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Education

EXTERNAL CARDIAC MASSAGE TRAINING OF MEDICAL STUDENTS: A RANDOMIZED COMPARISON OF TWO FEEDBACK METHODS TO STANDARD TRAINING

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☐ **Abstract—Background: The most recent recommendations support learning of external cardiac massage (ECM) through feedback devices. Objectives: The objective was to compare the effects on immediate and 3-month retention of ECM technical skills when using feedback devices compared with training without feedback as part of a half-day training session in medical students. Methods: This randomized study was performed using the Resusci Anne QCPR manikin in 64 medical students. We compared the quality of ECM with nonfeedback training in the control group (group 1) vs. 2 feedback learning methods (group 2, PocketCPR and group 3, Skill Reporter each used with visual display available to the trainee). At the end of the training session and 3 months later, students performed chest compressions blindly during a 2-min assessment session. The median compression score was the primary outcome for assessing immediate and long-term retention. Results: Regarding immediate retention, the median compression score was significantly lower in group 1 (23%) than in groups 2 (81%) and 3 (72%) (*p* < 0.05) with no difference between the 2 feedback methods. At 3 months, mean compression scores remained high but not significantly different between the 2 feedback groups. Conclusion: The use of a feedback device used for ECM training improves the quality of immediate retention of technical ECM skills compared with traditional teaching in medical students. At 3 months, the 2 groups with feedback retained a high level of performance. No significant difference could be demonstrated between the 2 feedback methods. © 2020 Published by Elsevier Inc.**

☐ **Keywords—basic life support; cardiopulmonary resuscitation; education; feedback device; simulation; skill retention**

INTRODUCTION

The annual incidence of out-of-hospital cardiac arrest (CA) in Europe is 84 cases per 100,000 persons. This is a serious event because survival from all causes is 10% in Europe (1). In 2015, the new recommendations of the European Resuscitation Council (ERC) on the management of cardiopulmonary resuscitation (CPR) were published (2). The "chain of survival" concept summarizes the 4 key steps for successful witness initiated resuscitation: early recognition, early CPR, early defibrillation, and postresuscitation care. For CPR to be effective, experts highlighted 5 critical parameters: chest displacement depth, which must be between 5–6 cm; frequency, which must be between 100–120 compressions/min; chest decompression, which must be complete, limiting interruptions, especially when changing rescuers every 2 min; and early defibrillation, within 3 min after

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CA (2). Since 2007, French medical students have received mandatory formal training of emergency procedures. During standard CPR training, an experienced instructor explains and demonstrates the various steps before trainees perform the procedure and are given feedback. This method has been shown to provide satisfactory learning outcomes in some studies but is generally regarded as being less potent than technology-enhanced methods (3,4). Although this beneficial effect has not been observed universally, most studies support the use of feedback to train laypeople as well as health care professionals (5–9).

The level of complexity of feedback devices varies widely, ranging from simple metronome devices that only guide the CPR frequency to more complex devices that combine audio or visual indication and allow, in addition to rate, monitoring of thoracic displacement depth and the absence of residual pressure during decompression. The Resusci Anne Skill Reporter device (Laerdal, Memphis, TN) is a purely training method that can only be used in a simulation session and provides visual feedback (10). By contrast, several apps can be used for both training and real-life CPR and provide both audio and visual feedback (11,12). In addition, being confident with the use of a device could facilitate its use in a real-life scenario. Unfortunately, there are few direct comparison studies that would indicate if one device is superior to another.

Being confronted with CA in a clinical situation is rare and unpredictable, and therefore questioning about the retention of technical skills is important. Wik et al. showed that skills acquired after initial training of naive trainees were maintained at 6 and 12 months, while a French study showed no effect on retention at 4 months in learners who were trained with the feedback device (9,13,14). Additional information is therefore necessary to determine if using a feedback training method is associated with improved long-term performance and when deterioration of retention starts to occur. Our objective was to compare the effects on immediate and 3-month retention of the technical competence of external cardiac massage (ECM) when using 2 feedback methods compared with the traditional teaching method.

MATERIALS AND METHODS

Participants were second-year medical students at the time of the training session on basic emergency procedures. Exclusion criteria were medical contraindication to physical exercise or refusal of the student. Instructors were anesthesiologists, intensivists, or emergency physicians all trained and experienced in practicing CPR. All of them had already participated in this training course in preceding years. Before the start of the training period, all instructors received updated information on emergency procedures and were particularly asked to review the most recent ERC Guidelines, which were sent by email (2). They were also invited to participate in a 1-h discussion to homogenize learning messages and avoid any confusion in terms and learning objectives. Each session included 16–20 students and was directed by 2 instructors in such a way that each task was done by no more than 10 students at a time. For each student involved, the training session had a 1-day duration and CPR training represented half of the day. Training of CPR was divided into steps, in which a main message was delivered (diagnosis of loss of consciousness, diagnosis of respiratory and cardiac arrest, cardiac massage procedural technique and simplified pathophysiology, external defibrillation use, and mechanism of action). At each new step, students performed an additional new part of the procedure but also all previous steps to embed the new part into a cumulative whole procedure. All steps were taught using a 2-rescuer situation. The ECM part of the training session was nearly 90 min, and each student performed the procedural task several times for a total of 5–8 min. The manikin used was a Resusci Anne which reproduces the resistance of an adult rib cage by previous calibration (a spring placed under the chest of the manikin was calibrated to receive a pressure equivalent to 30 kg and to create a 5-cm chest depression).

Subjects were randomized into 3 groups with the "random" function of Excel software (Microsoft, Redmond, WA). They were trained using one of the following methods. In the traditional ECM training method (control group or group 1, n = 20), the trainer interacted with students by performing initially the task then providing continuous feedback and immediately correcting errors made by students performing the tasks themselves. In group 2 (n = 21), training was done in the presence of the trainer but was guided by a feedback method, namely the iPhone App PocketCPR (ZOLL Medical, Chelmsford, MA). This is a free application created by the British Heart Foundation by which ECM data are analyzed using the smartphone's accelerometer (15). Algorithms are used to convert the movement produced into distance and acceleration. The phone is placed in one of the hands of the student who can see the smartphone screen (the grasp in hand method) which has been shown to provide better satisfaction by users (16). The application informs the trainee in real time by a voice synthesis system on the efficacy of the massage parameters: depth, rate of ECM, and rib cage relaxation.

Students in group 3 (n = 23) used the Resusci Anne-QCPR system equipped with Skill Reporter wireless software (Laerdal). This manikin is equipped with pressure sensors that allow real-time monitoring of the frequency and depth of massage displayed on a large screen in front of the student (https://www.laerdal.com/gb/products/simulation-training/resuscitation-training/SkillReporter-PC/). After explanations had been given by the instructor on how to read information on the screen (rate, depth, hand position, and rib relaxation), the students were left and adjusted continuously their performance to the visual information displayed.

In all 3 groups, final feedback on the main messages related to the chest compression technique were given to the whole group of students. Randomization was done by day and group. Day 1 was defined as group 1 and 2 training, day 2 as group 1 and 3 training, and day 3 as group 2 and 3 training. For each day, students were randomized to be trained in 1 of the 2 groups.

At the end of the day, students were individually assessed in a separate room. They were told that this had only formative value and would be used for research purposes only. In the chosen scenario, the student was the only rescuer for an out-of-hospital CA. It was explained that call for help and request to bring a defibrillator had already been launched. The student was asked to perform a 2-min ECM without interruption. In this final assessment part of the training day, data from each participant were recorded using the Resusci Anne-QCPR system with the Skill Reporter Wireless software (Laederal) which was not used as live feedback but was used by investigators to measure the various parameters and the overall score. Data related to their performance were therefore not available to the students during the massage (the screen was masked to the learner). They were, however, informed at the end about the quality of their performance by showing the screen and measurements obtained during massage. They were then given final advice on what needed to be improved.

Each student was individually invited by e-mail 3 months later to come back to the simulation center to perform the same assessment of ECM, according to the same scenario and measurements methods and without any recall of recommendations.

The primary outcome was the comparison of the overall quality of ECM by considering the compression score given by the Skill Reporter software (including ECM depth and frequency, complete relaxation, number of compressions per minute, and hand position) at 3 months after initial training. Of the 5 criteria of the compression score, 4 are taken up by the ERC 2015 recommendations in the definition of “high-quality CPR.” This score therefore seems robust for assessing the quality of learners’ ECM. Assuming that training with a feedback device would maintain retention at an overall quality score of about 50% above that provided by traditional training (70 vs. 35%), we calculated that a total of 62 students would be needed for inclusion (http://clincalc.com/Stats/SampleSize.aspx).

Secondary outcomes were the 5 different components of compression score (described above) analyzed separately as well as an evaluation of satisfaction by a Kirkpatrick level 1 questionnaire distributed at the end of the initial session.

Data were collected using the Skill Reporter software and transferred to an Excel file to form a data table. Qualitative data were expressed as percentages. Quantitative data were expressed as means (± standard deviation) or medians (interquartile range [IQR]). The Student’s *t*-test and repeated analyses of variance were used to compare quantitative and continuous parameters, and the chi-squared test to compare percentages. To search for a link between different parameters, univariate then multivariate analyses were performed. For univariate analysis, the chi-squared and Fisher exact tests were used. Multivariate analysis was performed using a logistic regression model. $p < 0.05$ was considered statistically significant. Statistical analyses were performed with the R software (R Core Team 2016).

The local Committee on Human Research (Comité de Protection des Personnes d’Ile-de-France VII, CHU de Bicêtre) stated that given the fact this was not a study involving patients but rather an educational trial, approval was not necessary. However, each participant received written information about the protocol and gave written consent for data acquisition and analysis.

RESULTS

A total of 64 students (18 men and 43 women) participated in the study. In the immediate assessment, 2 subjects were excluded because of technical problems in acquiring data on the manikin, and 1 for medical reasons (sciatica). Data from 61 students were analyzed (Figure 1). The median compression score of the control group was 22.5% (IQR 8.8–58.5), that of the PocketCPR group was 81% (IQR 62–91), and that of the Skill Reporter group was 72% (IQR 44–90). A statistically significant difference was found when comparing the control group with the PocketCPR group ($p = 0.0004$) and to the Skill Reporter group ($p = 0.007$). No statistical difference was found between the 2 feedback groups ($p = 0.6$) (Figure 2).

When assessing skill retention at 3 months, data from 55 students (16 men and 39 women) of 61 students were analyzed. One student was excluded because of missing data, 1 because of a medical contraindication, and 4 did not attend the second session. The median compression score for the control group was 43% (IQR 17–94%), for the PocketCPR group was 77% (IQR 63–92%), and for the Skill Reporter group was 71% (IQR 35–87%). Comparing 2 two sessions in each group, there was a statistically significant difference at 3 months on the

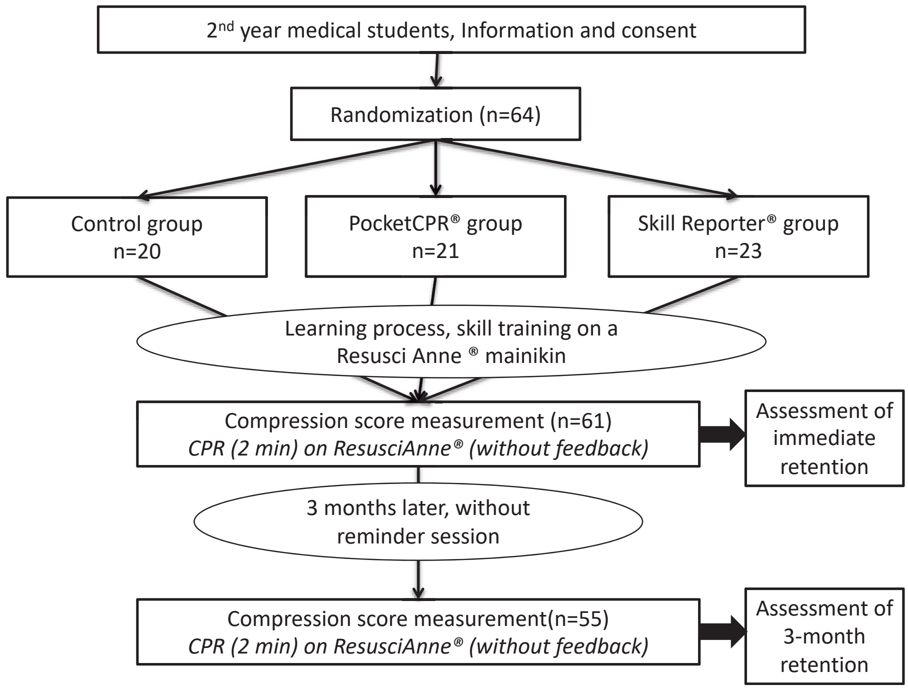

Figure 1. Flow chart. CPR = cardiopulmonary resuscitation.

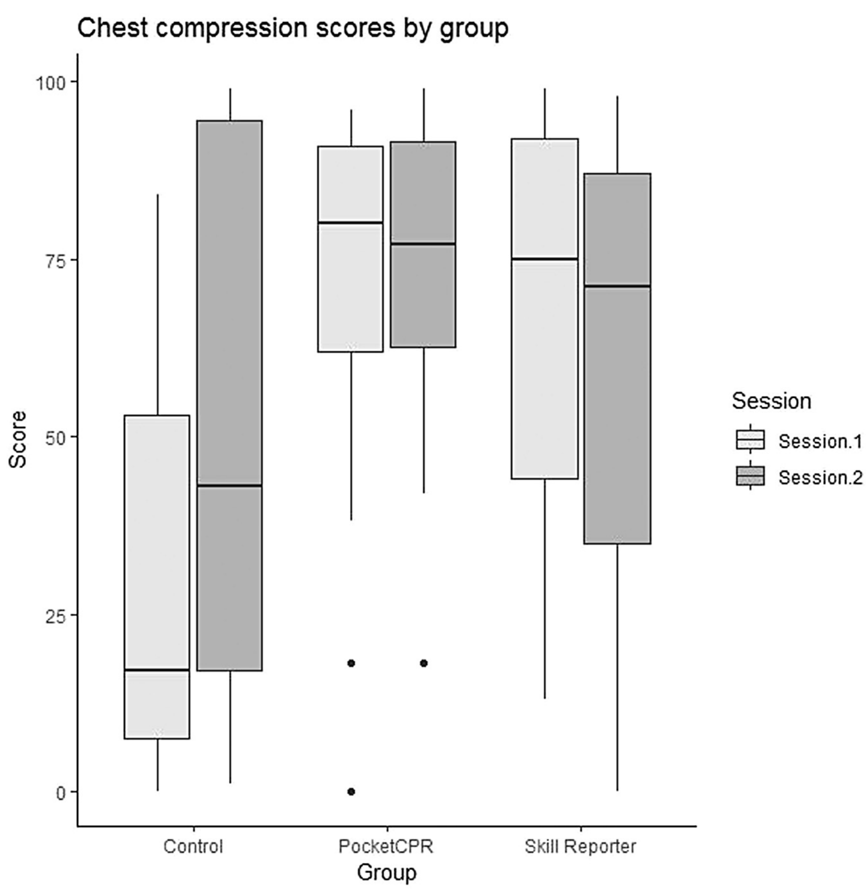

Figure 2. Chest compression scores in the 3 groups immediately after training and 3 months later. Statistical comparisons are discussed in the text.

Table 1. Components of the Compression Score in the 3 Groups Immediately After Training and at 3-Month Assessment and Trainees' Satisfaction Score at the End of the Session

	Immediate Assessment			3-Month Assessment		
	Standard	Pocket CPR	Skill Reporter	Standard	Pocket CPR	Skill Reporter
Compression depth (mm): mean (SD)	43 (35–49)	49 (46–52)	48 (42–53)	48 (39–54)	49 (44–55)	48 (40–52)
Compression rate (n/min): mean (SD)	132 (123–141)	119 (113–126)*	117 (107–123)†	116 (110–120)‡	117 (107–121)	104 (96–114)‡
Complete chest recoil (%): median (IQR)	95 (65–99)	93 (69–99)	98 (78–100)	32 (6–90)‡	47 (2–94)‡	31 (8–73)‡
Correct hand position (%): median (IQR)	100 (86–100)	100 (100–100)	100 (100–100)	100 (96–100)	100 (100–100)	100 (100–100)
Compression in 2 min (n): mean (SD)	261 (240–280)	235 (226–256)*	236 (218–252)†	236 (224–239)‡	237 (218–245)	212 (195–230)‡
Reaction level to training (Kirkpatrick 1 assessment)						
Perceived competence (0–10): mean (SD)	8 ± 1	8 ± 1	8 ± 1	—	—	—
Confidence (0–10): mean (SD)	8 ± 1	8 ± 1	7 ± 1	—	—	—
Session educational value (0–10): mean (SD)	9 ± 1	9 ± 1	8 ± 1	—	—	—

* $p < 0.05$ between groups 1 and 2 at initial assessment.
† $p < 0.05$ between groups 1 and 3 at initial assessment.

compression score in the control group ($p = 0.01$). However, there was no statistically significant difference between the 2 sessions in the PocketCPR ($p = 0.96$) and Skill Reporter ($p = 0.67$) groups.

There was no statistically significant difference in the mean ECM depth (in mm) between groups at early and late measurements and for each group between the initial and the 3-month session (Table 1). Heart compression rate was too fast in the control group at initial assessment whereas the 2 groups with feedback had heart rate within expected values. All 3 groups had the heart rate within expected values at 3 months. The control group had fewer chest compressions in 2 min between the first session and the second session. There was no statistically significant difference between the 2 sessions for the feedback groups (Table 1). In all 3 groups, complete chest recoil was within recommended values but initially decreased significantly at 3 months. Hand position was adequate in all 3 groups at all times (Table 1).

At the end of initial training, all 3 training methods were found to be satisfactory to learners and none appeared better than the other methods (Table 1).

DISCUSSION

The main findings of this study are that ECM training of medical students can be improved through the use of feedback methods when compared with a traditional teaching method, with no difference between the 2 tools tested. The 3-month performance improved in the control group and remained steady and high with the 2 feedback methods, showing that deterioration of skill retention has not yet occurred significantly at that time. Regarding our secondary results, we however observed a significant decrease in thoracic relaxation at 3 months, admittedly slightly depending on the mode of learning but overall chest relaxation had become incomplete in 50–70% of cases.

Most studies corroborate our results in terms of immediate retention. Beckers et al. showed some improvement in ECM performance (in terms of depth and frequency) when using feedback with accelerometer (CPRezy; Think Safe Inc., Cedar Rapids, IA) in medical students during simulation sessions (17). Another study found an improvement in the quality of ECM in simulation when nurses were trained with an accelerometer feedback (18). More recently, a Spanish study that was based on the ERC 2015 recommendations (as for our study) showed that laypeople having received ECM training with a feedback device (Resusci Anne equipped with Skill Reporter software) performed as well as health professionals when assessed immediately after training (19). Overall, our results are in line with a meta-analysis of initial studies which showed that using a feedback device improves immediate results obtained with manikin-based chest compression training (4). Indeed, when comparing the training efficacy of the 2 devices, we showed consistently that they are both associated with better compression scores when compared with standard BLS training at initial assessment but we were unable to demonstrate any difference between the 2 devices. This suggests that instructors may choose the device depending on other considerations than their training efficacy.

When looking specifically at data obtained with the Pocket CPR App, studies are sparse and controversial. A recent study reported that the Pocket CPR device had an overall lower performance than standard training while Park et al. showed that the Resusci Anne with the Skill Reporter software and the Pocket CPR App cannot be used interchangeably (5). These authors were unable to define which system performs better than standard training method in laypersons (16). Finally, another study suggests that the PocketCPR App overall performs better than standard training method in laypersons (15).

The Laerdal compression score is a proprietary tool and the respective contribution of each indicator is not known. Looking into details of parameters included, several differences could however be demonstrated. For example, we found that compression rate was too fast in the control group at initial assessment while at 3 months, all 3 groups compressed the chest in the recommended range. Chest compression recoil is an important part of the skill as animal studies have shown the harmful effect of incomplete decompression on hemodynamic parameters, in particular by reducing cerebral and coronary blood flow (20). It is a more difficult concept to conceptualize and probably would require a different approach to maintain skill. In the present study, a drastic decrease in complete thoracic relaxation was found for all 3 learning techniques at the 3-month assessment. Particular attention should therefore be paid to this point during training and retraining.

Although it seems now clear that feedback systems improve immediate skill acquisition, their efficacy at maintaining skill retention remains less well defined (21). The quality of ECM in the control group as measured by the global compression score, remained low three months after training but significantly progressed during this period. Our study population had had no clinical experience but had university education although this had not been found to be a factor favoring retention of ECM performance at 1 year (22). We suggest that the increased compression score of the control group can be explained by the experiential learning cycle described by Kolb which describes the learner's internal cognitive process (23). In this process, initial training represents a concrete experience which is followed by reflection facilitated by feedback provided by trainers during and at the end of the session. Then abstract conceptualization occurs and is finally followed by the active experiment phase when the learner practically applies what has been conceptualized before. We suggest that the time interval of 3 months between the 2 sessions may well correspond to the time needed to anchor the new skill into the learner's mind according to Kolb's description. Using the feedback devices may shorten or amplify the learning process in such way that increased scores observed initially are immediately at their maximum level.

Overall, although no more statistically significant at the 3-month assessment, chest compression scores were higher in the 2 feedback groups, again with no difference between the 2 groups. Buléon et al. showed that using a CPRmeter device during the initial testing session (no training before assessment) improved retention of chest compression quality in medical students at 4 months (8). An older study also found better technical competence at 6 weeks from ECM training in medical students who used feedback equipment compared with those who were traditionally trained (8). These data agree with the previous meta-analysis by Yeung et al., which despite acknowledging heterogeneity among the small number of studies available, suggested that feedback devices are useful to increase retention of CPR skills (24). In addition, our data reinforce the fact that there is likely little difference in training efficacy between these devices. In their 2015 guidelines, the ERC reviewing previous literature described that skills decay within 3–12 months after initial training (25). These guidelines recommended that retraining should take place every 12–24 months but this should be organized more often for some individuals after evaluation of personal skills and professional environment. Low complexity and short duration training, with or without an instructor, is also recommended for most people but it is recognized that for others more formal refresher process (25). Based on our results showing no major decay at 3 months after training with feedback training, retraining sessions with medical students should be completed in the interval suggested above.

Our study shows that learners appreciate the use of a feedback method; they were satisfied with their CPR with the help of either PocketCPR or the Skill Reporter device but without any difference when compared with guidance provided by the trainer. A recent meta-analysis found disparities in terms of satisfaction when trainees had used a feedback device (4). Discrepant results were also found between studies using the same device (4). Manufacturers must take this into consideration and focus on the user's comfort of use. Indeed, the use in real situations is often parasitized by noise, interruptions, and increased stress more than in a simulation session.

Limitations

Our study has several limitations. First, we had not anticipated in our calculation the number of subjects lost to follow-up at 3 months, considering that this training sequence is mandatory for medical students. The consequence was that we did not have enough students to meet the goal of 62 at the 3-month evaluation, but this was also true for the initial sequence of training and evaluation because early attrition was not anticipated. Second, we also did not anticipate that the control group developed such an important increase at the later assessment, thus minimizing the difference with 2 other groups. Moreover, because of the large variability in compression scores in all groups, the power of the study was less than expected. Nonetheless, the median compression score in the2 feedback device groups was almost twice as high than in the control group (43% vs. 74%). A posteriori calculation showed that using the data obtained here, it would have been necessary to include at least 76 students (i.e., only 6–10 students added in each group) to obtain a statistically significant better result at 3 months in the feedback groups.

CONCLUSIONS

The use of feedback devices during chest compression training improves the quality of immediate retention of technical skills compared with traditional training in second-year medical students. Students who learned with a feedback method maintained their skills when they were reassessed 3 months later.

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ARTICLE SUMMARY

1. Why is this topic important?

The quality of chest compressions is of utmost importance to improve patients' prognosis after cardiac arrest, but both lay people and health care professionals often do not perform cardiac massage effectively.

2. What does this study attempt to show?

Feedback devices are recommended but there are few direct comparison studies that would indicate if one device is superior to another.

3. What are the key findings?

Immediately after the training session, the median compression score was significantly higher in the group using the iPhone App PocketCPR and in the group using the Resusci Anne QCPR system equipped with Skill Reporter wireless software than in traditional teaching group with no difference between the 2 feedback methods. Three months later, compression scores with the 2 feedback devices remained high.

4. How is patient care impacted?

Given the improved efficacy of chest compression with the feedback devices, their use should be reinforced and epidemiologic studies are needed to evaluate the effect on patients' outcomes.