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Review

In situ simulation for cardiopulmonary resuscitation training: A systematic review

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Abstract

Objectives: To evaluate the effectiveness of in situ simulation for cardiopulmonary resuscitation (CPR) training on clinical and educational outcomes.

Methods: Randomised controlled trials (RCT) and non-randomised studies evaluating in situ simulation for cardiopulmonary resuscitation CPR training of healthcare workers in any setting compared to traditional training and reporting data on patients' survival, patients' outcomes, clinical performance and teamwork in actual or simulated resuscitation and resources needed were included. PubMed, Embase and Cochrane were searches from inception to October 28th 2024 (PROSPERO CRD42024521780). The assessment of risk of bias was done using RoB2 or ROBINS-I and the certainty of evidence was assessed by the GRADE approach. Meta-analysis was not possible due to significant heterogeneity in setting, interventions, control, and outcome definitions. The evidence was summarised according to the Synthesis Without Meta-Analysis (SwiM) reporting guidelines. No funding has been obtained.

Results: From 1062 records, 10 articles were included after full-text review (4 RCTs, 6 non-randomised). The risk of bias was judged as high or some concerns for RCTs and critical or serious for non-randomised studies. The certainty of evidence was very low for all the evaluated outcomes mainly due to risk of bias, inconsistency and imprecision. Two non-randomised studies reported data on patient survival, while two other non-randomized studies provided data on the review outcome of 'patient outcomes', suggesting a potential benefit of in situ simulation or no difference. Four non-randomised studies reported improving or no difference in clinical performance in actual resuscitation. One study reported improved teamwork in actual resuscitation while another reported no difference. Most included studies reported improved clinical performance, teamwork and CPR skill in simulated resuscitation after in situ simulation training vs. traditional training. No study evaluated the resources needed.

Conclusion: The heterogenous evidence suggests that in situ simulation should be considered as an option for CPR training. The certainty of evidence is very low and cost-benefit balance is uncertain due to lack of data about resource needed.

Keywords: In situ simulation, Cardiopulmonary resuscitation

List of abbreviations: CPR, Cardiopulmonary resuscitation, EIT, Education implementation and team, ILCOR, International Liaison Committee on Resuscitation, OR, Odds ratio, PICOST, Population, Intervention, Comparison, Outcome, Study design, Timeframe, PRISMA, Preferred Reporting Items for a Systematic Review and Meta-Analysis, RCT, Randomised controlled trial

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Introduction

Simulation-based learning is a widely accepted educational strategy for cardiopulmonary resuscitation (CPR) training.[1,2] Traditionally, simulation-based training is performed in classrooms or laboratories specifically equipped with mannequins, simulators and equipment needed for running the simulations. For logistic reasons, these places are usually located outside the areas dedicated to patients care.

In situ simulation in the medical education field refers to the provision of simulation scenarios for training purposes in the setting of the real workplace where the learners usually care for patients.[3] Providing simulation-based training *within* the specific areas dedicated to patient care have theoretical advantages such as facilitating the learning experience by the context where the experience is taking place ("situativity theory") and experiencing the interaction with the physical environment, the usual equipment, and organizational characteristics. This may help dealing with obstacles and barriers, improving team performance and non-technical skills.[4] The learning pathway on the performance of a cardiopulmonary resuscitation can benefit from in situ simulation. Indeed, the context in which cardiopulmonary resuscitation is provided is that of an emergency, offering the chance to simulate both technical and non-technical skills and to improve team performance. Given the potential role favoring the learning of both technical and non-technical skills, in situ simulation may increase the effectiveness of cardiopulmonary resuscitation training and improve patient outcomes compared to traditional training.[5,6]

The aim of this systematic review was to summarize the evidence available on in situ simulation-based CPR training, compared to traditional CPR training.

Methods

This systematic review was undertaken as part of the continuous evidence evaluation process of the International Liaison Committee on Resuscitation (ILCOR) Task Force on Education, Implementation, and Teams (EIT),[7,8] and was prospectively registered in PROSPERO (CRD42024521780). Results are reported in line with the Preferred Reporting Items for a Systematic Review and Meta-Analysis (PRISMA) reporting checklist (**Supplementary Material 1**).[9] The PICOST (Population, Intervention, Comparison, Outcome, Study design, Timeframe) frame specified the research question:

Population: Healthcare providers;

Intervention: In situ (workplace-based) simulation-based CPR training.

Comparators: Traditional training;

Outcomes: Patient survival (critical), CPR skill performance at course completion, CPR skill performance in actual resuscitation, CPR skill performance < 1 yr, CPR skill performance ≥ 1 yr of course completion; clinical performance (adherence to guidelines, time to critical interventions, medication errors etc.) (important), CPR quality (at course completion < 1 yr and ≥ 1 yr of course completion) (important); teamwork competencies (at course completion < 1 yr and ≥ 1 yr of course completion); resources (time, equipment, cost).

To this list of originally registered outcomes, the Task Force decided to add the outcome of patient outcomes (outcome category including measures of patient morbidity from included studies – critical) after the inclusion/exclusion process of the systematic review. Indeed, the Task Force decided to dichotomise the outcomes of clinical performance and teamwork competencies in "in actual resuscitation" (critical) and "in simulation" (important) to reduce heterogeneity.

Study design: Randomised controlled trials (RCTs) and non-randomised studies (non-randomised controlled trials, interrupted time series, controlled before-and-after studies, cohort studies with control groups) were eligible for inclusion. Studies with self-assessment as the only outcome, reviews and abstracts without full article were excluded. Unpublished studies (e.g., conference abstracts, trial protocols) were excluded. All relevant publications in any language were included as long as there was an English abstract.

Timeframe: Literature was searched from inception to 25 March 2024, and updated 28 October 2024.

Definitions

In situ simulation-based CPR training was defined as simulation courses including training in CPR, performed at the specific workplace of the healthcare providers who are joining the educational activity. Traditional training was defined as courses including CPR simulation performed in classroom or specific laboratory.

Eligibility criteria

Studies were eligible for inclusion if they investigated in situ simulation training with a specific emphasis on the review outcomes in actual resuscitations in adult, pediatric or neonatal clinical settings or in simulated scenarios. Of note, studies had to report information on the characteristics of training in the control group to be eligible. We excluded also studies that compared in situ simulation-based CPR training to no intervention.

Sources, search strategy, data extraction

The databases Medline, Embase and Cochrane were searched from inception to 25th March 2024, and lastly updated on 28th October 2024. Full search strategies are reported in the Supplementary material 2**.** Titles and abstracts were screened independently in pairs by 7 coauthors (ACo, MI, ACh, SN, AO, KL, CA) using Rayyan (https://www.rayyan.ai).[10] The same authors evaluated the full-texts to confirm eligibility and inclusion. Data from included studies was then extracted into a standard data extraction form by 2 co-authors (AC, MI). Discrepancies at any stage were solved by consensus.

Risk of bias assessment and synthesis method

Working in pairs, two co-authors (AC, MI, CA, SN) independently performed the risk of bias assessment using the 'Risk of Bias 2 (RoB 2)' tool for randomised controlled trials[11] and the 'Risk of Bias in Non-randomised studies of interventions (ROBINS-I)' tool for non–randomised studies.[12] Disagreement was discussed and resolved by consensus within the whole co-author team. The Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology was used to assess certainty of evidence.[13] At the stage of studies evaluation, the EIT task force decided not to perform *meta*-analysis, and subgroup analyses, due to high heterogeneity in

interventions, control and outcomes definitions and decided to summarise the evidence according to the Synthesis Without Meta-Analysis (SwiM) reporting guidelines.[14]

Results

Study characteristics

The literature search (including the updated search) identified 1062 records. After removal of duplicates, we screened the titles and abstracts of 761 articles. Twenty-five articles entered the full-text assessment and 15 were excluded (3 for wrong comparator, 4 for wrong outcomes and 8 for wrong study design) leaving 10 studies for the final analysis (flow chart in Fig. 1.) Table 1 reports the included studies' characteristics, designs, and data. Full description of data from included studies, per outcome, can be found in the **Supplementary material 3.** This results section contains a synthesis of results per outcomes from included studies.

Four studies were RCTs[15–18] and six were non-randomised studies.[19–24] Six studies were performed in the USA,[15,18,21–24] two in China,[17,19] one in France[16] and one in Austria.[20] Four studies concerned adult patients,[17,18,21,22] three studies focused on pediatric patients,[15,23,24] and three studies were conducted in neonatal settings.[16,19,20]

Risk of bias assessment

For RCTs, the overall risk of bias was judged high in two studies[16,17] and some concerns in another two studies.[15,18] For non-randomised

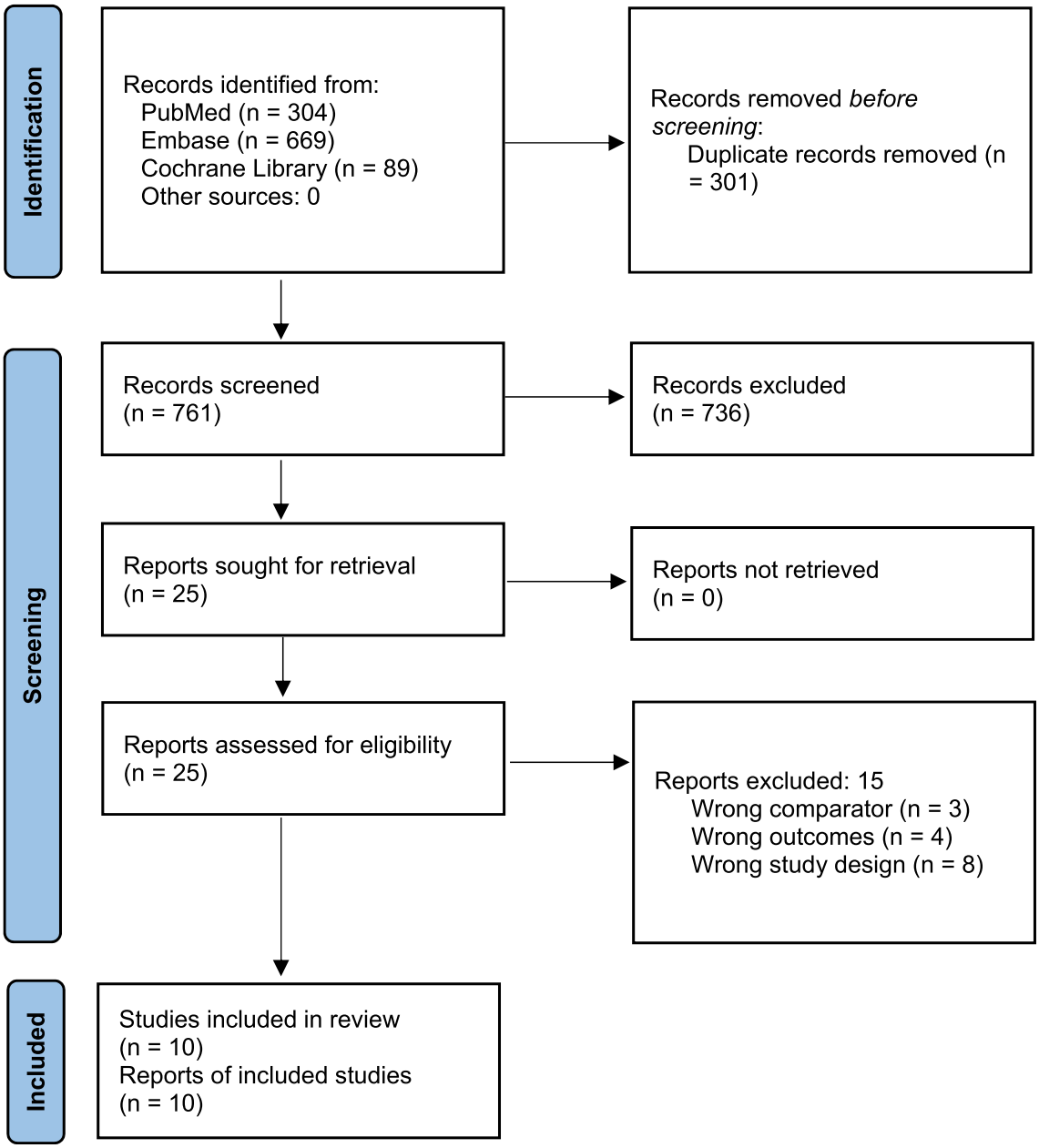

Fig. 1 – Inclusion/exclusion process in PRISMA Flow chart.

Table 1 – Characteristics of the included studies.

First author; Year; Country	Study design; Study size (N)	Population	Study intervention (# patients) / Study Comparator (# patients)	Primary Endpoint and Results	Main Results
Randomized controlled Trials (RCTs)					
Rubio-Gurung; 2015; France	Study design: Multicentre RCT Study size: 12 maternities (1 pediatrician and 9 midwives for each maternity)	Population: Level 1 and Level 2 maternities of the AURORE Perinatal Network with at least 1000 annual births, previous participation in the CEP before June 2011, and a commitment to not participate in any other training program during the study period	Intervention: 4-hour simulation training session delivered in situ for multidisciplinary groups of 6 professionals on the Sim New B high-fidelity simulator (n = 6) Comparator: (receiving "standard training", i.e. the training in the perinatal Network AURORE (n = 6)	**Outcome measures:** Primary: Technical score, team performance score Secondary: Frequency of achieving a heart rate >90 per minute at 3 minutes; >130 per minute at 5 minutes; number of hazardous events	Technical score: Scenario 1 (Control 17.4 [15.6–19.5], vs. Intervention 24.4 [18.7–26.6], P = 0.01) Scenario 2 (Control 17.5 [15.3–19.6] vs. Intervention 22.7 [21.3–25.0], P = 0.004) Teams performance score: Intervention 31.1 [20.8–36.8] vs Control ,19.9 [13.3–25.0], P <0.001
Kurosawa; 2014; USA	Study design: Single-center single-blinded RCT Sample size: 41 nurses and respiratory therapists in PICU	Population: PICU-nurses, respiratory therapists (RT), and nurse practitioners due for PALS recertification in 6–12 months	Intervention: Identical PALS recertification training content, reconstructed into six shorter sessions conducted monthly, with contextualized scenarios delivered "in situ" (PALS-r) Comparator: Standard high-quality simulation-based American Heart Association (AHA) PALS recertification training (PALS-s) course, delivered in 1 day, just prior to testing	**Outcome measures:** Primary: Skill performance measured by a validated Clinical Performance Tool (CPT) Secondary: behavioral performance measured by a Behavioral Assessment Tool	Improvement of CPT score: Intervention 6.2 (± 4.3) vs Control 1.2 (± 2.9); p = 0.004)
Mei; 2023 China	Study Design: Single-center RCT Sample size: 89	Inclusion criteria: Medical students (clerks/ internship)	Intervention: ACLS training with in-situ simulation at resuscitation room in ED or ICU (n = 44) Comparator: ACLS training with traditional simulation in a classroom (n=45)	**Outcome measures:** Clinical performance test including medical management and Teamwork	**Results:** Shown as mean (standard deviation) Clinical performance test (including medical management and Teamwork): Intervention 67.84 (±11.27) vs. Control 46.33 (±18.75), p < 0.001 Medical management: Intervention 57.09 (±9.18) vs. Control 38.47 (±15.69), p < 0.001 Teamwork: Intervention 10.84 (±3.26) vs Control 7.87 (±4.14), p < 0.001

Table 1 (continued)

First author; Year; Country	Study design; Study size (N)	Population	Study intervention (# patients) / Study Comparator (# patients)	Primary Endpoint and Results	Main Results
Sullivan; 2014; USA	Study design: Single-center RCT Sample size: 72 participants were enrolled, 18 in each group	Population: Non-intensive care unit nurses	Intervention: 15 min in-situ IHCA training sessions, usually two or three at each session, focusing on choreography and teamwork performed every two (2M), three (3M) or six months (6M) Comparator: standard AHA training	**Outcome measures:** Video recorded final assessment after 6 months. Evaluation done by two reviewers Primary: Time elapsed from call for help to: initiation of chest compressions and successful defibrillation. Secondary: Chest compression fraction Whether or not CPR adjuncts (i.e. stepstool and backboard) were utilized.	**Results:** Time elapse to call for help and initiation of chest compression reported as Median – IQR: C: 33(25–40) vs. 6M: 21(15–26) vs. 3M: 14(10–20) vs. 2M: 13(9–20); $p < 0.001$ Time elapse to successful defibrillation: [C: 157(140–254) vs. 6M: 138(107–158) vs. 3M: 115(101–119) vs. 2M: 109(98–129); $p < 0.001$]
Non Randomized studies					
Clarke 2018, USA	Study design: Single center longitudinal cohort study Sample size: 57 mock codes	Population: Mock codes involving nurses and hospital code blue team	Intervention: simulated 'mock codes' were held on Medical/ Surgical and Telemetry nursing units 2–3 times per month throughout the hospital for 3 years Comparator: BLS, ACLS training	**Outcome measures:** Assessed by 2 raters during the mock codes Primary: CPR fraction calculated by dividing the cumulative time that the manikin received chest compressions by the total pulseless time Secondary: Time to first epinephrine Time to first defibrillation	**Results:** Overall time trend of CPR fraction 1.8% per time interval (p value=0.02) Neither time to first epinephrine dosing nor time to defibrillation changed significantly
Hammontree, 2022, USA	Study design: Single-center before-after study Sample size: 237 Research Nurses (RN). (63 three months before intervention; 107 one month after intervention; 67 two yeas after intervention) Patients cohort: 90 code sheets (44 pre-intervention; 46 post-intervention)	Population: nurses working in a Pediatric Intensive Care Unit (PICU) Patients cohort: Code sheet analysis before (2016-2017) and after the intervention (2017-2018)	Intervention: After arm: Biannual mock code events with biannual or triannual supplemental events Comparator: Before arm: Basic life support and Pediatric Advanced Life Support certification every 2 year and annual mock code in the simulation laboratory	**Outcome measures** Program evaluation Code sheet review	**Results:** Code sheet review (mean (SD)): Code sheet total score: before (5.48 (1.55)); after (6.59 (1.57); P=.004) Nonadherence to PALS guidelines for subsequent epinephrine timing decreased by 39% (no p-value reported) No difference on behaviors of administering epinephrine every 3 to 5 min (P=.30)

(*continued on next page*)

Table 1 (continued)

First author; Year; Country	Study design; Study size (N)	Population	Study intervention (# patients) / Study Comparator (# patients)	Primary Endpoint and Results	Main Results
Herbers 2016, USA	Study design: 2-year single center quality improvement program Sample size: 152 participants to mock program	Population: 124 registered nurses and 28 nurse assistant from two Units	Intervention: In situ mock code quaternary for 2 years Comparator: Assumed as standard training since all the involved participants had mandatory BLS/ACLS AHA training in the pre- phase	**Outcome measures:** Assessed by an observational evaluation tool used during mock code, based on 2010 AHA guidelines Time for calling for help Time elapsed before initiation of chest compressions Time to initial defibrillation	**Results (**difference between the first evaluation and the last at the end of the 2 years): Time for calling for help improved 12% Time elapsed by initiation of chest compressions improved 52% Time to initial defibrillation improved 37%
Knight 2013, USA	Study design: Single-center prospective observational study with historical control Sample size: No N provided; 90% of core code team members. Patients cohort: 170 patients (124 pre-intervention; 46 post-intervention)	Population: PICU attendings and fellows, PICU charge nurses, respiratory therapists, pharmacists, and social workers Patients cohort: 124 CA events in the before arm pre-intervention; 46 CA events in the after arm	Intervention: AHA BLS for healthcare providers; AHA ALS certification; awareness of institution-specific code roles and responsibilities; familiarization with and training on emergency equipment; laboratory-based code blue simulation; in situ high-fidelity videotaped code blue simulation (every month) Comparator: AHA BLS for healthcare providers; AHA ALS certification; laboratory-based code blue simulation	**Outcome measures** Survival to discharge Change in neurologic morbidity from admission to discharge (pediatric cerebral performance category (PCPC)) Improvement in pediatric code team performance	**Results:** Survival to discharge: before arm (50/124(40.3%)); after arm (28/46 (60.9)); OR, 2.06 (95% CI, 1.02-4.25) After adjusting for adherence to Standard Operating Performance, survival remained improved in the intervention period (OR, 2.13 [95% CI, 1.06–4.36] PCPC: 0.11 vs 0.27; p = 0.37
Mileder 2024, Austria	Study design: Single center pre-post non controlled quality improvement study Sample size: 48 healthcare professioanals	Population: 21 Physicians and 27 nurses working in NICU who participated in 41 in situ simulation trainings Patient cohort: 20 neonates included in the 2-month pre-training phase; 13 neonates included in the 2-month post-training phase	Intervention: 41 in-situ simulation training during a 4-month period delivered regularly in interprofessional teams Comparator: Standard Neonatal Resuscitation Program training	**Outcome measures** Assessment by two external neonatologists by analysis of video recording Primary: Quality of non-technical skills and team interaction during actual postnatal stabilization and resuscitation measured by anaesthetists' Non-Technical Skills (ANTS) score Total number of five events of five teamwork events (sharing information, inquiry, assertion, teaching/advising, and evaluation of plans) Secondary: time from neonate's arrival at the resuscitation table to heart rate	**Results:** No significant difference between pre- and post-training in the main 4 individual ANTS categories or in any of the 15 ANTS elements. Significant increase in the frequency of the teamwork event "evaluation of plans" (0.5 (0.0-1.0) vs. 1.0 (1.0-2.0)); p=0.049) Increased total number of the recorded teamwork events from pre- to post-training phase (15.0 (10.0-24.3) to 18.0 (13.5-30.5) (p=0.056)) No differences in the clinical

Table 1 (continued)

First author; Year; Country	Study design; Study size (N)	Population	Study intervention (# patients) / Study Comparator (# patients)	Primary Endpoint and Results	Main Results
				auscultation and to first ventilation breath; Number of endotracheal intubation attempts during postnatal stabilization and resuscitation; SpO2 and heart rate 5 min after the neonate's arrival at the resuscitation table; Rectal body temperature during/ immediately after post- natal stabilization and resuscitation; Apgar scores at minutes 1, 5, and 10 after birth; Development of pneumothorax requiring chest tube insertion within 24 h after birth; Length of hospitalization; in-hospital mortality	outcomes
Xu 2023, China	Study design: Single-center pre-post study Sample size: 1503 participants (224 active participants)	Population: including NICU physicians, nurses, medical trainees, obstetricians, midwives in 81 simulations Patients cohort: 29759 live neonates (N= 15911 Pre-, N= 13848 Post-intervention)	Intervention: Weekly multidisciplinary in-situ simulation through collaboration between neonatal and obstetrical team (81 simulation cases) Comparator: Assumed as standard training since based on "ILCOR guidelines and NRP® with modifications for the context in China"	**Outcome measures** Incidence of neonatal asphyxia or low apgar score (cumulative or stand-alone) Severe asphyxia Hypoxic-ischemic encephalopathy Meconium aspiration	**Results: Number (%)** Neonatal asphyxia or low apgar score: Post-Intervention 111 (0.8%) vs. Control 154 (0.97%), P= .128 Neonatal asphyxia: Post-Intervention 88 (0.64%) vs. Control 133 (0.84%), P=.045 Low Apgar score: Post-intervention 23 (0.17%) vs. 21 (0.13%), P= .445 Severe asphyxia: Post-intervention 8(0.058%) vs. 22 (0.138%), P=.029 Hypoxic-ischemic encephalopathy: Post-intervention 2 (0.01%) vs. 16 (0.1%), P=0.003 Meconium aspiration syndrome: 12 (0.09%) vs. 31 (0.19%), P= .014

ANTS, Anaesthetists' Non-Technical Skills; AHA, American Heart Association; BLS, Basic Life Support; CA, Cardiac arrest; CPR, Cardiopulmonary Resuscitation; CPT, Clinical Performance Tool; ILCOR, International Liason Committee on Resuscitation; NICU, Neonatal Intensive Care Unit; PALS, Pediatric Advanced Life Support; PICU, Pediatric Intensive Care Unit; PCPC, Pediatric Cerebral Performance Category; RCT, Randomized Controlled Trial.

studies, it was judged as critical in four studies[19–22] and serious in two studies,[23,24] mainly due to bias in the confounding domain. Full risk of bias assessment is reported in Fig. 2 and Fig. 3.

Certainty of evidence

The full evidence profile is reported in **Supplementary material 3**. The certainty of evidence was judged as very low for all the evaluated outcomes. Main reasons for downgrading were risk of bias, inconsistency and imprecision.

Patient survival

One non-randomised before-after study[23] compared survival at hospital discharge after the implementation of a CPR training program based on in-situ simulation. The study showed a higher survival at hospital discharge in the "after intervention" period (in situ simulation group) vs. the "before" period, in pediatric patients who experienced cardiac arrest [28/46 (60.9%) vs. 50/123 (40.3%), OR, 2.06 (95% CI, 1.02–4.25)], but no difference in neurologic morbidity. Importantly, after adjusting for adherence to Standard Operating Performance, survival remained improved in the "after intervention" period (OR, 2.13 [95% CI, 1.06–4.36]. Another small non-randomised before-after study[20] showed no difference in patient survival at hospital discharge between the post-intervention vs. pre-intervention period.

Patient outcome

Two non-randomised studies reported patient outcomes.[19,20] One non-randomised before-after study[19] showed in the post intervention (in situ simulation) vs. pre-intervention period a lower incidence of neonatal asphyxia [88 (0.64%) vs. 133 (0.84%), P = 0.045], severe asphyxia [8 (0.058%) vs. 22 (0.138%), p = 0.029], hypoxic-ischemic encephalopathy [2 (0.01%) vs. 16 (0.1%), p = 0.003], and meconium aspiration syndrome [12 (0.09%) vs. 31 (0.19%), p = 0.014], but no difference in the composite outcome of neonatal asphyxia or low Apgar score and low Apgar score. One non-randomised before-after study[20] showed no difference between the pre-intervention period vs. post-intervention (in situ simulation) in SpO_2 five minutes after arrival at the resuscitation table, heart rate five min after arrival at the resuscitation table, rectal body temperature, Apgar at one minute], Apgar at five minutes [9 (8–9) vs. 8 (7–9), p = 0.045] (no difference after correcting for the 3 neonatal deaths), Apgar at ten minutes, pneumothorax within 24 h after birth, length of hospitalization.

Clinical performance in actual resuscitation

Four non-randomised studies reported clinical performance in actual resuscitation outcomes.[20,22–24] One non-randomised before-after study[23] reported no significant difference in neurologic morbidity from admission to discharge assessed by pediatric cerebral performance category in the intervention group, no significant improvement in performance of chest compressions < 60 s from heart rate < 60 s, significant improvement in performance of two minutes continuous chest compressions between rhythm checks [OR, 2.23 (95% CI, 1.18–4.22)] and no significant difference in the performance of shock < 3 min from recognized ventricular fibrillation/pulseless ventricular tachycardia. One non-randomised before-after study[22] reported improved time for calling for help by 12% between baseline and final evaluation, improved time elapsed to initiation of chest compressions by 52% and improved time to initial defibrillation by 37%. One non-randomised before-after study[24] reported non-adherence to PALS guidelines for subsequent epinephrine timing decreased by 39% and non-significant difference behaviors of administering epinephrine every 3 to 5 min. One non-randomised before-after study[20] showed no differences between the pre-intervention period vs. post-intervention (in situ simulation) in time in seconds from arrival at the resuscitation table to heart rate auscultation, time from arrival at the resuscitation table to first ventilation and number of endotracheal intubation attempts.

Teamwork competencies in actual resuscitation at course completion < 1 yr

One non-randomised before-after study[23] reported higher adherence to resuscitation standard operating performance as a measure of pediatric code team performance in the after arm [38/183 (20.8%) (23/64 (35.9); OR 2.14 (95% CI, 1.15–3.99)]. One non-randomised before-after study[20] showed no significant difference between pre- and post-training in the main four individual anaesthetists' Non-Technical Skills (ANTS) categories, no difference in any of the fifteen ANTS elements, non-significant increase in the total number of selected teamwork events (sharing information, inquiry, assertion, teaching/advising, and evaluation of plans) between pre-

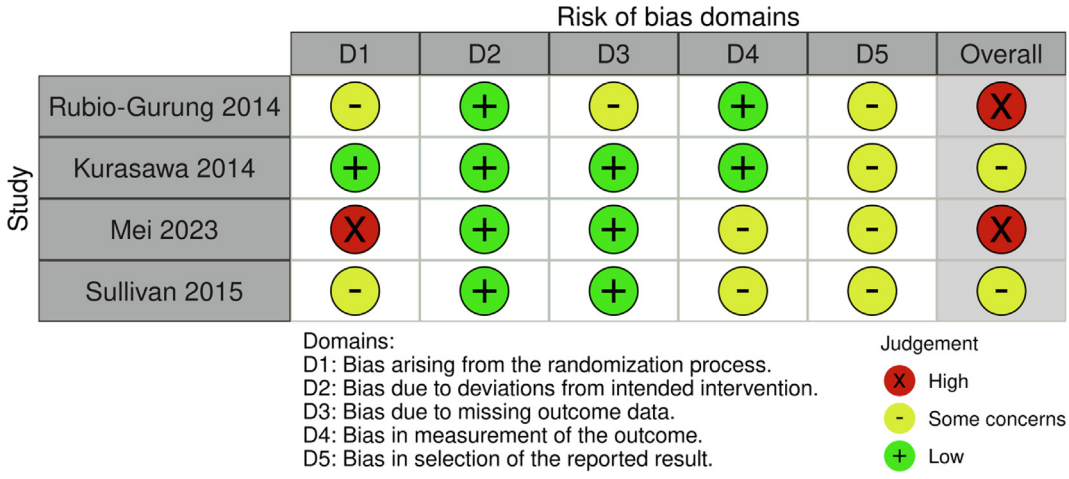

Fig. 2 – Traffic lights plot reporting the results of RoB2 assessment for randomised controlled trials.

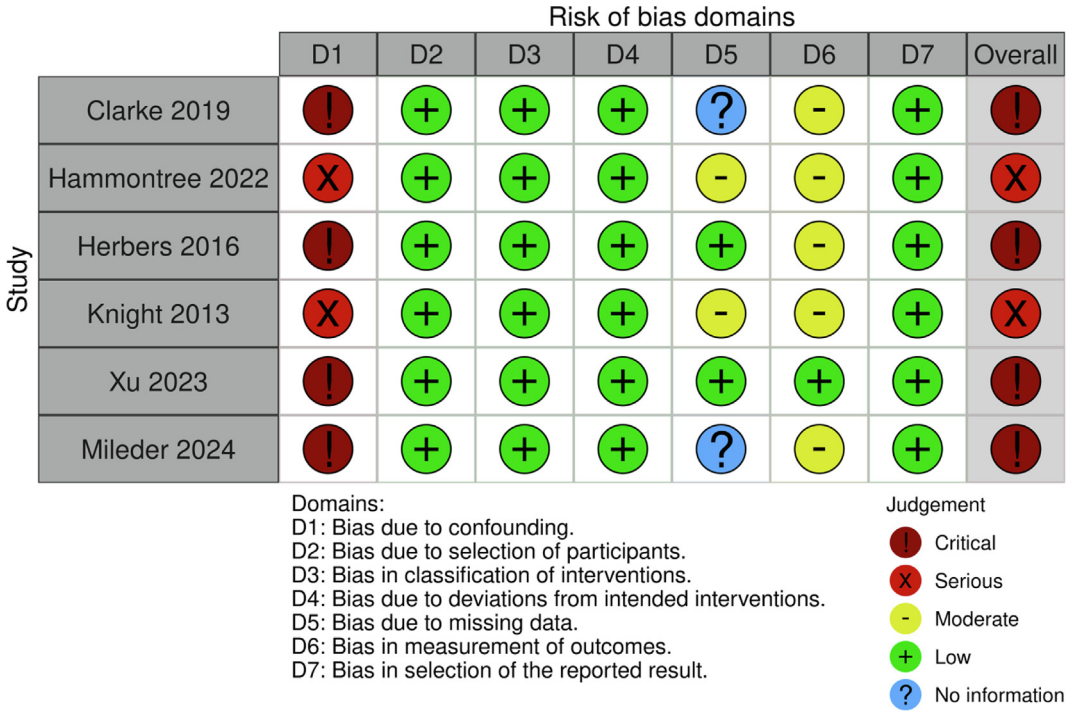

Fig. 3 – Traffic lights plot reporting the results of ROBINS-I assessment for non-randomised studies.

intervention and post-intervention phase [15.0 (10.0–24.3) vs. 18.0 (13.5–30.5) (p = 0.056)].

Clinical performance in simulation

Four RCTs[15–18] and one non-randomised study[21] reported clinical performance in simulation outcomes. One RCT[15] reported improved skill performance measured by the clinical performance tool. One RCT[18] compared different intervention groups involving in situ simulation training sessions performed at different follow-ups compared to standard training. This RCT reported shorted time elapse to call for help and initiation of chest compression in the intervention groups vs. control, time elapse to successful defibrillation and better score in the composite outcome of key priorities, compressions within twenty seconds defibrillation within 180 s and use of a backboard. One RCT[16] reported better technical score assessing technical skills and adherence to guidelines in the two simulation scenarios in the intervention group, lower occurrence of hazardous events in the intervention group, higher percentage of scenarios in which the heart rate was considered as the result of efficient resuscitation at three minutes. One RCT[17] reported better medical management test in the intervention group. One non-randomised study[21] reported no difference through the course of in situ mock code training in time to first epinephrine dosing and time to first defibrillation.

Teamwork competencies in simulation at course completion < 1 yr

Three RCTs[15–17] reported teamwork competencies in simulation at course completion as an outcome. One RCT[15] reported no difference in teamwork assessed by the Behavioral Assessment Score in the intervention group. One RCT[16] reported better team performance score in the intervention group. Another RCT[17] reported better teamwork in the intervention group.

CPR skill performance in simulation at course completion

One study[21] evaluated CPR fraction as measure of skill and found an improving overall trend per time interval of training.

Resource

We found no studies reporting data on resources.

CPR skill performance in actual resuscitation

For the important outcome of CPR skill performance in actual resuscitation, we found no studies.

Discussion

In this systematic review we found data from RCTs and non-randomised studies showing the effectiveness of in situ simulation CPR training over traditional training towards relevant outcomes, including the critical outcomes of patient survival, patient outcomes, clinical performance in actual resuscitation and teamwork competencies in actual resuscitation. The certainty of evidence is very low for all the evaluated outcomes, due to risk of bias of included studies, inconsistency and imprecision. These considerations are in line with a recent systematic review and *meta*-analysis, not specifically related only to CPR,[5] which concludes that available evidence suggests that adding in situ simulation to other types of training options (including no training) for healthcare workers may be associated with improved patient effect outcomes and clinician behaviors.[5]

The balance between the benefit and the resources needed may favor in situ simulation, especially when critical outcomes are considered. In situ simulation may improve the immersive experience of the learners, and have impact on patient-centered outcomes, as the learner will manage real cases in the same setting where he/she had

received simulated training.[5] Moreover, it can be useful because specific local characteristics (e.g. logistical or human) may be impossible to be simulated in a lab or dedicated room. Alternatively, in situ simulation may be associated with higher workloads, increased time needed for organization of the training course, potential disruption of clinical schedules, and potentially higher direct and indirect costs than traditional training performed in dedicated simulation labs or centers. Although in situ simulation is widely implemented, we found no data from included studies on resources including costs, equipment, time needed, and workload. Moreover, most of the included studies are from the USA and none from low-income countries or low resource settings. Overall, based on available evidence, The EIT Task Force stated that in situ simulation should be considered as an option for CPR training.

Knowledge gaps, research priorities, review limitations

Further research may identify training settings that benefit the most from in situ training. Since we did not perform a *meta*-analysis due to very high heterogeneity in the interventions and outcome definitions, formal subgroup analysis according to the type of cardiopulmonary resuscitation training (i.e. BLS, ACLS, PALS, NLS) could not be done. As the overall risk of bias for the outcomes ranged from serious to very serious, further high-quality research should strengthen the certainty of the evidence (i.e. adequate control for confounding factors in non-randomised studies, adequate randomization process in RCTs). We found no data on the important outcome of resources that includes direct and indirect costs, workload, equipment needed to perform in situ simulation-based cardiopulmonary resuscitation training compared to traditional training. We found high heterogeneity in terms of the characteristics of the interventions, namely simulation methodology (i.e. mock codes vs. longitudinal programs), duration of the training and simulation team composition. Further research should define the minimal standard for in situ simulation and explore characteristics of the training in the setting of cardiopulmonary resuscitation.[4]

Research is needed on resources and methods for implementation and maintenance of in situ simulation programs for resuscitation teaching. Further studies should report data on feasibility in low resource settings and remote areas.[25]

As limitations, we acknowledge that at the early stage of this review, we decided to include only articles clearly reporting information on the training of the control group, and this have led to the exclusion of articles where information was not available. Indeed, we also excluded studies that have no intervention as control. We did not include articles that evaluated the effectiveness of the in situ simulation on self-reported outcomes, knowledge, or on identifying latent safety threats. Thus, the conclusion of this systematic review should not be extrapolated to these aims and outcomes. For the outcomes of patient survival and patient outcome, data from studies in the neonatal and/or pediatric setting only were included. Since there may be important differences in the structure of neonatal, paediatric and adult CPR training, the generalisation of the findings to the adult setting should be done with caution. There are discrepancies about the PROSPERO registration and the final list of outcomes, and the absence of *meta*-analysis and subgroup analysis. However, the EIT Task Force decided to apply this modification to improve data categorization from included studies in meaningful outcome categories and to deal with the very high heterogeneity in interventions, control and outcome definitions from included studies with appropriate narrative synthesis.

Conclusions

The heterogenous evidence suggests that in situ simulation should be considered as an option for CPR training. The overall certainty of evidence is very low, and the cost-benefit balance is uncertain due to lack of data on resources needed to implement and maintain an in situ simulation program.

Authors' contributions

ACo, MI, CAG, SN, AO, KGL, YL, TS, JY, ASL, ACh, RG conceived the content, drafted the manuscript, approved the final version to be submitted. All authors have agreed on the journal to which the article will be submitted, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

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CRediT authorship contribution statement

Andrea Cortegiani: Writing – original draft, Data curation, Conceptualization. **Mariachiara Ippolito:** Writing – original draft, Data curation, Conceptualization. **Cristian Abelairas-Gómez:** Writing – review & editing, Data curation, Conceptualization. **Sabine Nabecker:** Writing – review & editing, Data curation, Conceptualization. **Alexander Olaussen:** Writing – review & editing, Data curation, Conceptualization. **Kasper G. Lauridsen:** Writing – review & editing, Data curation, Conceptualization. **Yiqun Lin:** . **Taylor Sawyer:** Writing – review & editing, Data curation, Conceptualization. **Joyce Yeung:** Writing – review & editing, Data curation, Conceptualization. **Andrew S. Lockey:** Writing – review & editing, Data curation, Conceptualization. **Adam Cheng:** Writing – review & editing, Data curation, Conceptualization. **Robert Greif:** Writing – original draft, Data curation, Conceptualization. **Aaron Donoghue:** . **Barbara Farquharson:** . **Chih-Wei Yang:** . **Heike Geduld:** . **Kathryn Eastwood:** . **Kevin Nation:** . **Sebastian Sch naubelt:** . **Tasuku Matsuyama:** . **Ying-Chih Ko:** . **Katherine S. Allen:** . **Tracy Kidd:** . **Jan Breckwoldt:** . **Ming-Ju Hsieh:** .

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: ACo, MI, CAG, SN, AO, KGL, YL, TS, JY, ASL, ACh, RG are members of the ILCOR EIT Task Force (RG is chair). RG is ERC Director of Guidelines and ILCOR; RG, KGL, JY, ACh are Editorial Board members of Resuscitation Plus.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100863.

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