AUDIO-VISUAL AND INSTRUCTOR LED FEEDBACK

14 studies: 8 randomised and 6 observational
1 neonatal, 1 paediatric, 9 adult
1 OOHCA, 1 IHCA
+ve for survival, CPR quality, skills retention

Positive effect	**No effect**
Survival • Bobrow et al. 2013 – AV feedback: CC rate, CC depth, CC fraction, pre-shock pause, ventilation rate	
Survival with favourable neurological function • Bobrow et al. 2013 – AV feedback: CC rate, CC depth, CC fraction, pre-shock pause, ventilation rate	
CPR quality AV feedback • Bobrow et al. 2013 – AV feedback (vs no AV feedback): CC rate, CC depth, CC fraction, pre-shock pause, ventilation rate • Cason et al. 2011 – visual feedback (vs no or auditory feedback): CC rate, CC depth • Cheng et al. 2015 – real time visual feedback during IHCA CPR (vs no visual feedback): CC rate, CC depth, CC fraction • Rieke et al. 2013 – real-time BP display: area under BP curve • Semeraro et al. 2013 – audiovisual feedback: CC depth, CC rate, Just in time or similar training • Cheng et al. 2015 – just in time training prior to IHCA (vs no training): CC rate, CC depth, CC fraction • Cheng et al. 2015 – just in time training prior to IHCA PLUS real time visual feedback during IHCA CPR: CC rate, CC depth, CC fraction • Diez et al. 2013 - voice advisory mannequin (vs instructor guidance): hand position, CC rate, CC depth • Hunt et al. 2014 - Rapid Cycle Deliberate Practice (RCDP): no-flow fraction, no-blow fraction, pre-shock pause, CC<1 minute, defibrillation <2 minutes Debriefing • Dine et al. 2008 - debriefing (vs no debriefing): CC rate, CC depth Instructor led feedback • Dine et al. 2008 - feedback (vs no feedback): CC rate, CC depth • Dine et al. 2008 - debriefing PLUS feedback (vs no feedback): CC rate, CC depth • Isbye et al. 2008 - instructor facilitated (vs voice advisory manikin):CPR performance (Cardiff scoring) • Sutton et al. 2011 – instructor only-training: CC rate, CC depth Other • Song et al. 2015 – smartphone feedback (manikin in tilted position): CC rate, CC depth • Sutton et al. 2011 – AED feedback: CC rate, CC depth • Sutton et al. 2011 – instructor only-training PLUS AED feedback: CC rate, CC depth • Yang et al. 2009 – interactive video communication: CC depth & CC rate	CPR quality • Song et al. 2015 – smartphone feedback (manikin in lateral position): CC rate, CC depth • Yang et al. 2009 – interactive video communication: time to commencement of CC compressions

Positive effect	**No effect**
Skills retention • Isbye et al. 2008 - instructor facilitated (vs voice advisory manikin): BVM skills retention after 3 months	
Skills acquisition	Skills acquisition • Min et al. 2016 – initial CPR skills: CC depth, % ventilations of appropriate volume
Mask ventilation • Binder et al. 2014 – technical feedback (vs auditory feedback): mask ventilation • Binder et al. 2014 – verbal feedback (vs auditory feedback): mask ventilation	

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
1. Binder, C., G. M. Schmolzer, M. O'Reilly, B. Schwaberger, B. Urlesberger and G. Pichler (**2014**). "**Human or monitor feedback to improve mask ventilation during simulated neonatal cardiopulmonary resuscitation**." Archives of Disease in Childhood Fetal & Neonatal Edition **99**(2): F120-123. OBJECTIVE: To investigate if external chest compressions (ECC) increase mask leak, and if human or technical feedback improves mask ventilation during simulated neonatal cardiopulmonary resuscitation (CPR). STUDY DESIGN: In this observational study, 32 participants delivered positive pressure ventilation (PPV) to a modified, leak-free manikin via facemask. Mask leak, tidal volume (VT), positive end expiratory pressure (PEEP) and respiratory rate (RR) were measured with a respiratory function monitor (RFM). Participants had to perform four studies. In the first study, participants performed PPV alone as baseline. Thereafter, three studies were performed in random order. In the PPV+ECC+manometer group, participants had to observe the manometer while the RFM was covered; in the PPV+ECC+RFM group, the RFM was used while the manometer was covered; and in the PPV+ECC+verbal feedback group, the RFM and manometer were covered while a team leader viewed the RFM and provided verbal feedback to the participants. RESULTS: Median (IQR) mask leak of all studies was 15% (5-47%). Comparing the studies, PPV+ECC+RFM and PPV+ECC+verbal feedback had significantly less mask leak than PPV+ECC+manometer. Mean (SD) VT of all studies was 9.5+/-3.5 mL. Comparing all studies, PPV+ECC+RFM had a significantly higher VT than PPV and PPV+ECC+manometer. As well, PPV+ECC+verbal feedback had a significantly higher VT than PPV. PEEP and RR were within our target, mean (SD) PEEP was 6+/-2 cmH2O and RR was 36+/-13/min. CONCLUSIONS: During simulated neonatal CPR, ECCs did not influence mask leak, and a RFM and verbal feedback were helpful methods to reduce mask leak and increase VT significantly.	• Observational • Neonatal • Manikin study • Participants characteristics unknown	• Manometer • Respiratory function monitor (RFM) • Instructor	Mask ventilation	+ve Technical (RFM) and verbal feedback • ↓ mask leak • ↑ tidal volume

Study		Study features	Type of feedback	Outcomes	Major finding
Feedback					
2.	Bobrow, B. J., T. F. Vadeboncoeur, U. Stolz, A. E. Silver, J. M. Tobin, S. A. Crawford, T. K. Mason, J. Schirmer, G. A. Smith and D. W. Spaite (**2013**). "**The influence of scenario-based training and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation quality and survival from out-of-hospital cardiac arrest.[Erratum appears in Ann Emerg Med. 2015 Mar;65(3):344]**." Annals of Emergency Medicine **62**(1): 47-56.e41. STUDY OBJECTIVE: We assess whether an initiative to optimize out-of-hospital provider cardiopulmonary resuscitation (CPR) quality is associated with improved CPR quality and increased survival from out-of-hospital cardiac arrest. METHODS: This was a before-after study of consecutive adult out-of-hospital cardiac arrest. Data were obtained from out-of-hospital forms and defibrillators. Phase 1 included 18 months with real-time audiovisual feedback disabled (October 2008 to March 2010). Phase 2 included 16 months (May 2010 to September 2011) after scenario-based training of 373 professional rescuers and real-time audiovisual feedback enabled. The effect of interventions on survival to hospital discharge was assessed with multivariable logistic regression. Multiple imputation of missing data was used to analyze the effect of interventions on CPR quality. RESULTS: Analysis included 484 out-of-hospital cardiac arrest patients (phase 1 232; phase 2 252). Median age was 68 years (interquartile range 56-79); 66.5% were men. CPR quality measures improved significantly from phase 1 to phase 2: Mean chest compression rate decreased from 128 to 106 chest compressions per minute (difference -23 chest compressions; 95% confidence interval [CI] -26 to -19 chest compressions); mean chest compression depth increased from 1.78 to 2.15 inches (difference 0.38 inches; 95% CI 0.28 to 0.47 inches); median chest compression fraction increased from 66.2% to 83.7% (difference 17.6%; 95% CI 15.0% to 20.1%); median preshock pause decreased from 26.9 to 15.5 seconds (difference -11.4 seconds; 95% CI -15.7 to -7.2 seconds), and mean ventilation rate decreased from 11.7 to 9.5/minute (difference -2.2/minute; 95% CI -3.9 to -0.5/minute). All-rhythms survival increased from phase 1 to phase 2 (20/231, 8.7% versus 35/252, 13.9%; difference 5.2%; 95% CI -0.4% to 10.8%), with an adjusted odds ratio of 2.72 (95% CI 1.15 to 6.41), controlling for initial rhythm, witnessed arrest, age, minimally interrupted cardiac resuscitation protocol compliance, and provision of therapeutic hypothermia. Witnessed arrests/shockable rhythms survival was 26.3% (15/57) for phase 1 and 55.6% (20/36) for phase 2 (difference 29.2%; 95% CI 9.4% to 49.1%). CONCLUSION: Implementation of resuscitation training combined with real-time audiovisual feedback was independently associated with improved CPR quality, an increase in survival, and favorable functional outcomes after out-of-hospital cardiac arrest. 	• Observational • Before-after study • Pre-hospital = adult OOHCA • Professional rescuers (? paramedcis / EMS)	• Scenario-based training with real-time audiovisual feedback	• CPR quality • Survival w favourable neurological outcome	+ve • improved CPR quality • increase in survival, and favourable functional outcomes

Study		Study features	Type of feedback	Outcomes	Major finding
Feedback					
3.	Cason, C. L., C. Trowbridge, S. M. Baxley and M. D. Ricard (**2011**). "**A counterbalanced cross-over study of the effects of visual, auditory and no feedback on performance measures in a simulated cardiopulmonary resuscitation**." BMC Nursing **10**: 15. BACKGROUND: Previous research has demonstrated that trained rescuers have difficulties achieving and maintaining the correct depth and rate of chest compressions during both in and out of hospital cardiopulmonary resuscitation (CPR). Feedback on rate and depth mitigate decline in performance quality but not completely with the residual performance decline attributed to rescuer fatigue. The purpose of this study was to examine the effects of feedback (none, auditory only and visual only) on the quality of CPR and rescuer fatigue. METHODS: Fifteen female volunteers performed 10 minutes of 30:2 CPR in each of three feedback conditions: none, auditory only, and visual only. Visual feedback was displayed continuously in graphic form. Auditory feedback was error correcting and provided by a voice assisted CPR manikin. CPR quality measures were collected using SkillReporter software. Blood lactate (mmol/dl) and perceived exertion served as indices of fatigue. One-way and two way repeated measures analyses of variance were used with alpha set a priori at 0.05. RESULTS: Visual feedback yielded a greater percentage of correct compressions (78.1 +/- 8.2%) than did auditory (65.4 +/- 7.6%) or no feedback (44.5 +/- 8.1%). Compression rate with auditory feedback (87.9 +/- 0.5 compressions per minute) was less than it was with both visual and no feedback ($p < 0.05$). CPR performed with no feedback (39.2 +/- 0.5 mm) yielded a shallower average depth of compression and a lower percentage (55 +/- 8.9%) of compressions within the accepted 38-50 mm range than did auditory or visual feedback ($p < 0.05$). The duty cycle for auditory feedback (39.4 +/- 1.6%) was less than it was with no feedback ($p < 0.05$). Auditory feedback produced lower lactate concentrations than did visual feedback ($p < 0.05$) but there were no differences in perceived exertion. CONCLUSIONS: In this study feedback mitigated the negative effects of fatigue on CPR performance and visual feedback yielded better CPR performance than did no feedback or auditory feedback. The perfect confounding of sensory modality and periodicity of feedback (visual feedback provided continuously and auditory feedback provided to correct error) leaves unanswered the question of optimal form and timing of feedback.	• Observational • Adult • Manikin study • Female volunteers	• None • Auditory only • Visual only	CPR quality rescuer fatigue	+ve visual feedback = better CPR performance than no or auditory feedback

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
4. Cheng, A., L. L. Brown, J. P. Duff, J. Davidson, F. Overly, N. M. Tofil, D. T. Peterson, M. L. White, F. Bhanji, I. Bank, R. Gottesman, M. Adler, J. Zhong, V. Grant, D. J. Grant, S. N. Sudikoff, K. Marohn, A. Charnovich, E. A. Hunt, D. O. Kessler, H. Wong, N. Robertson, Y. Lin, Q. Doan, J. M. Duval-Arnould, V. M. Nadkarni, R. International Network for Simulation-Based Pediatric Innovation and C. P. R. I. Education (**2015**). "**Improving cardiopulmonary resuscitation with a CPR feedback device and refresher simulations (CPR CARES Study): a Randomised clinical trial**." JAMA Pediatrics **169**(2): 137-144. IMPORTANCE: The quality of cardiopulmonary resuscitation (CPR) affects hemodynamics, survival, and neurological outcomes following pediatric cardiopulmonary arrest (CPA). Most health care professionals fail to perform CPR within established American Heart Association guidelines. OBJECTIVE: To determine whether "just-in-time" (JIT) CPR training with visual feedback (VisF) before CPA or real-time VisF during CPA improves the quality of chest compressions (CCs) during simulated CPA. DESIGN, SETTING, AND PARTICIPANTS: Prospective, Randomised , 2x2 factorial-design trial with explicit methods (July 1, 2012, to April 15, 2014) at 10 International Network for Simulation-Based Pediatric Innovation, Research, & Education (INSPIRE) institutions running a standardized simulated CPA scenario, including 324 CPR-certified health care professionals assigned to 3-person resuscitation teams (108 teams). INTERVENTIONS: Each team was Randomised to 1 of 4 permutations, including JIT training vs no JIT training before CPA and real-time VisF vs no real-time VisF during simulated CPA. MAIN OUTCOMES AND MEASURES: The proportion of CCs with depth exceeding 50 mm, the proportion of CPR time with a CC rate of 100 to 120 per minute, and CC fraction (percentage CPR time) during simulated CPA. RESULTS: The quality of CPR was poor in the control group, with 12.7% (95% CI, 5.2%-20.1%) mean depth compliance and 27.1% (95% CI, 14.2%-40.1%) mean rate compliance. JIT training compared with no JIT training improved depth compliance by 19.9% (95% CI, 11.1%-28.7%; P<.001) and rate compliance by 12.0% (95% CI, 0.8%-23.2%; P=.037). Visual feedback compared with no VisF improved depth compliance by 15.4% (95% CI, 6.6%-24.2%; P=.001) and rate compliance by 40.1% (95% CI, 28.8%-51.3%; P<.001). Neither intervention had a statistically significant effect on CC fraction, which was excellent (>89.0%) in all groups. Combining both interventions showed the highest compliance with American Heart Association guidelines but was not significantly better than either intervention in isolation. CONCLUSIONS AND RELEVANCE: The quality of CPR provided by health care professionals is poor. Using novel and practical technology, JIT training before CPA or real-time VisF during CPA, alone or in combination, improves compliance with American Heart Association guidelines for CPR that are associated with better outcomes. TRIAL REGISTRATION: clinicaltrials.gov Identifier: NCT02075450.	• Prospective, Randomised trial • Paediatric, IHCA • Manikin study • CPR-certified health care professionals	• Just in time training vs no just in time training crossed over with • real-time visual feedback vs no no real-time visual feedback	CPR quality – CC depth, rate, fraction,	+ve JIT training before IHCA or real-time VisF during IHCA alone or in combination, improves CPR quality

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
5. Diez, N., M. C. Rodriguez-Diez, D. Nagore, S. Fernandez, M. Ferrer and J. J. Beunza (**2013**). "**A Randomised trial of cardiopulmonary resuscitation training for medical students: voice advisory mannequin compared to guidance provided by an instructor**." Simulation in Healthcare: The Journal of The Society for Medical Simulation **8**(4): 234-241. INTRODUCTION: Current European Resuscitation Guidelines 2010 recommend the use of prompt/feedback devices when training for cardiopulmonary resuscitation (CPR). We aimed to assess the quality of CPR training among second-year medical students with a voice advisory mannequin (VAM) compared to guidance provided by an instructor. METHODS: Forty-three students received a theoretical reminder about CPR followed by a 2-minute pretest on CPR (compressions/ventilations cycle) with Resusci Anne SkillReporter (Laerdal Medical). They were then Randomised into a control group (n = 22), trained by an instructor for 4 minutes per student, and an intervention group (n = 21) trained individually with VAM CPR mannequin for 4 minutes. After training, the students performed a 2-minute posttest, with the same method as the pretest. RESULTS: Participants in the intervention group (VAM) performed more correct hand position (73% vs. 37%; P = 0.014) and tended to display better compression rate (124 min vs. 135 min; P = 0.089). In a stratified analyses by sex we found that only among women trained with VAM was there a significant improvement in compression depth before and after training (36 mm vs. 46 mm, P = 0.018) and in the percentage of insufficient compressions before and after training (56% vs. 15%; P = 0.021). CONCLUSIONS: In comparison to the traditional training method involving an instructor, training medical students in CPR with VAM improves the quality of chest compressions in hand position and in compression rate applied to mannequins. Only among women was VAM shown to be superior in compression depth training. This technology reduces costs in 14% in our setup and might potentially release instructors' time for other activities.	• Observational • Adult • Manikin • Medical students	• voice advisory mannequin (VAM) • instructor guidance	CPR quality	+ve VAM improved CC hand position and rate VAM improved CC depth on women only

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
6. Dine, C. J., R. E. Gersh, M. Leary, B. J. Riegel, L. M. Bellini and B. S. Abella (**2008**). "**Improving cardiopulmonary resuscitation quality and resuscitation training by combining audiovisual feedback and debriefing**." Critical Care Medicine **36**(10): 2817-2822. OBJECTIVE: Delivery of high-quality cardiopulmonary resuscitation increases survival from cardiac arrest, yet studies have shown that cardiopulmonary resuscitation quality is often poor during actual in-hospital resuscitation. Furthermore, recent work has shown that audiovisual feedback alone during cardiopulmonary resuscitation modestly improves performance. We hypothesized that a multimodal training method comprising audiovisual feedback and immediate debriefing would improve cardiopulmonary resuscitation performance among care providers. DESIGN: Prospective Randomised interventional study. SETTING: Simulated cardiac arrests at an academic medical center. SUBJECTS: A total of 80 nurses were Randomised to two groups. INTERVENTION: Each group underwent three trials of simulated cardiac arrest. The "feedback" group received real-time audiovisual feedback during the second and third trials, whereas the "debriefing-only" group performed cardiopulmonary resuscitation without feedback. Both groups received short individual debriefing after the second trial. MEASUREMENTS: Cardiopulmonary resuscitation quality was recorded using a cardiopulmonary resuscitation-sensing defibrillator that measures chest compression rate/depth and can deliver audiovisual feedback messages from both groups during the three trials. An adequate compression rate was defined as 90-110 compressions/min and an adequate depth as 38-51 mm. MAIN RESULTS: In the debriefing-only group, the percentage of participants providing compressions of adequate depth increased after debriefing, from 38% to 68% (p = 0.015). In the feedback group, depth compliance improved from 19% to 58% (p = 0.002). Compression rate did not improve significantly with either intervention alone. The combination of feedback and debriefing improved compression rate compliance from 45% to 84% (p = 0.001) and resulted in a doubling of participants providing compressions of both adequate rate and depth, 29% vs. 64% (p = 0.005). CONCLUSIONS: Significant cardiopulmonary resuscitation quality deficits exist among healthcare providers. Debriefing or feedback alone improved cardiopulmonary resuscitation quality, but the combination led to marked performance improvements. Cardiopulmonary resuscitation feedback and debriefing may serve as a powerful tool to improve rescuer training and care for cardiac arrest patients.	• Prospective Randomised • Adult • Manikin • Nurses	• real-time audiovisual feedback	CPR quality	+ ve Debriefing or real-time audiovisual feedback alone improved cardiopulmonary resuscitation quality, but the combination led to marked performance improvements

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
7. Hunt, E. A., J. M. Duval-Arnould, K. L. Nelson-McMillan, J. H. Bradshaw, M. Diener-West, J. S. Perretta and N. A. Shilkofski (**2014**). "**Pediatric resident resuscitation skills improve after "rapid cycle deliberate practice" training**." Resuscitation **85**(7): 945-951. INTRODUCTION: Previous studies reveal pediatric resident resuscitation skills are inadequate, with little improvement during residency. The Accreditation Council for Graduate Medical Education highlights the need for documenting incremental acquisition of skills, i.e., "Milestones". We developed a simulation-based teaching approach "Rapid Cycle Deliberate Practice" (RCDP) focused on rapid acquisition of procedural and teamwork skills (i.e., "first-five minutes" (FFM) resuscitation skills). This novel method utilizes direct feedback and prioritizes opportunities for learners to "try again" over lengthy debriefing. PARTICIPANTS: Pediatric residents from an academic medical center. METHODS: Prospective pre-post interventional study of residents managing a simulated cardiopulmonary arrest. Main outcome measures include: (1) interval between onset of pulseless ventricular tachycardia to initiation of compressions and (2) defibrillation. RESULTS: Seventy pediatric residents participated in the pre-intervention and fifty-one in the post-intervention period. Baseline characteristics were similar. The RCDP-FFM intervention was associated with a decrease in: no-flow fraction: [pre: 74% (5-100%) vs. post: 34% (26-53%); p<0.001)], no-blow fraction: [pre: 39% (22-64%) median (IQR) vs. post: 30% (22-41%); p=0.01], and pre-shock pause: [pre: 84 s (26-162) vs. post: 8s (4-18); p<0.001]. Survival analysis revealed RCDP-FFM was associated with starting compressions within 1 min of loss of pulse: [Adjusted Hazard Ratio (HR): 3.8 (95% CI: 2.0-7.2)] and defibrillating within 2 min: [HR: 1.7 (95% CI: 1.03-2.65)]. Third year residents were significantly more likely than first years to defibrillate within 2 min: [HR: 2.8 (95% CI: 1.5-5.1)]. CONCLUSIONS: Implementation of the RCDP-FFM was associated with improvement in performance of key measures of quality life support and progressive acquisition of resuscitation skills during pediatric residency. Copyright © 2014 Elsevier Ireland Ltd. All rights reserved.	• Observational • Prospective pre-post test • Paediatric • Manikin • Pediatric residents	• Rapid Cycle Deliberate Practice (RCDP)	CPR quality Time to first CC in pulseless VT Time to defibrillation in pulseless VT	+ve RCDP-FFM intervention • 40% ↓ no-flow fraction • 9% ↓ no-blow fraction • 76sec ↓ pre-shock pause • ↑ compressions < 1 min • ↑ defibrillation <2 min

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
8. Isbye, D. L., P. Hoiby, M. B. Rasmussen, J. Sommer, F. K. Lippert, C. Ringsted and L. S. Rasmussen (**2008**). "**Voice advisory manikin versus instructor facilitated training in cardiopulmonary resuscitation**." Resuscitation **79**(1): 73-81. BACKGROUND: Training of healthcare staff in cardiopulmonary resuscitation (CPR) is time-consuming and costly. It has been suggested to replace instructor facilitated (IF) training with an automated voice advisory manikin (VAM), which increases skill level by continuous verbal feedback during individual training. AIMS: To compare a VAM (ResusciAnne CPR skills station, Laerdal Medical A/S, Norway) with IF training in CPR using a bag-valve-mask (BVM) in terms of skills retention after 3 months. METHODS: Forty-three second year medical students were included and CPR performance (ERC Guidelines for Resuscitation 2005) was assessed in a 2 min test before randomisation to either IF training in groups of 8 or individual VAM training. Immediately after training and after 3 months, CPR performance was assessed in identical 2 min tests. Laerdal PC Skill Reporting System 2.0 was used to collect data. To quantify CPR performance a scoring system based on the Cardiff test was used. Groups were compared with a Mann Whitney rank sum test. RESULTS: There was no statistically significant difference between the two groups when considering change in overall CPR performance score from before training to 3 months after training (P=0.12). However, the IF group performed significantly better than the VAM group in the total score, both immediately after (P=0.0008) and 3 months after training (P=0.02). This difference was primarily related to the BVM skills. CONCLUSION: Skill retention in CPR using a bag-valve-mask was better after 3 months when training with an instructor than with an automated voice advisory manikin.	• Randomised • Adult • Manikin • Medical students	• instructor facilitated (IF) • voice advisory manikin (VAM)	CPR performance (Cardiff scoring) bag-valve-mask (BVM) skills retention after 3 months	+ve IF group better than VAM group in CPR quality total score, immediately after & 3 months after training This difference was primarily related to the BVM skills.

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
9. Min, M. K., S. R. Yeom, J. H. Ryu, Y. I. Kim, M. R. Park, S. K. Han, S. H. Lee, S. W. Park and S. C. Park (**2016**). "**Comparison between an instructor-led course and training using a voice advisory manikin in initial cardiopulmonary resuscitation skill acquisition**." Clinical & Experimental Emergency Medicine **3**(3): 158-164. OBJECTIVE: We compared training using a voice advisory manikin (VAM) with an instructor-led (IL) course in terms of acquisition of initial cardiopulmonary resuscitation (CPR) skills, as defined by the 2010 resuscitation guidelines. METHODS: This study was a Randomised , controlled, blinded, parallel-group trial. We recruited 82 first-year emergency medical technician students and distributed them randomly into two groups: the IL group (n=41) and the VAM group (n=37). In the IL-group, participants were trained in "single-rescuer, adult CPR" according to the American Heart Association's Basic Life Support course for healthcare providers. In the VAM group, all subjects received a 20-minute lesson about CPR. After the lesson, each student trained individually with the VAM for 1 hour, receiving real-time feedback. After the training, all subjects were evaluated as they performed basic CPR (30 compressions, 2 ventilations) for 4 minutes. RESULTS: The proportion of participants with a mean compression depth >=50 mm was 34.1% in the IL group and 27.0% in the VAM group, and the proportion with a mean compression depth >=40 mm had increased significantly in both groups compared with >=50 mm (IL group, 82.9%; VAM group, 86.5%). However, no significant differences were detected between the groups in this regard. The proportion of ventilations of the appropriate volume was relatively low in both groups (IL group, 26.4%; VAM group, 12.5%; P=0.396). CONCLUSION: Both methods, the IL training using a practice-while-watching video and the VAM training, facilitated initial CPR skill acquisition, especially in terms of correct chest compression.	• Randomised , controlled, blinded • Adult • Manikin • EMT students	• voice advisory manikin (VAM) • instructor-led (IL)	Acquisition of initial cardiopulmonary resuscitation (CPR) skills	No significant difference

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
10. Rieke, H., M. Rieke, S. K. Gado, P. J. Nietert, L. C. Field, C. A. Clark, C. M. Furse and M. D. McEvoy (**2013**). "**Virtual arterial blood pressure feedback improves chest compression quality during simulated resuscitation**." Resuscitation **84**(11): 1585-1590. INTRODUCTION: Quality chest compressions (CC) are the most important factor in successful cardiopulmonary resuscitation. Adjustment of CC based upon an invasive arterial blood pressure (ABP) display would be theoretically beneficial. Additionally, having one compressor present for longer than a 2-min cycle with an ABP display may allow for a learning process to further maximize CC. Accordingly, we tested the hypothesis that CC can be improved with a real-time display of invasively measured blood pressure and with an unchanged, physically fit compressor. METHODS: A manikin was attached to an ABP display derived from a hemodynamic model responding to parameters of CC rate, depth, and compression-decompression ratio. The area under the blood pressure curve over time (AUC) was used for data analysis. Each participant (N=20) performed 4 CPR sessions: (1) No ABP display, exchange of compressor every 2 min; (2) ABP display, exchange of compressor every 2 min; (3) no ABP display, no exchange of the compressor; (4) ABP display, no exchange of the compressor. Data were analyzed by ANOVA. Significance was set at a p-value<0.05. RESULTS: The average AUC for cycles without ABP display was 5201 mm Hgs (95% confidence interval (CI) of 4804-5597 mm Hgs), and for cycles with ABP display 6110 mm Hgs (95% CI of 5715-6507 mm Hgs) (p<0.0001). The average AUC increase with ABP display for each participant was 20.2+/-17.4% 95 CI (p<0.0001). CONCLUSIONS: Our study confirms the hypothesis that a real-time display of simulated ABP during CPR that responds to participant performance improves achieved and sustained ABP. However, without any real-time visual feedback, even fit compressors demonstrated degradation of CC quality. Copyright © 2013 Elsevier Ireland Ltd. All rights reserved.	• Observational study • Adult • Manikin • Participants characteristics unknown	• real-time display of invasively measured blood pressure	CPR quality - CC	+ Average AUC increase with ABP display for each participant was 20.2+/-17.4% 95 CI (p<0.0001).

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
11. Semeraro, F., A. Frisoli, C. Loconsole, F. Banno, G. Tammaro, G. Imbriaco, L. Marchetti and E. L. Cerchiari (**2013**). "**Motion detection technology as a tool for cardiopulmonary resuscitation (CPR) quality training: a randomised crossover mannequin pilot study**." Resuscitation **84**(4): 501-507. INTRODUCTION: Outcome after cardiac arrest is dependent on the quality of chest compressions (CC). A great number of devices have been developed to provide guidance during CPR. The present study evaluates a new CPR feedback system (Mini-VREM: Mini-Virtual Reality Enhanced Mannequin) designed to improve CC during training. METHODS: Mini-VREM system consists of a Kinect() (Microsoft, Redmond, WA, USA) motion sensing device and specifically developed software to provide audio-visual feedback. Mini-VREM was connected to a commercially available mannequin (Laerdal Medical, Stavanger, Norway). Eighty trainees (healthcare professionals and lay people) volunteered in this randomised crossover pilot study. All subjects performed a 2 min CC trial, 1h pause and a second 2 min CC trial. The first group (FB/NFB, n=40) performed CC with Mini-VREM feedback (FB) followed by CC without feedback (NFB). The second group (NFB/FB, n=40) performed vice versa. Primary endpoints: adequate compression (compression rate between 100 and 120 min(-1) and compression depth between 50 and 60mm); compressions rate within 100-120 min(-1); compressions depth within 50-60mm. RESULTS: When compared to the performance without feedback, with Mini-VREM feedback compressions were more adequate (FB 35.78% vs. NFB 7.27%, p<0.001) and more compressions achieved target rate (FB 72.04% vs. 31.42%, p<0.001) and target depth (FB 47.34% vs. 24.87%, p=0.002). The participants perceived the system to be easy to use with effective feedback. CONCLUSIONS: The Mini-VREM system was able to improve significantly the CC performance by healthcare professionals and by lay people in a simulated CA scenario, in terms of compression rate and depth. Copyright © 2012 Elsevier Ireland Ltd. All rights reserved.	• Randomised crossover • Adult • Manikin • Healthcare professionals & lay people volunteers	• Mini-VREM= audio-visual feedback	CPR quality CC rate, depth	+ Feedback improved CC rate and depth

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
12. Song, Y., J. Oh, Y. Chee, Y. Cho, S. Lee and T. H. Lim (**2015**). "**Effectiveness of chest compression feedback during cardiopulmonary resuscitation in lateral tilted and semirecumbent positions: a randomised controlled simulation study**." Anaesthesia **70**(11): 1235-1241. Feedback devices have been shown to improve the quality of chest compression during cardiopulmonary resuscitation for patients in the supine position, but no studies have reported the effects of feedback devices on chest compression when the chest is tilted. Basic life support-trained providers were randomly assigned to administer chest compressions to a manikin in the supine, 30degree left lateral tilt and 30degree semirecumbent positions, with or without the aid of a feedback device incorporated into a smartphone. Thirty-six participants were studied. The feedback device did not affect the quality of chest compressions in the supine position, but improved aspects of performance in the tilted positions. In the lateral tilted position, the median (IQR [range]) chest compression rate was 99 (99-100 [96-117]) compressions.min(-1) with and 115 (95-128 [77-164]) compressions.min(-1) without feedback (p = 0.05), and the proportion of compressions of correct depth was 55 (0-96 [0-100])% with and 1 (0-30 [0-100])% without feedback (p = 0.03). In the semirecumbent position, the proportion of compressions of correct depth was 21 (0-87 [0-100])% with and 1 (0-26 [0-100])% without feedback (p = 0.05). Female participants applied chest compressions at a more accurate rate using the feedback device in the lateral tilted position but were unable to increase the chest compression depth, whereas male participants were able to increase the force of chest compression using the feedback device in the lateral tilted and semirecumbent positions. We conclude that a feedback device improves the application of chest compressions during simulated cardiopulmonary resuscitation when the chest is tilted. Copyright © 2015 The Association of Anaesthetists of Great Britain and Ireland.	• Randomised • Adult • Manikin • Participants characteristics unknown	• feedback device incorporated into a smartphone	CPR quality- CC	**Mixed** No change Feedback did not affect CC quality in the supine position + Feedback improved aspects of CC quality in tilted positions (lateral tilt & semirecumbant)

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
13. Sutton, R. M., D. Niles, P. A. Meaney, R. Aplenc, B. French, B. S. Abella, E. L. Lengetti, R. A. Berg, M. A. Helfaer and V. Nadkarni (**2011**). ""**Booster" training: evaluation of instructor-led bedside cardiopulmonary resuscitation skill training and automated corrective feedback to improve cardiopulmonary resuscitation compliance of Pediatric Basic Life Support providers during simulated cardiac arrest**." Pediatric Critical Care Medicine **12**(3): e116-121. OBJECTIVE: To investigate the effectiveness of brief bedside "booster" cardiopulmonary resuscitation (CPR) training to improve CPR guideline compliance of hospital-based pediatric providers. DESIGN: Prospective, Randomised trial. SETTING: General pediatric wards at Children's Hospital of Philadelphia. SUBJECTS: Sixty-nine Basic Life Support-certified hospital-based providers. INTERVENTION: CPR recording/feedback defibrillators were used to evaluate CPR quality during simulated pediatric arrest. After a 60-sec pretraining CPR evaluation, subjects were randomly assigned to one of three instructional/feedback methods to be used during CPR booster training sessions. All sessions (training/CPR manikin practice) were of equal duration (2 mins) and differed only in the method of corrective feedback given to participants during the session. The study arms were as follows: 1) instructor-only training; 2) automated defibrillator feedback only; and 3) instructor training combined with automated feedback. MEASUREMENTS AND MAIN RESULTS: Before instruction, 57% of the care providers performed compressions within guideline rate recommendations (rate >90 min(-1) and <120 min(-1)); 71% met minimum depth targets (depth, >38 mm); and 36% met overall CPR compliance (rate and depth within targets). After instruction, guideline compliance improved (instructor-only training: rate 52% to 87% [p .01], and overall CPR compliance, 43% to 78% [p < .02]; automated feedback only: rate, 70% to 96% [p = .02], depth, 61% to 100% [p < .01], and overall CPR compliance, 35% to 96% [p < .01]; and instructor training combined with automated feedback: rate 48% to 100% [p < .01], depth, 78% to 100% [p < .02], and overall CPR compliance, 30% to 100% [p < .01]). CONCLUSIONS: Before booster CPR instruction, most certified Pediatric Basic Life Support providers did not perform guideline-compliant CPR. After a brief bedside training, CPR quality improved irrespective of training content (instructor vs. automated feedback). Future studies should investigate bedside training to improve CPR quality during actual pediatric cardiac arrests.	• Prospective, Randomised trial • Paediatric • Manikin • Certified hospital-based BLS providers	• instructor-only training • automated defibrillator feedback only • instructor training combined with automated feedback	CPR quality – CC rate, depth	+ CPR quality improved irrespective of training content (instructor vs. automated feedback)

Study	Study features	Type of feedback	Outcomes	Major finding
Feedback				
14. Yang, C. W., H. C. Wang, W. C. Chiang, C. W. Hsu, W. T. Chang, Z. S. Yen, P. C. Ko, M. H. Ma, S. C. Chen and S. C. Chang (**2009**). "**Interactive video instruction improves the quality of dispatcher-assisted chest compression-only cardiopulmonary resuscitation in simulated cardiac arrests**." Critical Care Medicine **37**(2): 490-495. OBJECTIVE: Bystander cardiopulmonary resuscitation (CPR) significantly improves survival of cardiac arrest victims. Dispatch assistance increases bystander CPR, but the quality of dispatcher-assisted CPR remains unsatisfactory. This study was conducted to assess the effect of adding interactive video communication to dispatch instruction on the quality of bystander chest compressions in simulated cardiac arrests. DESIGN: A Randomised controlled study with a scenario developed to simulate cardiac arrest in a public place. SETTING: The victim was simulated by a mannequin and the cell phone for dispatch assistance was a video cell phone with both voice and video modes. Chest compression-only CPR instruction was used in the dispatch protocol. SUBJECTS: Ninety-six adults without CPR training within 5 years were recruited. INTERVENTIONS: The subjects were Randomised to receive dispatch assistance on chest compression with either voice instruction alone (voice group, n = 53) or interactive voice and video demonstration and feedback (video group, n = 43) via a video cell phone. MEASUREMENTS AND MAIN RESULTS: Performance of chest compression-only CPR throughout the scenario was videotaped. The quality of CPR was evaluated by reviewing the videos and mannequin reports. Chest compressions among the video group were faster (median rate 95.5 vs. 63.0 min-1, p < 0.01), deeper (median depth 36.0 vs. 25.0 mm, p < 0.01), and of more appropriate depth (20.0% vs. 0%, p < 0.01). The video group had more "hands-off" time (5.0 vs. 0 second, p < 0.01), longer time to first chest compression (145.0 vs. 116.0 seconds, p < 0.01) and total instruction time (150.0 vs. 121.0 seconds, p < 0.01). CONCLUSION: The addition of interactive video communication to dispatcher-assisted chest compression-only CPR initially delayed the commencement of chest compressions, but subsequently improved the depth and rate of compressions. The benefit was achieved mainly through real-time feedback.	• Randomised controlled study • Prehospital • Manikin • Lay people	• interactive video communication added to dispatch instruction CC only CPR	CPR quality - bystander chest compressions	**Mixed** Feedback initially delayed the commencement of chest compressions, but subsequently improved CC depth & rate