig. 1.

Table 1 presents the characteristics of OHCA patients before and after the implementation of Continuous Quality Improvement (CQI) initiatives, starting from 2021. Approximately half of the patients received bystander CPR, with no significant difference between 2019 and 2023 (47.73% vs 53.85%, *p*-value = 0.413). The utilization of public automated external defibrillators (AEDs) before EMS arrival was comparable between both groups (6.82% vs 5.49%, *p*-value = 0.712). The incidence of bystander-witnessed cardiac arrest patients presenting with an initial shockable rhythm was 12.50% in 2019 and 13.19% in 2023, with no significant difference noted (*p*-value = 0.868). Notably, following the emphasis on advanced airway management within the projects, EMS providers significantly increased the rate of prehospital ETI between 2019 and 2023 (70.45% vs 93.40%, *p*-value < 0.001). However, the rate of drug administration remained similar between both groups (*p*-value = 0.536).

The primary outcome revealed a insignificant increase in survival to discharge from 2.27% in 2019 to 7.69% in 2023 (*p*-value = 0.27). The adjusted odds ratio (aOR) comparing survival to discharge in 2023 versus 2019 was 3.81 with a 95% confidence interval (CI) of 0.46 – 31.79. However, the initiatives led to a significant increase in prehospital return of spontaneous circulation (ROSC) from 30.68% in 2019 to 49.45% in 2023 (*p*-value = 0.012), with an aOR of 2.16 and a 95% CI of 1.14–4.07 comparing prehospital ROSC in 2023 versus 2019. When stratifying witnessed and initial shockable rhythm patients, a insignificant increase in prehospital ROSC was observed (aOR 7.47, 95% CI 0.47–119.62). Furthermore, there was a insignificant increase in the odds of survival to discharge

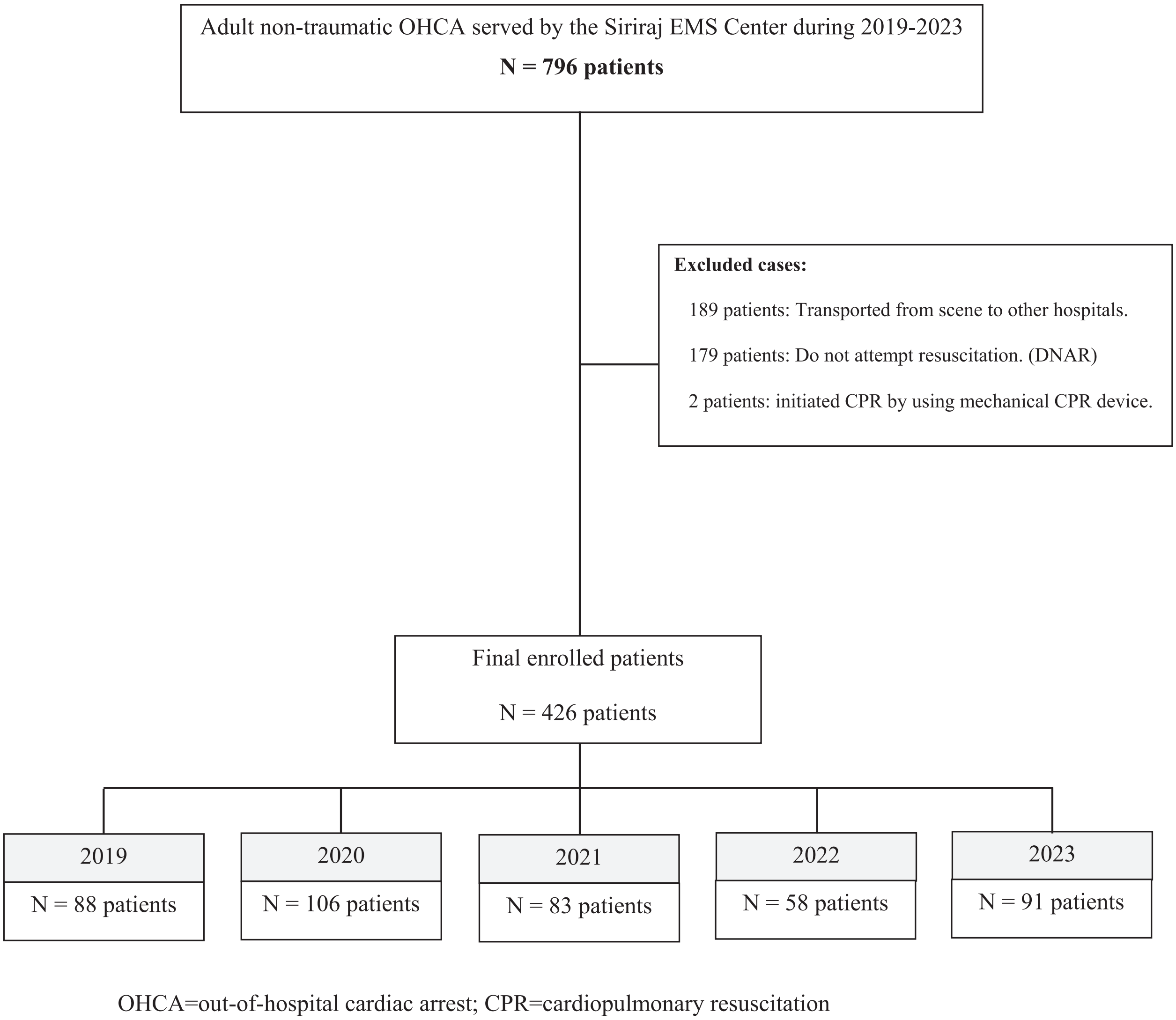

Fig. 1 – Flow of the study data.

(aOR 7.81, 95% CI 0.28–218.09). Further details of the comparison of survival outcomes are provided in Table 2. Fig. 2 illustrates the temporal trends of survival outcomes from 2019 to 2023, revealing significant increasing trends in prehospital return of spontaneous circulation (ROSC) (*p* for trend = 0.002) and survival to discharge (*p* for trend = 0.013).

One of the process indicators of the Continuous Quality Improvement (CQI) initiatives was the quality CPR metrics, which have been collected since 2021. Table 3 highlights a significant improvement in the average percentage of chest compression rate in the standard, increasing from a median of 72.76% with an interquartile range (IQR) of [43.73–85.80%] in 2021 to 85.68% with an IQR of [67.41–87.76%] in 2023 (*p*-value = 0.025). Additionally, there was an improvement in the average chest compression fraction (CCF), rising from a median of 86.83% with an IQR of [75.72–91.59%] in 2021 to 91.01% with an IQR of [86.26–93.54%] in 2023 (*p*-value = 0.003). Fig. 3 depicts the run chart for CCF and prehospital ROSC. The CCF chart indicates a significant drop in performance during the fourth quarter of 2021, followed by a progressive increase from 2022 to 2023. Meanwhile, the prehospital ROSC chart shows a significant increase in prehospital ROSC starting from the first quarter of 2023.

Discussion

In the present study, the impact of Continuous Quality Improvement (CQI) initiatives was assessed by comparing survival outcomes before (2019) and after the full implementation of interventions (2023). Our findings demonstrated a significant increase in the likelihood of prehospital ROSC following the complete implementation, as compared to the control group. Moreover, positive trends in survival outcomes were observed annually post-implementation of the initiatives.

A key initiative introduced in 2023 was the implementation of the High-Performance CPR (HP-CPR) protocol. This protocol emphasizes real-time CPR feedback, team-focused choreography, and post-event debriefing, aiming not only to deliver standard-quality CPR but also to minimize unnecessary interruptions and enhance chest compression fraction (CCF) to improve outcomes. Following

Table 1 – Characteristics and outcomes of cardiac arrest patients in the study.

Characteristics	2019 (*N* = 88)	2020 (*N* = 106)	2021 (*N* = 83)	2022 (*N* = 58)	2023 (*N* = 91)	*p*-value*
Age, mean (SD), y	63.92 ± 17.01	64.3 ± 16.84	62.48 ± 15.31	62.14 ± 15.9	63.65 ± 16.78	0.914
Male, *n* (%)	50 (56.81)	79 (74.52)	55 (66.27)	39 (67.24)	63 (69.23)	0.085
Initial shockable rhythm, *n* (%)	13 (14.77)	18 (16.98)	11 (13.25)	9 (15.52)	15 (16.48)	0.858
Initial shockable rhythm and witness arrest, *n* (%)	11 (12.50)	17 (16.03)	10 (12.05)	9 (15.52)	12 (13.19)	0.868
Arrest at home residence, *n* (%)	61 (69.32)	90 (84.91)	68 (81.93)	52 (89.66)	77 (84.62)	0.15
Bystander CPR, *n* (%)	42 (47.73)	57 (53.77)	36 (43.37)	27 (46.55)	49 (53.85)	0.413
Public AED utilization, *n* (%)	6 (6.82)	6 (5.66)	8 (9.64)	7 (12.07)	5 (5.49)	0.712
Prehospital endotracheal intubation, *n* (%)	62 (70.45)	48 (45.28)	25 (30.12)	46 (79.31)	85 (93.40)	< 0.001
Prehospital drugs administration, *n* (%)	78 (88.64)	97 (91.51)	70 (84.34)	52 (89.66)	84 (92.31)	0.536
Response time, median [IQR], mins	10 [8–13]	10 [8–14]	14 [11–16]	14 [11.75–18]	12 [9–15]	0.101
Scene time, median [IQR], mins	17 [12–23.25]	16 [12.5–20.5]	15 [10–19]	18 [15–20]	15 [11–19]	0.154
Outcomes among all patients						
Prehospital ROSC, *n* (%)	27 (30.68)	18 (16.98)	10 (12.05)	11 (18.97)	45 (49.45)	0.012
Survival to admission, *n* (%)	18 (20.45)	18 (16.98)	11 (13.25)	12 (20.69)	26 (28.57)	0.207
Survival to hospital discharge, *n* (%)	2 (2.27)	0 (0)	2 (2.41)	1 (1.72)	7 (7.69)	0.27
Outcomes among witnessed and initial shockable rhythm patients						
Prehospital ROSC, *n* (%)	1 (9.09)	1 (5.88)	0 (0)	0 (0)	5 (41.67)	0.076
Survival to admission, *n* (%)	4 (36.36)	5 (29.41)	5 (45.45)	0 (0)	7 (58.33)	0.292
Survival to hospital discharge, *n* (%)	1 (9.09)	0 (0)	0 (0)	0 (0)	4 (33.33)	0.099

* *p*-value; compare between 2019 and 2023, ROSC; return of spontaneous circulation

Table 2 – Comparison survival outcomes between before (2019) and after (2023) implementation of quality improvement projects.

Characteristics	Crude odd ratio (95% confidence interval)	*p*-value	Adjusted odd ratio* (95% confidence interval)	*p*-value
All patients				
Prehospital ROSC	2.17 (1.18–4.01)	0.013	2.16 (1.14–4.07)	0.018
Survival to admission	1.56 (0.78–3.10)	0.209	1.73 (0.82–3.64)	0.149
Survival to discharge	2.55 (0.47–13.91)	0.281	3.81 (0.46–31.79)	0.216
Witnessed and initial shockable rhythm				
Prehospital ROSC	7.14 (0.68–75.22)	0.102	7.47 (0.47–119.62)	0.155
Survival to admission	2.45 (0.46–13.16)	0.296	1.79 (0.26–12.17)	0.551
Survival to discharge	12.00 (0.51–280.09)	0.122	7.81 (0.28–218.09)	0.227

ROSC; return of spontaneous circulation

* All patients; adjusted odd ratio by using age, bystander CPR, and initial shockable rhythm Witnessed and shockable rhythm group; adjusted odd ratio by using age, and bystander CPR.

the implementation of the HP-CPR protocol, which included annual workshops, monthly simulation training sessions, and weekly post-debriefings with video recording in 2023, our results revealed an increase in CCF and subsequent improvements in prehospital ROSC. These findings align with similar studies. For instance, Pearson et al. reported their experience with the implementation of HP-CPR in a statewide protocol in North Carolina, US, which demonstrated increased survival and improved neurological outcomes post-implementation.[9] Similarly, the Victoria ambulance reported positive effects of HP-CPR on survival outcomes in both overall non-traumatic OHCA and EMS-witnessed cardiac arrest cases.[5,10]

Our results indicate a significant increase in the rate of prehospital advanced airway insertion observed during the period of 2022 to 2023 compared to 2019 to 2021. This shift can be attributed to revisions made to our OHCA protocol in response to the COVID-19 pandemic.[12] During the COVID-19 era, our previous protocol discouraged prehospital intubation in patients under investigation (PUI) for COVID-19.[12] As evidenced in our prior publication, this approach resulted in a decrease in the prehospital intubation rate.[12] Subsequently, in 2022, we revised our protocol to include the insertion of advanced airway devices at the scene. Specifically, we selected the video laryngoscope as the primary equipment for this procedure, with the aim of maintaining CCF as demonstrated in previous studies.[15,16] Despite previous research suggesting that supraglottic airway (SGA) devices may better maintain CCF compared to ETI,[17,18] our study found that the prehospital ETI strategy, when combined with CQI efforts, effectively maintained CCF. Our protocol emphasized initiating basic ventilation initially and then proceeding

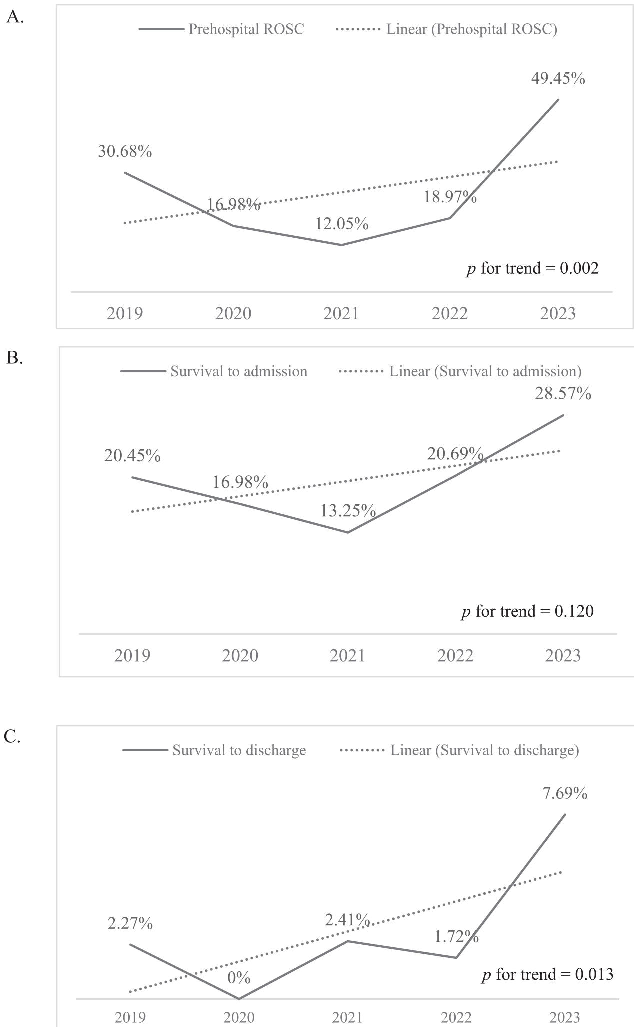

Fig. 2 – Temporal trend of survival outcomes during 2019 to 2023. A; Prehospital ROSC B; Survival to admission C; Survival to discharge ROSC; return of spontaneous circulation.

with intubation once all necessary equipment was prepared. Additionally, we conducted reviews of video recordings to identify instances of CPR interruption during intubation and provided feedback to the team accordingly. This approach aligns with the recommendations outlined in the National Association of EMS Physicians (NAEMSP) position statement on airway management in cardiac arrest, which emphasizes the importance of maintaining focus on resuscitation efforts and minimizing interruptions during the insertion of definitive airways.[19]

Our CQI approach incorporated the concept of low-dose, high-frequency training to optimize training duration, allowing for training during EMS shift work while awaiting calls. This concept, previously utilized in in-hospital cardiac arrest (IHCA) settings, has demonstrated success in improving CPR quality. For instance, a hospital in Ohio, US, implemented quarterly short CPR training sessions for providers, achieving high compliance rates of 97–99% and resulting in improved CPR quality in IHCA cases.[7] However, our implementation faced challenges due to having fewer full-time providers compared to part-time providers in our setting. Part-time providers were unable to consistently attend monthly training sessions, and some found it challenging to comply with complex protocols such as HP-CPR. As a result, we adopted a phased approach, initially focusing on providing feedback on cases using video recording and quality CPR metrics in 2021. Subsequently, we introduced monthly CPR and prehospital advanced airway training in 2022, followed by the implementation of the HP-CPR protocol and training in 2023. Our results demonstrated an improvement in CCF from 2021, although there was a temporary drop during the fourth quarter of 2021, possibly due to the Hawthorne effect.[20] Following the introduction of monthly training sessions, our CPR metrics improved, with the team maintaining CPR metrics comparable to other prehospital studies. With the full implementation of the HP-CPR protocol, survival outcomes progressively increased in early 2023. The specifics of our HP-CPR metrics are reported in Supplement 2, with the majority of indicators utilizing video recording and review to assess qualitative measurements in the HP-CPR protocol. Our approach highlighted the potential value of audiovisual medical direction in out-of-hospital cardiac arrest (OHCA) settings. While we employed teleconsultation with the EMS medical director, our emphasis primarily centered on advanced resuscitation

Table 3 – Quality of chest compression in prehospital resuscitation during 2021 – 2023.

Characteristics	2021–2023 (*N* = 214)	2021 (*N* = 75)	2022 (*N* = 55)	2023 (*N* = 84)	*p*-value
Average percentage of rate in standard[1] (100–120 /min), median [IQR], %	79.19 [56.23–87.27]	72.76 [43.73–85.80]	81.42 [66.99–89.10]	85.68 [67.41–87.76]	0.025
Average percentage of depth in standard[1] (4–6 cm), median [IQR], %	70.45 [47.87–88.71]	66.20 [45.64–90.10]	69.57 [47.90–87.22]	76.50 [64.06–90.42]	0.153
Average of chest compression fraction, median [IQR], %	89.28 [84.51–92.29]	86.83 [75.72–91.59]	87.99 [84.53–91.30]	91.01 [86.26–93.54]	0.003
Average percentage of chest compression quality[2] (both rate and depth in standard), median [IQR], %	59.5 [39.36–75.67]	N/A	N/A	59.5 [39.36–75.67]	N/A

[1] The compression metrics were collected from January 2021 to June 2023 (*N* = 164).
[2] The compression metrics were collected from January 2023 to December 2023 (*N* = 84).

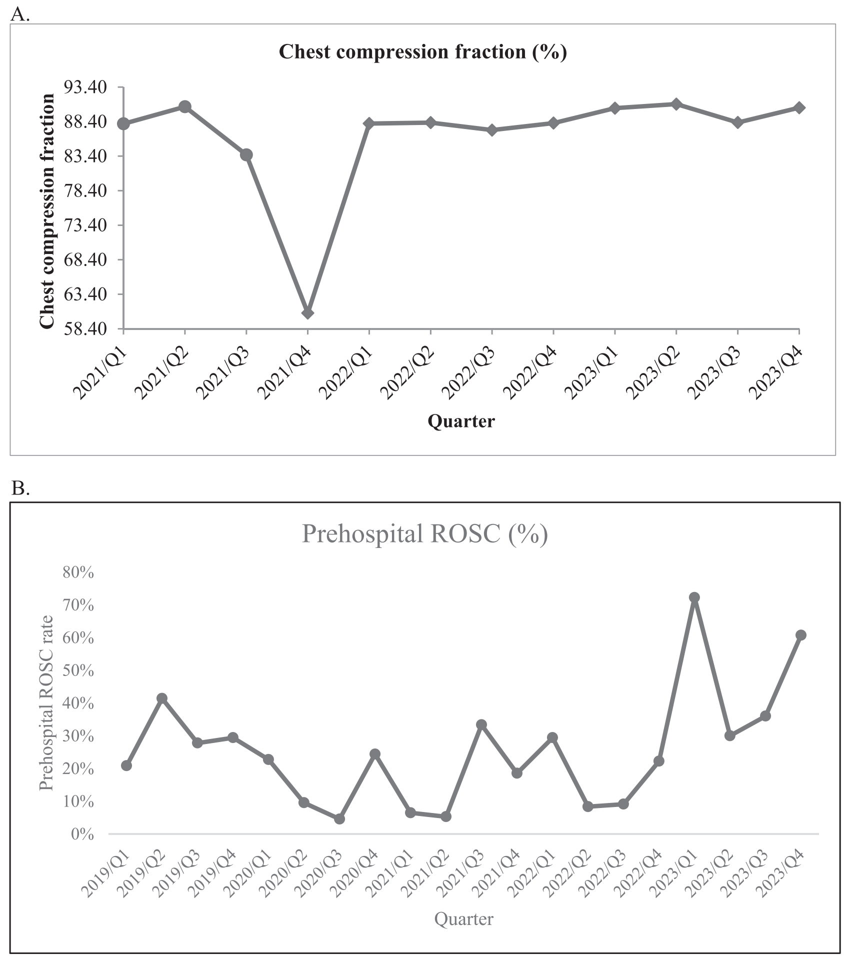

Fig. 3 – Run chart of chest compression fraction and prehospital ROSC by quarter. ROSC; return of spontaneous circulation.

rather than CPR coaching. This differed from a Korean study that utilized audiovisual teleconsultation specifically for CPR coaching and demonstrated improved outcomes.[21]

To the best of our knowledge, this study represents the first investigation into the positive impact of CQI initiatives, particularly the HP-CPR protocol, on survival outcomes in a developing EMS setting for OHCA management. However, several limitations warrant consideration. Firstly, the study was conducted solely within a single EMS center in Bangkok, Thailand, potentially limiting the generalizability of the findings to the broader Thai EMS system. Additionally, our study had a small number of patients, which might not have had enough power to identify the impact on survival to discharge. Furthermore, the study focused on evaluating the overall impact of CQI rather than assessing individual initiatives, precluding the use of a randomized controlled trial design and potentially introducing confounding variables that were not accounted for. For example, we did not collect and adjust for in-hospital interventions like primary percutaneous coronary intervention (PCI), targeted temperature management, and extracorporeal membrane oxygenation (ECMO). Since our primary outcome was survival to discharge, these variables might have impacted the outcome. Additionally, the exclusion of patients transferred from scene to other hospitals may have introduced bias and impacted the overall study outcomes. Moreover, data collection via the OHCA registry by EMS providers during post-resuscitation may have been subject to recall bias, although efforts were made to mitigate this through weekly OHCA reviews and data quality assessments. Another noteworthy limitation pertained to the challenge of providing monthly training to all EMS personnel, particularly those employed part-time. In 2023, we hired trained EMS personnel as full-time providers. This co-intervention might have impacted the outcomes as another confounding factor.

Conclusion

In conclusion, the implementation of HP-CPR CQI initiatives, including a team-focused choreography protocol, low-dose high-frequency CPR training, real-time CPR feedback during actual events, and post-event debriefing with video recording, associated with a significant increase in prehospital ROSC. However, these interventions did not result in a significant improvement in survival to discharge compared to pre-implementation levels.

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CRediT authorship contribution statement

Sattha Riyapan: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Pimpanit Sanyanuban:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Jirayu Chantanakomes:** Writing – original draft, Conceptualization. **Pakorn Roongsaenthong:** Writing – original draft, Methodology, Conceptualization. **Bongkot Somboonkul:** Writing – review & editing, Project administration, Methodology, Formal analysis, Conceptualization. **Wichayada Rangabpai:** Writing – review & editing, Conceptualization. **Netiporn Thirawattanasoot:** Writing – review & editing, Conceptualization. **Wasin Pansiritanachot:** Writing – review & editing, Conceptualization. **Nattida Phinyo:** Writing – review & editing, Investigation. **Pannaphat Konwitthayasin:** Writing – review & editing, Investigation. **Kanpaphop Buangam:** Writing – review & editing, Investigation. **Panisara Seangsung:** Writing – review & editing, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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We extend our sincere appreciation to all EMS providers in our center for their dedication to self-improvement through regular training sessions and weekly quality reviews. Their commitment has been instrumental in demonstrating the impact on survival outcomes observed in this study. We hope that their dedication will serve as a model for EMS providers in other regions, particularly in developing EMS systems, inspiring similar efforts to enhance patient care and outcomes in OHCA management.

Appendix A. Supplementary material

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