Original Article

Improving Quality of Chest Compression in Thai Emergency Department by Using Real-Time Audio-Visual Feedback Cardio-Pulmonary Resuscitation Monitoring

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Background: High-quality cardiopulmonary resuscitation (CPR) is challenging in real life situations. Real-time audio-visual feedback (RTAVF) during resuscitation could improve CPR quality. Although recent studies showed improvements in CPR quality after using of RTAVF, there has been little data from Asian population, especially in Thailand.

Objective: To compared CPR quality before and after use of RTAVF system in a Thai emergency department. Quality was determined in terms of chest compression (CC) depth, rate, and CC fraction. CPR outcomes were also evaluated.

Materials and Methods: The present study was a before-and-after study of adult out-of-hospital cardiac arrest (OHCA) patients in the emergency department at a university hospital in Bangkok, Thailand between May and October 2017. Phase I (P1) included 16 patients with standard CPR, and phase II (P2) included 16 patients with RTAVF. CC depth and rate were compared between the two phases.

Results: Thirty-two OHCA patients were included. The mean age was 63.4±14.4 years and 68.8% were male. Initial rhythm was ventricular fibrillation in 28.1% of all patients. CC depth was increased from 38.8±11.5 mm in P1 to 48.0±9.2 mm in P2 (p=0.018). CC rate was decreased from 139.3±8.9/minute in P1 to 117.2±7.4/minute in P2 (p<0.001). No significant differences were identified between the two groups in CC fraction, peri-shock pause, ROSC rate, survival to hospital discharge, nor favorable neurological outcome.

Conclusion: RTAVF monitoring can improve CPR quality especially in CC depth and rate among OHCA patients in a Thai emergency department without significant changes of long-term cerebro-cardiovascular outcomes.

Keywords: CPR, Quality of chest compression, Real-time audio-visual feedback device

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Out of hospital cardiac arrest (OHCA) is an important global public health problem. It affects many people around the world. Among the U.S. population, 424,000 people a year suffer from this condition[1,2]. In Europe, the incidence of OHCA is 275,000 people a year[3], with a survival rate of only 7.9% to 10.6%[1-3]. Improving OHCA survival is challenging. More research in recent years has revealed high quality cardiopulmonary resuscitation (CPR) as an intervention that improves survival[4-7].

The 2015 American Heart Association (AHA) Guidelines for CPR and Emergency Cardiovascular Care (ECC) recommend that high quality CPR should include all critical components. Chest compression (CC) depth and rate should be within 5 to 6 cm and 100 to 120 beats per minute, respectively. Complete chest recoil should be allowed for after each compression. CC interruption should not be longer than 10 seconds. CC fraction should be more than 80%. Furthermore, excessive ventilation should be avoided[8,9]. In spite of these recommendations, providing high quality CPR in real situations is challenging. Previous studies demonstrated poor CPR quality both in-hospital and pre-hospital resuscitation[10,11]. A real-time audio-

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visual feedback (RTAVF) device was developed to improve and maintain the quality of CPR in real cardiac arrest situation.

Previous studies demonstrated the effect of RTAVF in improving the quality of CPR in several settings. Bobrow et al implemented RTAVF in Emergency Medical Service (EMS) and found an improvement of CPR quality in terms of CC depth, rate and CC fraction[12]. Furthermore, their study showed that RTAVF improved survival rate[12]. Crowe et al also reported improvements in CC depth after using RTAVF in an emergency department (ED)[13]. However, the CC rate and CC fraction were not significantly different when compared with CC without use of RTAVF[13].

Although prior studies showed that quality of CPR was improved by the feedback function, data from Asian populations has been limited[12-16]. Asian populations, especially Thai populations, tend to have a smaller chest wall diameter than European and American populations[17]. Because of this, the effect of RTAVF might be different from previous studies. Therefore, this research was conducted to determine the effects of RTAVF on the quality of CPR in a Thai ED.

Materials and Methods

The present research was a quasi-experimental study collecting CPR quality of adult non-traumatic OHCA before and after using RTAVF in an ED. The study was conducted in a university hospital in Bangkok, Thailand. The hospital had 200 annual adult non-traumatic OHCA cases. The present study was reviewed and approved by the Institutional Review Board (IRB) of the Faculty of Medicine Siriraj Hospital and was registered in the Thai Clinical Trials Registry (TCTR20170109001).

The present study included adult non-traumatic OHCA patients who received CPR in the ED for at least two minutes. The authors excluded patients who were not resuscitated by RTAVF or in cases when the machine did not record the CPR quality. The patients at end of life care and that had a do-not-resuscitate (DNR) order were also excluded.

At the beginning of the study, the investigators trained all providers in the ED, including attending physicians, emergency medicine residents, nurses, and nurse-aids. The training consisted of machine instruction and team-based simulation training. Then, the study period was divided into two phases. The phase I was between May and July 2017. The ED providers resuscitated the OHCA patients using defibrillator with CPR pad from Zoll R-series® (Zoll Medical Corporation, Chelmsford, MA). However, the authors turned off the RTAVF function in the machine. Therefore, the ED providers performed CPR as usual but were not able to monitor CPR quality from the machine during resuscitation. The second phase of the study was between August and October 2017. The ED providers resuscitated OHCA patients with the same defibrillator, with the machine providing real-time CPR quality on the monitor such as CC rate, CC depth, and the release of each compression. The feedback device also provide audio feedback sounds such as "Push harder" and "Push faster" when the ED providers did not perform CPR at the level of quality as set in the recent guidelines.

The investigators exported the data from the defibrillator after resuscitations in both phases. The present study compared the CPR quality only in the first five minutes of the resuscitation in the ED. The primary outcome considered was average CC depth. Secondary outcomes were other CPR quality indicators, for example CC rate, CC fraction, and peri-shock pause time. CC fraction is the percentage of total time of CC divided by total time of resuscitation. Peri-shock pause time was the time between providers halting CPR and when they defibrillate a patient. Furthermore, we compared the percentage of CPR quality, defined as the duration of CC rate and depth as in recent guidelines divided by total time of CC. In addition, we compared clinical outcomes such as return of spontaneous circulation (ROSC), survival to admission, survival to hospital discharge, and survival with favorable neurological outcome.

The authors calculated the sample size by identifying the improvement of CC depth from a previous study[13]. The study demonstrated the CC depth was 45 mm before using RTAVF and increased to 60 mm after implementing the use of feedback[13]. However, it was very difficult to achieve 60 mm CC depth in an Asian population because the average chest wall diameter is smaller than that of a Caucasian population[17]. Therefore, the authors made the assumption that the RTAVF would improve CC depth from 45 mm to 55 mm in the Thai population. Sample size for each group was calculated to be 16 participants using a type I error of 5% and power of 80% and added 10% for incomplete data. Primary and secondary outcomes were analyzed by Student's t-test for continuous data and Chi-square test for categorical. The p-value below 0.05 was defined as statistically significant. IBM SPSS version 18.0 (IBM, North Castle, NY) was used for data analysis.

Table 1. Demographic data of patients

Characteristics	Overall (n = 32) n (%)	Phase 1 (n = 16) n (%)	Phase 2 (n = 16) n (%)	p-value
Age (years), Mean±SD	63.4±14.4	68.4±13.4	58.5±14.1	0.051
Sex: male	22 (68.8)	9 (56.3)	13 (81.3)	0.252
Comorbidity				
Hypertension	10 (31.3)	5 (31.3)	3 (31.3)	1.000
Diabetes mellitus	9 (28.1)	5 (31.3)	4 (25.0)	1.000
Coronary artery disease	5 (15.6)	3 (18.8)	2 (12.5)	1.000
Chronic kidney disease	3 (9.4)	0 (0.0)	3 (18.3)	0.226
Cerebrovascular disease	1 (3.1)	1 (6.3)	0 (0.0)	1.000
COPD	1 (3.1)	1 (6.3)	0 (0.0)	1.000
Prehospital data				
Witness arrest	26 (81.3)	13 (81.3)	13 (81.3)	1.000
Bystander CPR	14 (43.8)	8 (50.0)	6 (37.5)	0.722
Defibrillation	2 (6.3)	1 (6.3)	1 (6.3)	1.000
ECG monitor	6 (18.8)	4 (25.0)	2 (12.5)	0.524
Intubation	5 (15.6)	3 (18.8)	2 (12.5)	1.000
Adrenaline	6 (18.8)	4 (25.0)	2 (12.5)	0.524
Initial rhythm at ED				0.456
VF	9 (28.1)	3 (18.8)	6 (37.5)	
PEA	11 (34.4)	7 (43.8)	4 (25.0)	
Asystole	12 (37.5)	6 (37.5)	6 (37.5)	
Presumed cause of arrest				
Cardiac cause	12 (37.5)	5 (31.3)	7 (43.8)	0.716
Hypoxia	7 (21.9)	6 (37.5)	1 (6.2)	0.070
Hyperkalemia	5 (15.6)	1 (6.2)	4 (25.0)	0.127
Hypovolemia	3 (9.3)	2 (12.5)	1 (6.3)	1.000
Acidosis	8 (25.0)	2 (12.5)	6 (37.5)	0.065
Pulmonary embolism	1 (3.1)	1 (6.3)	0 (0.0)	1.000

SD=standard deviation; COPD=chronic obstructive pulmonary disease; CPR=cardiopulmonary resuscitation; ECG=electrocardiogram; ED=emergency department; VF=ventricular fibrillation; PEA=pulseless electrical activity

Phase I: standard CPR, Phase II: CPR using real-time audio-visual feedback

Results

One hundred eighty-six cardiac arrest patients were resuscitated in the ED during the study period. The authors excluded 29 in-hospital cardiac arrest patients, 95 patients who had a DNR order, and 20 patients for which RTAVF was not utilized during CPR. The investigators were unable to export CPR quality data in 10 OHCA patients (six patients in phase I and four patients in phase II). Therefore, 32 OHCA patients were included in the present study. There were 16 OHCA patients in each phase. The study flow is demonstrated in Figure 1.

The demographics of OHCA patients who had CPR quality data are provided in Table 1. The mean age of all patients was 63.4 years. Most patients were witnessed arrest (81.3%). However, only 43.8% of OHCA patients received bystander CPR. The initial cardiac rhythm in ED was 28.1% shockable rhythm. There was presumed cardiac etiology in 37.5% of all OHCA patients. There was no significant demographic difference between the two phases.

Table 2 demonstrates CPR quality before and after using RTAVF. The present study showed a significant increase in mean CC depth from 38.8 mm to 48.0 mm after using RTAVF ($p=0.018$). The average CC rate was significantly decreased from 139.3 compressions/minute (cpm) to 117.2 cpm ($p<0.001$). The average CC quality was significantly improved after using RTAVF (0% versus 33.0%, $p<0.001$). However, there was no significant difference in CC fraction and the peri-shock pause time between the two phases. Moreover, there was no difference in clinical outcomes between

Table 2. Quality of CPR and clinical outcomes before and after using real-time audio-visual feedback device

Characteristics	Overall (n = 32)	Phase 1 (n = 16)	Phase 2 (n = 16)	p-value
CC depth (mm), Mean±SD	43.4±11.3	38.8±11.5	48.0±9.2	0.018
CC rate (cpm), Mean±SD	128.2±13.8	139.3±8.9	117.2±7.4	<0.001
Peri-shock pause (seconds), Mean±SD	8.22±3.0	8.5±3.3	8.0±3.2	0.824
Chest compression fraction (%), Mean±SD	81.1±10.3	81.1±10.3	85.2±10.2	0.258
CPR quality (%), Median (IQR)	0.8 (0.0 to 33.3)	0.0 (0.0)	33.0 (2.5 to 39.0)	<0.001
CPR duration (minutes), Median (IQR)	23.5 (9 to 35.8)	18.0 (7.0 to 29.8)	30.0 (12.5 to 36.8)	0.239
Defibrillation, n (%)	20 (62.5)	9 (56.3)	11 (68.8)	0.716
ROSC, n (%)	19 (59.4)	10 (62.5)	9 (56.3)	1.000
Survival to hospital admission, n (%)	10 (31.3)	5 (31.3)	5 (31.3)	1.000
24-hour survival, n (%)	8 (25.0)	4 (25.0)	4 (25.0)	1.000
30-day survival, n (%)	3 (9.4)	1 (6.3)	2 (12.5)	1.000
Favorable neurological outcome at 30-day*, n (%)	2 (6.3)	0 (0.0)	2 (12.5)	0.417

SD=standard deviation; IQR=interquartile range; CC=chest compression; CPR=cardiopulmonary resuscitation; ROSC=return of spontaneous circulation

Phase I: standard CPR, Phase II: CPR using real-time audio-visual feedback

* Favorable neurological outcome is cerebral performance category (CPC) 1 and 2

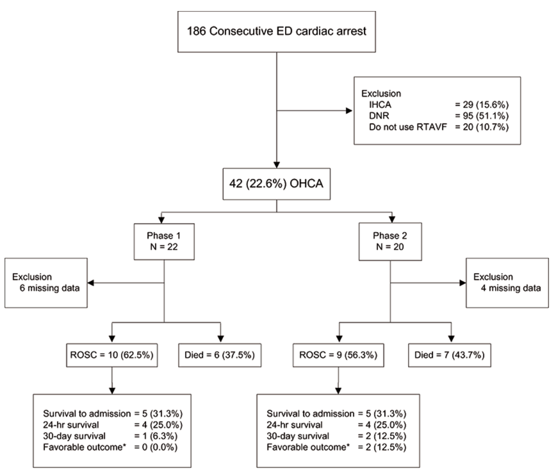

Figure 1. Flow of the study.

* Favorable outcome at 30-day, Phase 1: standard CPR; Phase2: CPR using real-time audio visual feedback

IHCA, in-hospital cardiac arrest; OHCA, out-of-hospital cardiac arrest; DNR, do-not-resuscitate; RTAVF, real-time audio-visual feedback

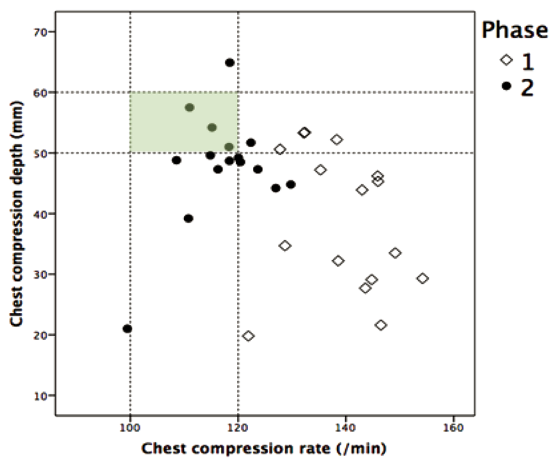

Figure 2. Scatter plot of chest compression rate and depth of individual patient in both phases.

Highlight box is the high-quality CPR recommended by the international guideline

Phase 1: standard CPR; Phase 2: CPR using real-time audio-visual feedback

the two groups such as ROSC, survival to admission, survival to hospital discharge, and survival with favorable neurological outcome.

Figure 2 demonstrates that the CC depth and rate in the phase II were within the recommendations more than in the phase I. When set the cut point of good CC depth at 45.6 mm to 6 mm, then the CC depth in the second phase reached the cut point more than the first phase (75% in phase II to 37.5% in phase I) (Figure 3). Moreover, 62.5% of patients after using RTAVF received CC rate within 100 to 120 cpm, which were more than the 0% of patients without using RTAVF (Figure 4).

Discussion

Providing high quality CPR is challenging in real clinical practice. The present study measured CC quality during under real OHCA conditions in ED before and after using RTAVF. The authors found that mean CC depth was shallower than the

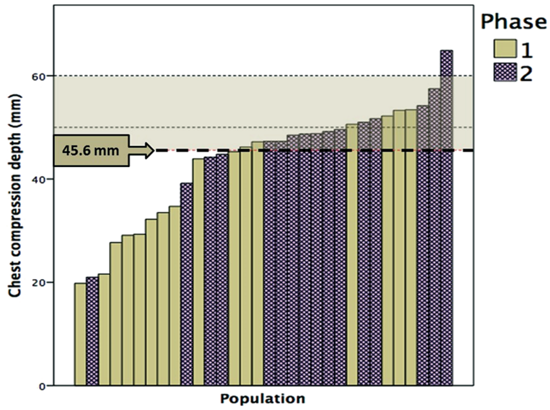

Figure 3. Chest compression depth of individual patient in both phases.

Phase 1: standard CPR; Phase 2: CPR using real-time audio-visual feedback

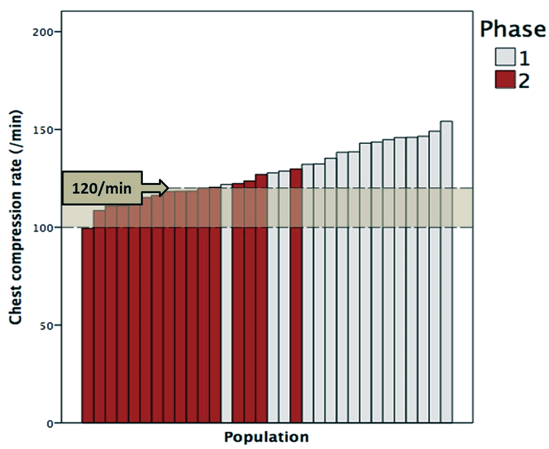

Figure 4. Chest compression rate of individual patient in both phases.

Phase 1: standard CPR; Phase 2: CPR using real-time audio-visual feedback

recommendation guideline when providing CC without RTAVF. Furthermore, the result revealed mean CC rate in the phase I was faster than the standard recommendation. The CC depth and rate were significantly improved after using RTAVF in the phase II. However, the peri-shock pause, CC fraction, and clinical outcomes were comparable between the two phases.

Previous studies reported RTAVF improved CC depth during real CPR session(4,12,13). Bobrow et al implemented RTAVF in pre-hospital resuscitation and increased CC depth from 45.2 mm to 54.6 mm(12). Moreover, Crowe et al demonstrated the improvement of CC depth during CPR in ED from 46.7 mm to 61.8 mm(13). Although the present study result concurred with those studies, the present study mean CC depth was only 48.0 mm after using RTAVF, which did not meet the recommendation from the international guidelines(9). The current standard recommendation used a majority of the data from Western countries whose populations tend to have a larger chest wall diameter than those in Asian populations(17). The authors set the cut point of high-quality CC depth at 45.6 mm, which increased highest chance of survival compared with the previous study(5). The authors found that RTAVF significantly increased the percentage of high-quality CC depth. It might be difficult to compress more than 50 mm in depth among Asian populations. Singapore Basic life Support Guideline recommends CC depth from 40 mm to 60 mm(18). Resuscitation Council of Asia states CC depth is "approximately 5 cm" and no more than 6 cm(19). Further studies would be recommended to investigate the appropriate cut point of high quality CC depth among Asian population.

In the present study, providers performed extremely fast CC when CPR without RTAVF. The CC rate was slower and within the recommendation guideline after using RTAVF(9). It might be because the CC rate was simple to control when receiving objective feedback. When providing CC without RTAVF, CPR leaders might give subjective feedback to team members, leading to unreliable results. The present findings also concurred with a previous study that showed improved CC rate after using RTAVF(12).

The current international guideline recommends that CC fraction should be more than 80% and peri-shock pause time should not exceed 10 seconds(8,9). The present study providers have already performed a good quality of those indicators in both phases. This might be why the present study demonstrated no difference in CC fraction and peri-shock pause time before and after using RTAVF.

Although the present study showed that RTAVF improved quality of CPR in the authors' institution, the study did not present better clinical outcomes. This might be due to the relatively small number of patients. A previous study reported insignificant difference in survival to hospital discharge in the RTAVF group compared to the non-RTAVF group(4). On the contrary, Bobrow et al demonstrated significant improvements in survival to hospital discharge after using RTAVF(12). Further studies should investigate clinical impacts when using RTAVF during CPR in Thailand.

The present study has several limitations. It was a non-randomized controlled trial. There might be some confounding factors that affected the outcomes. However, the advantage of the study design was decreasing a chance of contamination between groups. The providers randomly performed CPR with RTAVF might practice high quality CPR. If so, then they would be able to provide a high quality of CPR without RTAVF afterwards. Furthermore, the authors conducted a single center study in Thailand. This might be problematic when generalizing the result to other hospitals in the region. As mentioned above, the sample size was too small to detect the difference of clinical outcomes among OHCA patients.

Conclusion

The authors conducted a study before and after using RTAVF as an intervention to improve CPR quality in a Thai ED. The present cohort demonstrated that RTAVF significantly improved CC depth and CC rate during CPR. Nonetheless, the RTAVF did not improve CC fraction and peri-shock pause time. Because there were a relatively small number of patients, the authors could not determine the effect of RTAVF on survival. Further studies should be conducted to investigate the impact on clinical outcomes.

What is already known on this topic?

High-quality CPR is challenging in cardiac arrest resuscitation. Although recent studies showed improvements in CPR quality after the usage of RTAVF devices, there has been little data from Asian population, especially in Thailand.

What this study adds?

This study is the first study conducted in Thai ED. The findings demonstrated that RTAVF can significantly improve CPR quality especially in CC depth and rate among OHCA patients in the Thai population. However, the mean depth of CC did not meet the standard recommendation guideline.

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Conflicts of interest

The authors declare no conflict of interest.

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