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Review

Cognitive aids used in simulated resuscitation: A systematic review

Sabine Nabecker[a,], Kevin Nation[b], Elaine Gilfoyle[c], Cristian Abelairas-Gomez[d,e], Elina Koota[f], Yiqun Lin[g], Robert Greif[h,i], on behalf of the Education Implementation Team Task Force of the International Liaison Committee on Resuscitation (ILCOR)*

Abstract

Objectives: To compare the effectiveness of cognitive aid use during resuscitation with no use of cognitive aids on cardiopulmonary resuscitation quality and performance.

Methods: This systematic review followed the PICOST format. All randomised controlled trials and non-randomised studies evaluating cognitive aid use during (simulated) resuscitation were included in any setting. Unpublished studies were excluded. We did not include studies that reported cognitive aid use during training for resuscitation alone. Medline, Embase and Cochrane databases were searched from inception until July 2019 (updated August 2022, November 2023, and 23 April 2024). We did not search trial registries. Title and abstract screening, full-text screening, data extraction, risk of bias assessment (using RoB2 and ROBINS-I), and certainty of evidence (using GRADE) were performed by two researchers. PRISMA reporting standards were followed, and registration (PROSPERO CRD42020159162, version 19 July 2022) was performed. No funding has been obtained.

Results: The literature search identified 5029 citations. After removing 512 duplicates, reviewing the titles and abstracts of the remaining articles yielded 103 articles for full-text review. Hand-searching identified 3 more studies for full-text review. Of these, 29 studies were included in the final analysis. No clinical studies involving patients were identified. The review was limited to indirect evidence from simulation studies only. The results are presented in five different populations: healthcare professionals managing simulated resuscitations in neonates, children, adult advanced life support, and other emergencies; as well as lay providers managing resuscitations. Main outcomes were adherence to protocol or process, adherence to protocol or process assessed by performance score, CPR performance and retention, and feasibility of chatbot guidance. The risk of bias assessment ranged from low to high. Studies in neonatal, paediatric and adult life support delivered by healthcare professionals showed benefits of using cognitive aids, however, some studies evaluating resuscitations by lay providers reported undesirable effects. The performance of a *meta*-analysis was not possible due to significant methodological heterogeneity. The certainty of evidence was rated as moderate to very low due to serious indirectness, (very) serious risk of bias, serious inconsistency and (very) serious imprecision.

Conclusion: Because of the very low certainty evidence from simulation studies, we suggest that cognitive aids should be used by healthcare professionals during resuscitation. In contrast, we do not suggest use of cognitive aids for lay providers, based on low certainty evidence.

Keywords: Cognitive aids, Cardiopulmonary resuscitation, Basic and advanced life support, Simulation, Checklist

Introduction

In the complex management of cardiac arrests or other medical emergencies, medical errors and team dynamics are known major contributors to adverse outcomes.[1] To help mitigate errors, cognitive aids were first widely used in aeronautical professions to improve safety and to reduce the burden of the workload of crewmembers in routine and especially in stressful emergencies.[2] In medicine,

* Corresponding author at: Department of Anesthesiology and Pain Management, Sinai Health System, University of Toronto, 600 University Avenue, M5G 1X5 Toronto, Ontario, Canada.

E-mail address: sabine.nabecker@sinaihealth.ca (S. Nabecker).

@@sabinenabecker (S. Nabecker)

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the importance of cognitive aids was acknowledged as early as 1924.[3] Dr. Babcock suggested that 'a fixed emergency routine, posted on the walls of every operating room and drilled into every member of the staff, should be enforced'.[3] Since then, a wide variety of cognitive aids have been used in medicine in multiple disciplines.

They are used to improve adherence to guidelines, improve performance, and reduce errors.[4] Cognitive aids are supposed to support clinicians during stressful clinical situations by guiding them through a series of complex steps and help prevent omissions of key steps.[5] An ideal cognitive aid should possess content based on current treatment guidelines, and an effective design for use in emergencies, providers should be familiar with the cognitive aid before using it in an emergency, and the cognitive aid should assist the whole team in coordinated task performance.[5]

Cognitive aids can be used in elective situations as well as in emergencies. For example, the use of surgical safety checklists, which are used in an elective situation, and not in an emergency, has been shown to reduce mortality and morbidity of surgical patients.[6–11] In clinical emergencies, cognitive aids showed a reduction in the incidence of missed care steps from 43% to 11% (RR (95% CI) 0.29 (0.15–0.16); p <0.001) with a moderate certainty of evidence.[12] Cognitive aid use also decreased error incidence in clinical emergencies.[12,13]

Resuscitation councils worldwide use cognitive aids for educating their members in the form of algorithms, flowcharts, checklists, posters, digital applications, and other formats. They also recommend indirectly through their publication and directly in their guidelines the use of these cognitive aids during training and in clinical practice.[1,14,15,16] Evidence on the effect of cognitive aid use in resuscitation may lead to improved resuscitation performance and better patient outcomes. However, currently, there is no systematic review available that specifically focuses on the effectiveness of cognitive aid use versus no use of cognitive aids in resuscitation. Therefore, the aim of this systematic review is to compare the effectiveness of cognitive aid use during resuscitation with no use of cognitive aids on cardiopulmonary resuscitation quality and performance.

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). The review was registered at PROSPERO (CRD42020159162, version 19 July 2022). We followed the guidance of the Preferred Reporting Items for a Systematic Review and Meta-Analysis (PRISMA).[17]

The PICOST (Population, Intervention, Comparison, Outcome, Study design, Timeframe) frame specified the research question:

Population: Adults, children and neonates in any setting (in-hospital or out-of-hospital) requiring resuscitation provided by lay providers or health care professionals.

Intervention: The use of cognitive aids during resuscitation.

Comparators: No use of cognitive aids.

Outcomes: Survival to hospital discharge with good neurological outcomes and survival to hospital discharge were ranked as critical outcomes. Quality of performance in actual resuscitations, skill performance 1 year after course conclusion, skill performance between course conclusion and 1 year, skill performance at course conclusion, and knowledge at course conclusion were included as important outcomes. Measures of effect outcomes included adherence to resuscitation guidelines, CPR quality, and test scores.

Study Designs: Randomised controlled trials (RCTs) and non-randomised studies (interrupted time series, controlled before-and-after studies, cohort studies, case reports) were eligible for inclusion. Unpublished studies (e.g., conference abstracts, trial protocols) were excluded.

Timeframe: All years and all languages were included if there was an English abstract. The literature search was updated from inception to 23 April 2024.

In contrast to the PROSPERO registration, we did not include studies that reported cognitive aid use during resuscitation education, due to the number of studies for resuscitation alone. Also, teaching for resuscitation is a different question, therefore the ILCOR EIT task force decided that cognitive aid use during resuscitation education warrants a separate future systematic review. We did not search trial registries. Also, in contrast to the PROSPERO registration, we removed the words "or checklist" from the intervention and comparator, as checklists are one type of cognitive aid, and therefore subsumed under cognitive aids. As specified in the PROSPERO registration main outcomes have been adapted after the registration and after the literature search in discussion with the EIT taskforce. Outcomes presented here reflect what was decided in the ILCOR priority team and EIT task force meetings after identifying what outcomes have been studied. Changes have been made before data extraction.

Definitions

We defined cognitive aid as the "presentation of prompts aimed to encourage recall of information to increase the likelihood of desired behaviours, decisions, and outcomes".[4] We separated the cognitive aids into interactive and non-interactive cognitive aids. Interactive cognitive aids were defined as cognitive aids that provide the user with the opportunity to interact with it in different ways. Data flows bidirectionally from user to cognitive aid and back. Examples of interactive cognitive aids include tablet apps, smartphone apps, audio voice guidance applications, computer-based clinical decision display systems, Personal Digital Assistant apps, augmented reality decision support tools, or a Chatbot. Non-interactive cognitive aids were defined as being static with no possibility to interact. Data flow is single-directional from cognitive aid to user. Examples of non-interactive cognitive aids include posters, checklists, smartphone apps, flowcharts, instruction cards, and tablets with auditory and visual prompts.

Checklists were defined as "a list of action items or criteria arranged systematically, allowing the user to record the presence or absence of the individual items listed, thereby ensuring that all have been considered or completed".[18]

We defined the intervention as the use of cognitive aids (both interactive and non-interactive) during resuscitation.

Eligibility criteria

Studies were included if they investigated adult, paediatric, or neonatal resuscitation in any setting (in-hospital or out-of-hospital) including simulation studies.[5] Studies, that only evaluated cognitive aid use in health care professional or lay provider training were excluded, because the EIT taskforce considers this a topic for a separate systematic review. Providers included were health care profes-

sionals and lay providers. Schoolchildren were excluded. Studies were included if they reported the use of a cognitive aid during resuscitation compared to no use of a cognitive aid.

Information, sources and search strategy

An information specialist hired by ILCOR developed the search strategy, the updated searches were performed by a co-author (YL) on this systematic review using the same search strategy. The databases Medline, Embase, and Cochrane were searched from inception until July 2019, updated August 2022, November 2023, and again updated April 2024. The detailed search strategy can be found in Appendix 1. Additionally, hand-searching of article biographies was performed.

Data extraction

Each title and abstract were screened by SN and EG independently using Covidence (https://www.covidence.org, Veritas Health Innovation Ltd, Melbourne, Australia) to exclude ineligible studies. Disagreements were resolved in consensus between SN and EG or with the advice of another member of the author group or the ILCOR EIT taskforce. Each remaining paper was full-text screened by SN and KN individually. The studies characteristics' and outcomes were subsequently extracted into a spreadsheet by SN and KN (year, country, aim, study design, population, data collection, type of cognitive aid, intervention, comparator, main findings).

Risk of bias assessment

KN and either SN or CAG analyzed the included studies using the 'Risk of Bias 2 (RoB 2) tool'[19] for randomised controlled trials and "risk of bias in non-randomised studies of interventions (ROBINS-I) tool'[20] for non-randomised controlled trials. Any disagreement was resolved by discussion between KN, SN and CAG.

Synthesis method

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology was applied to assess certainty of evidence.[21] We did not attempt to perform a *meta*-analysis because the included studies showed a significant level of methodological heterogeneity. Therefore, we followed the Synthesis Without Meta-Analysis (SWiM) reporting guidelines.[22] Potential subgroup analyses were considered for adult, paediatric and neonatal resuscitations by healthcare professionals, resuscitations by lay providers, and healthcare professionals managing other emergencies.

Results

Study characteristics

The literature search identified 5029 citations. After removing 512 duplicates, titles and abstracts of the remaining 4517 articles were screened. One hundred and three articles for full-text review were identified. Seventy-seven studies were excluded in the full-text review because they did not fulfill the inclusion criteria. Reasons for exclusion were wrong study intervention, wrong comparator, wrong patient/participant population, not a peer-reviewed primary study, wrong study design, wrong outcomes and 1 study was excluded because we were unable to locate the full-text due to missing identifiers in Covidence. Hand-searching article bibliographies led to the inclusion of 3 further studies.[23–25] A total of 29 studies were included in the final analysis. For the flow chart please refer to Fig. 1. The PRISMA checklist can be found in Appendix 2.

Appendix 3 displays the included studies' characteristics, designs, and main outcomes. Table 1 shows an overview of the study characteristics.

We were unable to find studies involving patients, however, all studies included simulated cardiac arrests respective emergencies, which the ILCOR EIT task force valued as surrogates for real resuscitations.[5]

Risk of bias assessment and certainty of evidence

Risk of bias for included individual studies ranged from 'low' to 'high'. The detailed risk of bias assessment tables can be found in Appendix 4. Overall, the included studies varied considerably in methodology used, cognitive aids evaluated, types of outcomes and provider population. For details, please refer to Table 1 and 2. Certainty of evidence was mainly rated as 'very low' (Appendix 5), downgraded for serious indirectness, serious/very serious risk of bias, serious inconsistency, and/or serious/very serious imprecision. One outcome (CPR quality) was rated as low certainty evidence, downgraded for very serious indirectness; and one outcome (feasibility of Chatbot guidance) was rated as moderate certainty evidence downgraded for serious indirectness.

Overview of study outcomes

Table 2 displays a summary of the types of outcomes, the overall findings, as well as the risk of bias assessment for no cognitive aid use compared to cognitive aid use. Since we were unable to identify studies in patients, we did not identify any relevant studies for the critical outcomes of survival to hospital discharge with good neurological outcome, and survival to hospital discharge. The results are divided into five different populations: healtcare professionals managing simulated resuscitations in neonates, children, adult advanced life support, and other emergencies; as well as lay providers managing resuscitations.

Healthcare professionals managing simulated resuscitation in neonates (compare RoB Table 1 in Appendix 4 and Table 2)

For the important outcome of adherence to a protocol or process, we identified very low certainty evidence (downgraded for serious indirectness and serious impression) from 4 studies[26–29] with a total of 89 participants in the intervention groups and 84 participants in the control groups. One study[29], investigating an electronic decision support tool demonstrated improvement in performance scores. One study[27] investigating an audio-visual prompt device demonstrated fewer deviations from a resuscitation algorithm. One study[28] investigating an audio-visual guidance tool demonstrated improved adherence to a resuscitation algorithm and performance to a guideline. And one study[26] investigating a poster of an algorithm demonstrated no difference in performance.

Healthcare professionals managing simulated resuscitation in children (compare RoB Table 2 in Appendix 4 and Table 2)

For the important outcome of CPR quality, we found low certainty evidence from two RCTs.[30,31] One study investigating the use of a checklist by 16 individuals in the intervention and control groups found no difference in CPR performance.[31] One study investigating

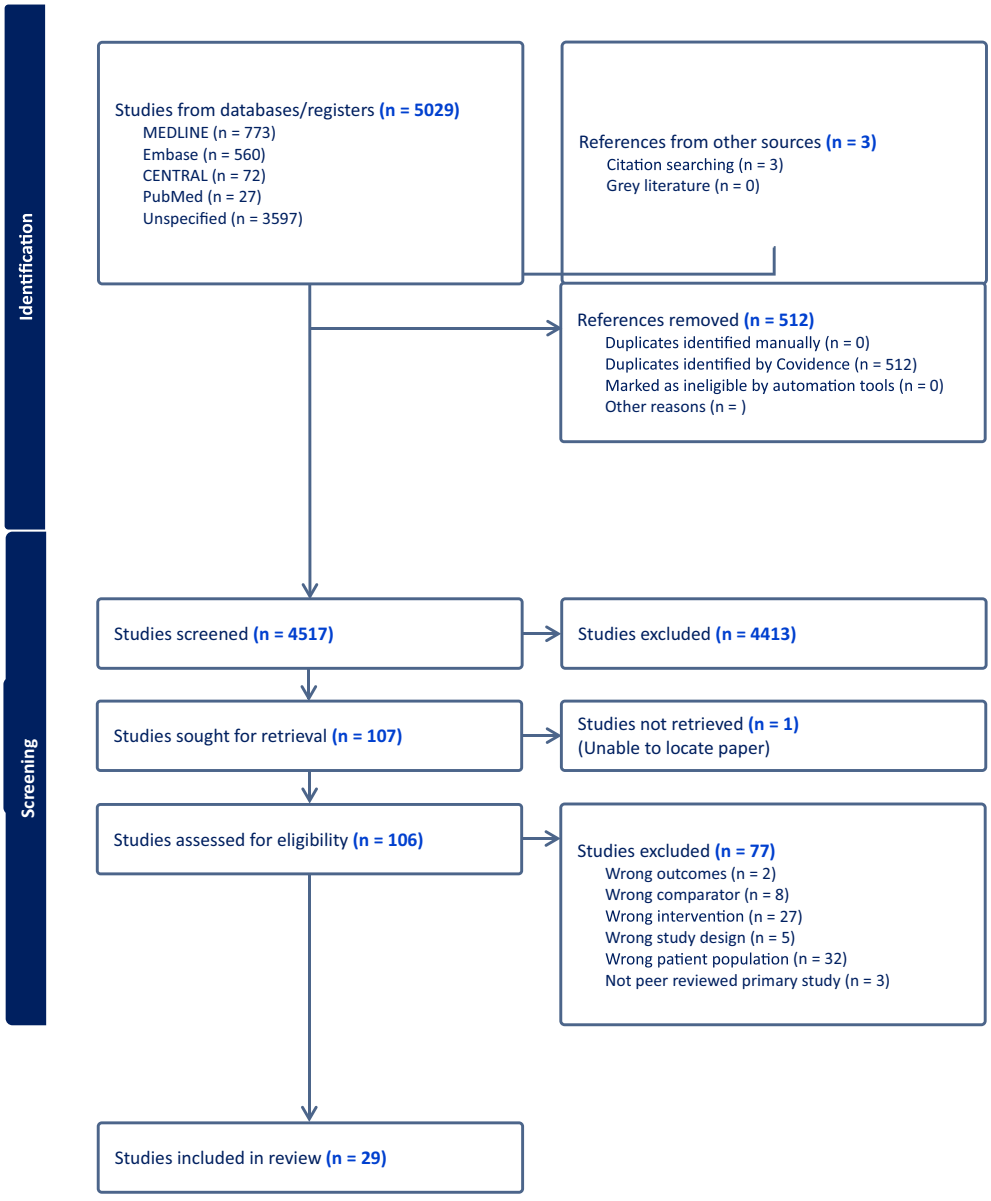

Fig. 1 – Consort flow diagram.

a decision support app with 32 teams in the intervention group and 75 teams in the two control arms also showed no difference in CPR quality metrics.[30]

For the important outcome of adherence to a protocol or process we found very low certainty evidence (downgraded for very serious risk of bias and serious indirectness) from two RCTs.[30,32] One study investigating a computer-based resuscitation tool found improvements in the number of tasks completed with the tool. Other time-relevant interventions showed no benefit.[32] One study investigating a decision support app found significantly fewer deviations from guideline recommendations in the intervention group.[30]

Healthcare professionals managing adult advanced life support (compare RoB Table 3 in Appendix 4 and Table 2)

For the important outcome adherence to a protocol or process, we identified very low certainty evidence (downgraded for very serious risk of bias and serious indirectness and very serious imprecision) from eight RCTs.[23–25,33–37] Four studies[24,33,36,37] investigated the use of interactive smartphone apps. Two of them reported improved performance scores[33,37], two demonstrated significantly improved adherence to correct sequences and reduced errors of commission.[24,36].

One study using an interactive computer prompt device demonstrated little difference in performance between the intervention and control group in managing familiar algorithms but improved performance in the intervention group when managing less familiar protocols.[23].

Another study using an interactive large-screen clinical decision display system demonstrated several interventions performed closer to ACLS® recommendations.[34] Two studies[25,35] investigated the use of interactive tablet apps. One study[35] showed improved performance scores in the intervention group. One study[25] showed variable results between the intervention and control groups.

Table 1 – Cognitive aid use in resuscitation – a systematic review: Overview study characteristics.

Years of publication	1995–2023
Countries of studies	**Europe** (5 Germany[35,38,39,45,47], 2 United Kingdom[25,37], 2 Austria[44,49], 1 The Netherlands[29], 1 Italy[30], 1 France[31], 1 Sweden[40], 1 Ireland[43], 1 Spain[50]) **North America** (9 USA[13,23,24,27,32,34,36,41,48], 2 Canada[26,33]) **Middle East** (1 Israel[28]) **Asia** (1 Korea[42], 1 China[46])
Population	Healthcare professionals managing neonatal resuscitations (n = 4)[26–29] Healthcare professionals managing paediatric resuscitations (n = 3)[30–32] Healthcare professionals managing adult advanced life support (n = 8)[23–25,33–37] Healthcare professionals managing other emergencies (n = 5)[13,38–41] Lay provider managing resuscitations(n = 9)[42–50]
Non-interactive cognitive aids (n = 12)[13,26,27,31,38–42,44,46,49]	Poster (n = 1)[26] Tablet with auditory and visual prompts (n = 1)[27] Checklist (n = 6)[13,31,38–41] Smartphone app (n = 2)[42,44] Flowchart (n = 1)[49] Instruction card (n = 1)[46]
Interactive cognitive aids (n = 17)[23–25,28–37,43,45,47,48,50]	Audio voice guidance app (n = 1)[28] Augmented reality decision support tool (n = 1)[29] Tablet app (n = 4)[24,25,30,35] Personal digital assistant app (n = 3)[32,47,48] Smartphone app (n = 5)[33,36,37,43,45] Computer-based clinical decision display system (n = 2)[23,34] Chatbot (n = 1)[50]

n = number of studies.

Table 2 – Cognitive aid use in resuscitation – a systematic review: Overview of the types of outcomes, the overall findings, risk of bias (RoB) assessments for no cognitive aid use compared to cognitive aid use (primary outcomes).

Types of Outcome	Population	Number of studies	Neutral	In favour of no cognitive aid	In favour of cognitive aid	Risk of Bias of single studies
Adherence to protocol or process	Neonates	4[26–29]	1[26]	–	3[27–29]	Low[26,28] High[27,29]
	Paediatric	2[30,32]	–	–	2[30,32]	High[30,32]
	Adult Advanced Life Support	8[23–25,33–37]	1[25]	–	7[23,24,33–37]	Low[33,36] High[23–25,34,35,37]
	Other emergencies	4[13,38–40]	–	–	4[13,38–40]	Low[39] High[13,38,40]
	Lay provider	1[47]	–	–	1[47]	Low[47]
Adherence to protocol or process assessed by performance score	Lay provider	5[42–46]	1[45]	–	4[42–44,46]	Low[42,45] High[43,44,46]
CPR quality	Paediatric	2[30,31]	2[30,31]	–	–	Low[31] High[30]
	Other emergencies	1[41]	1[41]	–	–	High[41]
	Lay provider	3[44,48,49]	–	3[44,48,49]	2[48,49]	High[44,48,49]
CPR performance and retention	Other emergencies	1[41]	–	–	1[41]	High[41]
Feasibility of chatbot guidance	Lay provider	1[50]	1[50]	–	–	Low[50]

Healthcare professionals managing other emergencies related to resuscitation (compare RoB Table 4 in Appendix 4 and Table 2)

For the important outcome of adherence to a protocol or process, we identified very low certainty evidence (downgraded for very serious risk of bias and serious imprecision) from four RCT.[13,38–40] Two studies[13,38] with a total of 79 participants in each of the intervention and control groups demonstrated highly significant increases in average performance scores[38] and reduced failure to adhere to critical steps.[13] Two studies[39,40] with 607 participants in 85 teams in the intervention and 95 teams in control groups demonstrated that using a medical emergency checklist resulted in 9% absolute and 15% relative risk reduction of failure to adhere to guideline-adherent critical process steps. All teams had a lower failure rate for adherence to key

processes with the intervention.[39] With a checklist, the intervention groups had significantly shorter time to adequate administration of glucose in hypoglycemia (median times 632 s with checklist, 756 s without checklist, p = 0.03) but did not shorten the time to performance of the other nine emergency interventions. Access to crisis checklists had no impact on whether emergency interventions were carried out or not.[40].

For the important outcome CPR performance and retention, we identified very low certainty evidence (downgraded for very serious risk of bias, serious indirectness and serious imprecision) from one RCT[41] indicating long checklists superior to short checklists or no checklist for overall performance on procedural variables but not for CPR quality.[41]

Lay providers delivering resuscitation (compare RoB Table 5 in Appendix 4 and Table 2)

For the important outcome of adherence to a protocol or process assessed by a performance score, we identified very low certainty evidence (downgraded for very serious risk of bias, serious inconsistency and very serious impression) from five RCTs.[42–46] Three studies[42–44] investigating the use of mobile phone applications, demonstrated improved adherence to a process measured using a checklist or performance score. One study[45] investigating a mobile phone application using yes/no questions found no significant improvement. One study investigating the use of an instruction card by individuals found improved adherence to the sequence of AED use and improved time to shock.[46]

For the important outcome of adherence to a protocol or process (assessed with an Objective Structured Clinical Examination (OSCE) score), we found low certainty evidence (downgraded for very serious indirectness) from one observational study[47]. Investigating the use of speech recognition software on a personal digital assistant device the study demonstrated improved OSCE points scores.[47]

For the important outcome of quality of CPR we identified very low certainty evidence (downgraded for very serious risk of bias, serious inconsistency and serious indirectness) from two RCTs.[48,49] One study[48] investigating the use of a voice-activated visual and auditory-assisted decision device demonstrated improved adherence to a 30:2 CPR ratio. One study[49] investigating the use of a flowchart demonstrated reduced hands-off time during CPR.

We identified moderate certainty evidence (downgraded for serious indirectness) from one observational study[50] investigating the feasibility of Chatbot guidance which demonstrated thirty-three percent of participants achieved high-quality CPR, 86% achieved quality chest release, 38% did so in depth of compressions and only 5% in compression rate. Twenty-four percent achieved a mean depth between 50 and 60 mm and 62% achieved a mean rate between 100 and 120 compressions/min.[50].

We found very low certainty evidence from three studies[44,48,49] involving lay providers with a total of 255 participants that demonstrated potentially undesirable effects. Two RCTs[48,49] identified significant increases in time to commencing chest compressions. One RCT[44] found delays in calling emergency services and delays in commencing chest compressions.

Discussion

Cognitive aids are widely used in medicine to improve patient care, improve adherence to guidelines, improve performance, and reduce errors.[4] Their effectiveness in reducing errors in elective situations[11] as well as in clinical emergencies has[12,13] been demonstrated, whereas in other clinical situations, results remain inconclusive.[5] Resuscitation councils worldwide produce cognitive aids and recommend their use in education and clinical practice, even though their effectiveness in cardiopulmonary resuscitation to improve patient outcome and/or provider performance has not been conclusively proven. In this systematic review, we identified 29 studies in five different populations populations (healthcare professionals providing resuscitation for neonates, children, adult advanced live support, other emergencies related to resuscitation, and lay providers providing resuscitation). All included studies evaluate cognitive aid use in simulated cardiac arrests, which the ILCOR EIT task force validated as a surrogate for real cardiac arrests. With very low certainty evidence from simulation studies, cognitive aids should be used by healthcare professionals during resuscitation, but not by lay providers (low certainty evidence).

Because we were unable to identify relevant outcomes for the critical outcomes of survival to hospital discharge with good neurological outcome, and survival to hospital discharge in patients sustaining cardiac arrest, we were unable to determine if cognitive aids are effective in improving patient outcomes. Additionally, it is unclear whether cognitive aid use during resuscitation improves provider performance during actual resuscitations, as no evidence has been found for the use of cognitive aids by trained healthcare professionals or lay providers during actual cardiac arrests. However, since simulated cardiac arrests can be seen as surrogates for actual cardiac arrests[5], evidence from this systematic review might still be transferrable to the clinical setting.

In cardiac arrest situations where healthcare professionals are present, there is consistent evidence in favour of cognitive aid use during resuscitation, however, in cardiac arrest situations where lay providers manage the arrest, there is consistent evidence that there are potentially clinically important delays in initiating CPR when using a cognitive aid.[44,48,49] Also, delays in calling emergency services have been observed.[44] Therefore we recommend differentiating between healthcare professionals and lay providers, and conclude that with very low certainty evidence, cognitive aids should be used by healthcare professionals during resuscitation, but not by lay providers (low certainty evidence) to avoid probable adverse effects on patient outcomes.

In this systematic review, we have included both interactive and non-interactive cognitive aids and summarized them as one entity. Interactive cognitive aids might perform differently than non-interactive cognitive aids. We cannot comment on the difference in performance between use of interactive and non-interactive cognitive aids, since there is such a heterogeneity between cognitive aids used, there is a risk of bias with this approach.

The ILCOR Education Implementation and Team (EIT) taskforce has previously considered the trauma resuscitation environment as being sufficiently similar to the cardiopulmonary resuscitation environment to extrapolate evidence, which shows that trauma resuscitation teams better adhere to resuscitation guidelines, make fewer errors and perform key clinical tasks more frequently while using cognitive aids.[51,52] Due to the recent sufficient new studies addressing the use of cognitive aids in resuscitation, albeit in a simulated environment, the ILCOR EIT taskforce decided to exclude trauma studies from this review. The decision has been made after discussion because there may be important differences between cardiac arrest management and trauma management.

Several studies included in this systematic review used composite scores as their primary outcome (e.g., scores calculated based on the completion of multiple clinical tasks). We have decided to include these outcomes in the review, however, because of their high heterogeneity, it was impossible to compare and consolidate the results. These outcomes can be found in Appendix 3.

Limitations of the systematic review, knowledge gaps, and future research

This systematic review was limited to the use of cognitive aids in healthcare professionals and lay providers during cardiopulmonary resuscitation. We did not examine the use of cognitive aids in training in cardiopulmonary resuscitation for healthcare professionals and/or lay providers. This aspect will be examined separately in the future.

The most crucial limitation of the results of this review is that no study was identified looking at real-life resuscitations, therefore simulated cardiac arrests were used as surrogates for real cardiac arrest to issue the recommendations. Therefore, there is an urgent need for adequately powered studies investigating the impact of cognitive aid use during real-life resuscitations and on patient survival and other outcomes. Due to the high heterogeneity of methodological approaches, we deemed it impossible to perform a *meta*-analysis. Interactive and non-interactive cognitive aids were analyzed together as one entity, and not separately.

Currently, there is worldwide increase in new technology in the form of Artificial Intelligence. In this review, we have included one observational study evaluating the feasibility of Chatbot guidance in lay providers.[50] We consider this the first study of this kind published. Future updates will need to look at new technologies used increasingly as cognitive aids in various circumstances.

Most studies included in this review were performed either in Europe or North America in middle to high-income countries. Studies performed in other regions of the world, and in low-resource settings are necessary to determine if there are differences in performance while using cognitive aids.

Further studies need to investigate effective implementation strategies of cognitive aids during training, simulated cardiac arrest and real-life resuscitation efforts for healthcare professinals and lay providers. It is also crucial to perform cost-effectiveness studies on cognitive aid use during resuscitation and training, as development cost might be an issue, and to investigate which cognitive aids are more effective than others. While we have not included studies looking specifically at cognitive aid use during healthcare professional and lay provider cardiopulmonary resuscitation training, there is a need for further studies in this area.

Conclusion

This systematic review assessed cognitive aid use during resuscitation – using simulation studies as a surrogate of resuscitation in real life, and found very low certainty evidence from simulation studies. Therefore, we suggest that healthcare professionals should use cognitive aids during adult, paediatric and neonatal resuscitations as well as during management of other emergencies related to resuscitation. However, because of potential adverse effects (delay in starting chest compressions) lay providers should not use cognitive aids when initiating cardiopulmonary resuscitation. As we did not examine the use of cognitive aids in health care professional or lay provider training, we cannot recommend for or against the use of cognitive aids during training.

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CRediT authorship contribution statement

Sabine Nabecker: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Kevin Nation:** Writing – review & editing, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Elaine Gilfoyle:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Cristian Abelairas-Gomez:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Elina Koota:** Writing – review & editing, Visualization, Validation, Supervision, Methodology. **Yiqun Lin:** Writing – review & editing, Supervision, Data curation. **Robert Greif:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: SN, KN, CAG, EK, and RG are members of the ILCOR EIT Task Force (RG is chair). RG is ERC Director of Guidelines and ILCOR, RG is Editorial Board member of Resuscitation Plus.

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Appendix A. Supplementary data

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Author details

on behalf of the Education Implementation Team Task Force of the International Liaison Committee on Resuscitation (ILCOR) [a]*Department of Anesthesiology and Pain Management, Sinai Health System, University of Toronto, Toronto, Canada* [b]*New Zealand Resuscitation Council, Wellington, New Zealand* [c]*Department of Critical Care Medicine, The Hospital for Sick Children, Toronto, Canada* [d]*Faculty of Education Sciences and CLINURSID Research Group, Universidade de Santiago de Compostela, Santiago de Compostela, Spain* [e]*Simulation and Intensive Care Unit of Santiago (SICRUS) Research Group, Health Research Institute of Santiago, University Hospital of Santiago de Compostela-CHUS, Santiago de Compostela, Spain* [f]*HUS Joint Resources, Helsinki University Hospital, University of Helsinki, Helsinki, Finland* [g]*KidSIM Simulation Education and Research Program, Alberta Children's Hospital, University of Calgary, Calgary, Alberta, Canada* [h]*University of Bern, Bern, Switzerland* [i]*Department of Surgical Science, University of Torino, Torino, Italy*

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