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Review

Efficiency of two-member crews in delivering prehospital advanced life support cardiopulmonary resuscitation: A scoping review

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Abstract

Background: Advanced Life Support (ALS) during cardiopulmonary resuscitation (CPR) for out-of-hospital cardiac arrest (OHCA) is frequently administered by two-member crews. However, ALS CPR is mostly designed for larger crews, and the feasibility and efficacy of implementing ALS guidelines for only two rescuers remain unclear.

Objective: This scoping review aims to examine the existing evidence and identify knowledge gaps in the efficiency of pre-hospital ALS CPR performed by two-member teams.

Design: A comprehensive search was undertaken across the following databases: PubMed, Web of Science, SCOPUS, Cochrane Library Trials, and ClinicalTrials.gov. The search covered publications in English or German from January 1, 2005, to November 30, 2023. The review included studies that focused on ALS CPR procedures carried out by two-member teams in adult patients in either simulated or clinical settings.

Results: A total of 22 articles were included in the qualitative synthesis. Seven topics in two-person prehospital ALS/CPR delivery were identified: 1) effect of team configuration on clinical outcome and CPR quality, 2) early airway management and ventilation techniques, 3) mechanical chest compressions, 4) prefilled syringes, 5) additional equipment, 6) adaptation of recommended ALS/CPR protocols, and 7) human factors.

Conclusion: There is a lack of comprehensive data regarding the adaptation of the recommended ALS algorithm in CPR for two-member crews. Although simulation studies indicate potential benefits arising from the employment of mechanical chest compression devices, prefilled syringes, and automation-assisted protocols, the current evidence is too limited to support specific modifications to existing guidelines.

Keywords: Advanced life support, Cardiopulmonary resuscitation, Out-of-hospital cardiac arrest, Two-member team, Crew size, Emergency medical service

Introduction

The early start of high-quality Advanced Life Support (ALS) has been shown to increase the incidence of return of spontaneous circulation (ROSC) and survival to hospital discharge after out-of-hospital cardiac arrest (OHCA).[1] It is often administered by two-member ambulance crews as the first responders in diverse pre-hospital emergency care (PHEC) systems.[2] However, for such small teams, adhering to high-performance ALS protocols during the initial stages of CPR presents a significant challenge[3] and, for example, ALS section of European Resuscitation Council (ERC) Guidelines for Resuscitation is typically designed with unspecified, though usually larger, teams in mind who can share the workload.[4]

The ALS algorithm in ERC Guidelines differentiates its treatment priorities based on whether the OHCA presents with a shockable or

Abbreviations: AED, automated external defibrillator, ALS, advanced life support, BLS, basic life support, BMV, bag mask ventilation, CCF, chest compression fraction, CPR, cardiopulmonary resuscitation, EMS, emergency medical services, HEMS, helicopter emergency medical services, LMA, laryngeal mask airway, OHCA, out-of-hospital cardiac arrest, PHEC, pre-hospital emergency care, ROSC, return of spontaneous circulation

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non-shockable initial rhythm.[4] For a two-person team, significant difficulties arise in applying ALS during CPR mostly due to advanced airway management and drug preparation and administration.[3] Given that the ALS algorithm in the ERC Guidelines[4] comprises several procedures, it becomes challenging for a two-person team to prioritize actions, since performing multiple tasks simultaneously, as larger teams do, is difficult.

Previous simulation studies have examined the feasibility of adapting the ALS algorithm for CPR delivered by two-person teams in helicopter emergency medical services (HEMS)[5] and military settings.[6] There is also sporadic data on the use of mechanical chest compression devices[7,8] and supraglottic airway devices [9,10] during ALS CPR by two member crew, but these interventions were not primarily intended to free the hands of the pair of rescuers. Also, other aspects such as human factors[11] including equipment ergonomics[12] or automation-assisted protocols[13] are understudied, as trials tend to focus more on patient-centred outcomes.[14,15] However, despite its practical importance in the initial CPR phase until a larger crew has gathered on-site, the implementation of ALS protocols[4] for two professional rescuers is not covered in current research directions.[16]

It could be hypothesized that in pre-hospital emergency settings where human resources are limited, modifications to ALS guidelines aimed at freeing the hands of rescuers could improve the quality of ALS CPR and, potentially, patient outcomes.

The aim of this scoping review is to synthetise and critically appraise the existing evidence in the field and also identify knowledge gaps in research on ALS provided by two-member teams.

Methods

The scoping review was conducted in accordance with the Joanna Briggs Institute methodology for scoping reviews[17] and adhered to the Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols extension for Scoping Reviews (PRISMA-ScR).[18] The objectives, inclusion criteria, and methods were defined and detailed a priori in a protocol. This protocol was collaboratively revised by the academic research team members (DP, MK, MR, RS) and prospectively registered with the Open Science Framework (OSF) on September 1, 2023.[19] No ethical approval was required for this study.

Studies published between January 1, 2005, and November 30, 2023, were included as the resuscitation guidelines stated the 30 compressions to 2 rescue breaths ratio in the year 2005. The selection criteria for the studies were determined using PICOS framework, formulated as follows. **Population**: Two-member teams performing ALS CPR in out-of-hospital setting. **Intervention:** Any specific strategy to deliver ALS CPR by two-member teams to adult patients (18 years and older, adult patient simulations) in cardiac arrest with both shockable and non-shockable rhythms. **Comparison:** Any type of comparisons was assessed, including no comparison. **Outcome:** Any type of outcomes was assessed (clinical or simulated). **Study design**: No limitations to type of research (qualitative or quantitative), study design (randomised, observational, retrospective) or setting (clinical or simulated).

Excluded from this review were studies focusing on cardiac arrest in children, studies evaluating very specific circumstances (e.g., CPR during patient transportation, aviation or spaceflight, maritime settings, sports events, etc.) and studies with outcomes or study focus other than performing ALS procedures. While case reports, letters to the editor, correspondences, editorials, conference abstracts, systematic reviews, guidelines, and trial protocols were referenced for secondary sources, they were not included in the analysis.

The initial search was conducted in PubMed and Web of Science to establish keywords and a search strategy. Subsequent searches encompassed databases such as PubMed, Web of Science, Scopus, and the Cochrane Library Trials, along with the ClinicalTrials.gov register to identify potentially relevant papers, including published trial protocols. A secondary reference search was conducted from all the selected papers. The full search strategy for these databases, as revised by a university librarian, is presented in Appendix A. The results of the database search were exported to Zotero (an open-source research tool, Corporation for Digital Scholarship, USA, zotero.org) for duplicate removal.

Titles and abstracts were independently screened by two reviewers (MK and RS) against the inclusion and exclusion criteria (agreement in 93.1%, Cohen's kappa 0.76). If there was no agreement on inclusion of selected articles, discrepancies were resolved through discussion with a third reviewer (DP) and frequently needed examination of full-texts. Subsequently, full-text articles were downloaded and thoroughly assessed by the same reviewers. Reasons for exclusion at the full-text assessment stage (Cohen's kappa 1.0) included the provision of CPR only within BLS, more than only two crew members, or data deemed irrelevant by the reviewers. Details of the data extraction process can be found in Appendix B. Outcomes were not pre-defined, and extracted data included information about study populations, methods, and outcomes relevant to the scoping review.

Content analysis from found sources of evidence was performed. The extracted data was subsequently grouped into categories depending on the topic. A narrative approach was employed to address the research question.

Results

Selection of sources of evidence

The initial search yielded 216 articles. Following the removal of duplicates and screening of abstracts, 33 full-text articles were assessed for eligibility with 22 full-text papers retrieved for the final analysis. The selection process is detailed in the PRISMA-ScR flow diagram (Fig. 1).

Characteristics of sources of evidence

The included studies predominantly featured simulation data ($n = 21$) alongside one pre-hospital clinical study ($n = 1$). Quantitative methods were employed in nineteen articles, while three utilized mixed methods. None of the studies used solely qualitative methods. The designs and main subjects of these studies are summarized in Table 1. Twelve studies explicitly stated a focus on two-member teams in their titles or objectives (marked with asterisk in Table 1). The remaining studies incorporated two-member teams as part of their methodology to address various objectives. Detailed information on each article, including the rescuer population, sample size (rescuers or patients), context, relevant outcomes, and key findings, is summarized in Table 2.

Synthesis of results

The studies were classified into seven coding categories based on content analysis, with some studies fitting into multiple categories. These categories were further divided into subgroups (Table 3).

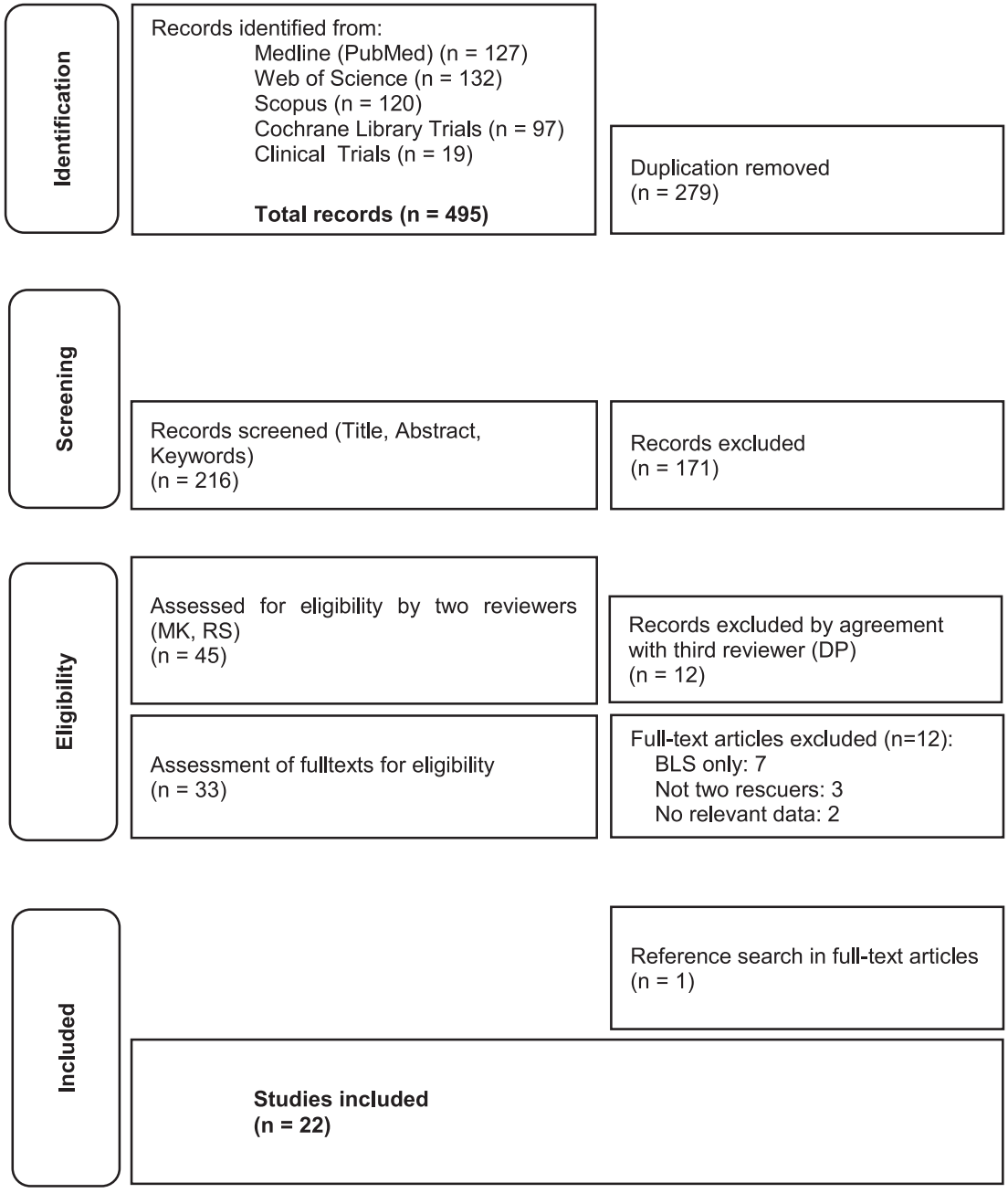

Fig. 1 – PRISMA Flow Diagram for the scoping review proces.

Team configuration and CPR quality

One and five studies investigated **the effect of ALS team configuration on clinical outcome and quality of CPR respectively.**[14,20–24] Five of these examined the effects of team size. [14,20–23] One retrospective clinical study involving 10 057 OHCA patients found that having more than two paramedics at the scene did not improve survival to hospital discharge (2 paramedics – 8.7%, 3 paramedics – 8.7%, ≥4 paramedics – 8.4%, $p = 0.88$).[14] Several simulation studies demonstrated superior CPR quality (chest compression quality and fraction) in teams larger than two, along with a more efficient achievement of critical CPR endpoints such as rhythm recognition, adrenaline administration, and tracheal intubation.[20–22] No significant difference in the no-flow fraction was observed between teams of two, three, and four paramedic students in one simulated ALS/CPR study.[23] One study comparing team compositions found that teams of two paramedics were more prone to errors and generally slower in most interventions (except for tracheal intubation), compared to paramedic-emergency medical technician (EMT) teams.[24]

Early airway management and ventilation

Another five simulation studies examined **the efficacy of early airway management and patient ventilation** by two-member crews.[5,6,9,25,26] In a cross over study of two member teams the asynchronous patient ventilation during continuous chest compressions with a LMA inserted by a physician resulted in higher tidal volumes and ventilation frequencies than recommended compared to asynchronous face mask ventilation.[25] Other four works found were feasibility studies of securing the airway in a two-member team without

Table 1 – Characteristics of sources evidence.

Author and year	Country	Design	Method	Type	Main topic
Asselin (2018)[11]	USA	Randomized, controlled	Mixed methods	Simulation	Workload and physical exertion
Bayley (2008)[24] *	USA	Two group design	Quantitative	Simulation	Team configuration
Brucke (2007)[5] *	Germany	Feasibility study	Quantitative	Simulation	Protocol adaptation
Choi (2016)[13]	USA	Randomized, controlled	Quantitative	Simulation	Protocol adaptation
Dundar (2021)[25]	Turkey	Randomized, cross-over	Quantitative	Simulation	Airway management
Eschmann (2009)[14] *	USA	Retrospective observation	Quantitative	Clinical	Team configuration
Guyette (2006)[9]	USA	Feasibility study	Quantitative	Simulation	Protocol adaptation
Harari (2020)[12]	Israel	Experiment, observation	Mixed methods	Simulation	Workload and physical exertion
Kern (2010)[31]	USA	Randomized, controlled	Quantitative	Simulation	Protocol adaptation
Klosiewicsz (2020A)[7] *	Poland	Randomized, cross-over	Quantitative	Simulation	Mechanical CC
Klosiewicsz (2020B)[8] *	Poland	Randomized, cross-over	Quantitative	Simulation	Mechanical CC
Krzyzanowski (2021)[21] *	Poland	Randomized, controlled	Quantitative	Simulation	Team configuration
Martin-Gill (2010)[23] *	USA	Randomized, controlled	Quantitative	Simulation	Team configuration
Nitzschke (2017)[32]	Germany	Randomized, controlled	Quantitative	Simulation	Additional equipment
Robak (2020)[27] *	Poland	Randomized, controlled	Quantitative	Simulation	Prefilled syringes
Robakowska (2022)[22] *	Poland	Randomized, controlled	Quantitative	Simulation	Team configuration
Siebers (2009)[26]	Germany	Feasibility study	Quantitative	Simulation	Airway management
Tsai (2020)[20] *	Taiwan	Randomized, multiple group	Mixed methods	Simulation	Team configuration
Ventzke (2011)[6] *	Germany	Feasibility, two group	Quantitative	Simulation	Airway management
Zalewski (2020A)[28]	Poland	Randomized, cross-over	Quantitative	Simulation	Airway management
Zalewski (2020B)[30]	Poland	Randomized, cross-over	Quantitative	Simulation	Prefilled syringes
Zalewski (2020C)[29] *	Poland	Randomized, cross-over	Quantitative	Simulation	Prefilled syringes

Legend: Studies in which the evaluation of two-member teams was declared in the title or the study aims are marked with an asterisk. CC, chest compressions.

further comparison.[5,6,9,26] Basic EMTs achieved a 78% success rate in LMA insertion during CPR in one feasibility study.[9] Another feasibility study showed that paramedics and physicians secured airways with a laryngeal tube in an average of 17 s with a 75% success rate on the first attempt and 100% on the second attempt.[6] Another study recorded tracheal intubation attempts by EMTs and paramedics, noting an average duration of 82 ± 27 s and a 70% success rate on the first attempt, while the no-flow fraction was high (41.7 ± 6.7%).[26] A feasibility study on HEMS teams tested a modified ALS/CPR algorithm focusing on early tracheal intubation before rhythm check, finding it feasible with acceptable chest compression and ventilation quality, though the time to first shock was not mentioned.[5]

Mechanical chest compressions

Three simulation studies investigated **the use of mechanical chest compression devices** by two-member teams.[7,8,13] An experimental automation-assisted ALS/CPR protocol study showed improved chest compression depth and a reduction in inadequate chest compressions.[13] Two simulation studies found that mechanical chest compressions enhanced the quality of chest compressions and improved adherence to ALS guidelines, with the earlier achievement of resuscitation goals.[7,8]

Pre-filled syringes

Three simulation studies in two-member ALS teams focused on the effect of using **pre-filled syringes** with medication.[27–29] All three studies reported reduced time to adrenaline administration[27–29], while two noted a shorter time to intravenous or intraosseous access.[27,29] One study found a higher chest compression fraction and quicker airway management.[28]

Additional equipment

Four simulation studies evaluated **the use of additional equipment** in two-member teams of rescuers.[9,30–32] One study found that adhesive defibrillation electrodes improved chest compression quality and electrotherapy application speed.[30] A feasibility study demonstrated a 94% first-pass success rate of intraosseous access by EMTs.[9] Another study indicated less variance in chest compression and ventilation rates with metronome use.[31] A prototype resuscitation assist device (AED, ventilator, and ALS instructions) did not overall improve hands-off time but negatively impacted CPR quality in highly trained two-provider teams.[32]

Adaptations of protocol

Two simulation studies explored **adaptations to the ALS/CPR protocol** in case of two ALS providers.[11,13] An experimental automation-assisted, goal-directed OHCA protocol (including mechanical chest compressions, AED, ventilator, supraglottic airway devices, and early intraosseous access) used by EMTs resulted in improved chest compression depth, higher minute ventilation, and more appropriate medication administration.[13] This protocol also reduced physical exertion and perceived workload in another study.[11]

Workload and physical exertion

A simulation study focusing on **workload and physical exertion** in two-member crew found that the placement of the equipment bag around the patient during simulated OHCA affected CPR quality, work efficiency, effort, and biomechanical loads.[12]

Discussion

This scoping review reveals a significant shortfall in the evidence required to develop a comprehensive ALS protocol tailored to the unique dynamics of two-member (ambulance) crews. The evidence found is not sufficiently robust to formulate recommendations for informing training, protocols, or equipment choices. Published studies suggest that certain interventions, such as the implementation

Table 2 – Results of individual source of evidence.

Author and year of publication	Population and sample size (rescuers / patients)	Context	Outcomes relevant to the review	Findings
Asselin (2018)[11]	EMTs (*n* = 40)	Experimental protocol	Physical exertion and workload	Experimental approach: reduced physician exertion and lower workload
Bayley (2008)[24]	EMTs and paramedics (*n* = 60)	ALS/CPR by different crew configurations	Errors, time to critical interventions, compliance with continuous CPR	Paramedic-paramedic crews: significantly more errors than paramedic-EMT crews. Most interventions not performed more rapidly with the exception of TI.
Brucke (2007)[5]	Physicians and paramedics (*n* = 40)	Early TI during ALS/CPR. Feasibility study.	No-flow time, CC quality	Algorithm with early TI proved feasible in manikin setting.
Choi (2016)[13]	EMTs (*n* = 40)	ALS/CPR using automation assisted protocol	CC quality, defibrillation quality, airway securing, medication.	Automation assisted protocol: improved quality of CCs, ventilation and medication administration.
Dundar (2021)[25]	Physicians (*n* = 92)	LMA versus asynchronous BVM ventilation during ALS/CPR	Primary: Ventilation quality measuresSecondary: CC quality measures	Asynchronous ventilations by BVM compared to asynchronous ventilations by LMA: lower quality of but still sufficient ventilation.
Eschmann (2010)[14]	EMTs and paramedics. (*n* = 10057 patients)	Retrospective database review.	Primary: Survival to hospital dischargeSecondary: ROSC, survival to hospital admission, time to defibrillation	Three or more paramedics in team during OHCA: not associated with improved survival to hospital discharge as compared to crews of two paramedics.
Guyette (2006)[9]	EMTs (*n* = 18)	Advanced resuscitation interventions by EMTs.	Time to critical interventions	EMTs were able to initiate use of LMA and IO access in a simulated cardiac arrest.
Harari (2020)[12]	Paramedics (*n* = 24)	Equipment positioning during ALS/CPR	Quality measures of CPR, work efficiency measures, physiological effects, ergonomic assessments.	Positions of the equipment around the patient during OHCA affect CPR quality and measures of paramedic's work efficiency, effort, and biomechanical loads.
Kern (2010)[31]	EMTs (*n* = 68)	Metronome use during ALS/CPR	CC rate, ventilation rate	Metronome group: significantly better CC rate, less rate variance.
Klosiewicsz (2020A)[7]	Paramedics (*n* = 104)	Mechanical CC during ALS/CPR	CC quality	Use of mechanical CC device increased CC quality measures
Klosiewicsz (2020B)[8]	Paramedics (*n* = 104)	Mechanical CC during ALS/CPR	Intervals between rhythm checks, duration of rhythm check, time to medication	Use of mechanical CC device: improved adherence to ALS protocol and earlier achievement of resuscitation endpoints.
Krzyzanowski (2021)[21]	Paramedics (*n* = 463)	Team size comparison	Time to critical interventions, CC quality measures, medication errors	Three-member teams: faster times to critical interventions, higher CC quality, less medication errors.
Martin-Gill (2010)[23]	Paramedic students (*n* = 40)	Team size comparison	No-flow fraction	No significant difference in no-flow fraction between 2-, 3- and 3-member teams.
Nitzschke (2017)[32]	EMTs and paramedic (*n* = 112)	ALS/CPR using prototype CPR assist device	Primary: Hands-off timeSecondary: CC quality, ventilation quality. Correct medications, time to critical interventions	No difference in the hands-off time when using prototype CPR assist device compared to standard equipment.
Robak (2020)[27]	Paramedics (*n* = 40)	ALS/CPR with pre-filled medication syringes	Time to critical interventions	The use of pre-filled adrenaline syringes: shorter time to intraosseous access, shorter time to adrenaline.
Robakowska (2022)[22]	Paramedics (*n* = 463)	Team size comparison	CC quality, time to critical interventions	3-member teams: critical interventions faster, quality of CC comparable.
Siebers (2009)[26]	EMTs and paramedics (*n* = 104)	Early TI during ALS/CPR	CC interruptions. No-flow time. TI success rate.	Early TI: increased no-flow time, higher TI failure rate by not well-trained personnel.
Tsai (2020)[20]	Paramedics (*n* = 140)	Team size comparison	CC fraction, time to critical interventions, quality of team performance	CC fraction improved as team size increased. Shorter times to critical interventions with larger teams.

(*continued on next page*)

Table 2 (continued)

Author and year of publication	Population and sample size (rescuers / patients)	Context	Outcomes relevant to the review	Findings
Ventzke (2011)[6]	Physicians and paramedics (*n* = 40)	Early laryngeal tube insertion and over-the-head CC during ALS/CPR	Time to secured airways, CC quality measures, ventilation quality measures	Early use of laryngeal tubus and over-the-head CC were feasible with 2 rescuers.
Zalewski (2020A)[28]	Paramedics (*n* = 200)	ALS/CPR with pre-filled medication syringes	CC quality measures. Time to airway securing.	The use of pre-filled syringes with adrenaline: improved CC quality, shorter time to airway securing.
Zalewski (2020B)[31]	Paramedics (*n* = 200)	ALS/CPR using self-adhesive electrodes	CC quality measures, duration for *peri*-shock pause. Time to airway securing	The use of multifunction pads: improved CC quality, earlier airway securing.
Zalewski (2020C)[29]	Paramedics (*n* = 106)	ALS/CPR with pre-filled medication syringes	Time to critical interventions, CC quality measures	The use of pre-filled syringes with adrenaline and amiodarone: faster achievement of critical interventions, CC quality did not differ.

Legend. CC, chest compressions. EMTs, emergency medical technicians. NFF, no-flow fraction. TI, tracheal intubation.

Table 3 – Coding categories and subgroups.

Effect of team configuration on CPR quality and outcome
Team size
Team composition
Early airway management and ventilation technique
Mechanical chest compressions
Prefilled syringes
Use of additional equipment
Adhesive defibrillation electrodes
Intraosseous access
Metronome use
Prototype CPR assist device
Adaptation of ALS/CPR protocols
Human factors
Workload
Physical exertion

of mechanical chest compressions, the use of pre-filled syringes, and the utilization of an automation-assisted protocol, may enhance the performance of such teams.

Predominantly, the subject has been explored through simulation and feasibility studies, which exhibit considerable methodological heterogeneity. Several themes emerged that could influence the effectiveness and efficiency of ALS CPR performed by two-member ambulance crew in OHCA setting.

Larger crew sizes appear to be less error-prone and more efficient in airway management and overall performance, including CPR quality.[20–23] However, clinical outcomes for OHCA patients treated by two-member crews have only been evaluated in a single retrospective study, which did not detail specific protocols or contributions of first professional responders beyond crew size.[14]

In various simulation studies, thematic areas have been identified that could inform the optimal sequence and interplay of ALS procedures during CPR for maximal performance and adherence to ALS guidelines.

Early airway management remains a contentious issue,[33] but the supraglottic airway devices use appears not to be inferior to tracheal intubation as a method of initial airway management in OHCA.[34–36] Its use may have a positive impact on achieving ROSC, though its effect on other clinical outcomes in OHCA remains uncertain.[37] The ease of inserting a laryngeal mask allows for ergonomic approaches like over-the-head CPR and ventilation.[38]

While continuous compressions and ventilation at a rate of 10 breaths per minute are recommended after securing the airway,[4] the early insertion of laryngeal mask might permit one rescuer to continue with a 30:2 ratio[38] while the other prepares for additional procedures.[4] Future recommendations and studies should distinguish between aspects of airway management in shockable and non-shockable rhythms due to differing priorities, especially regarding the criticality of timely defibrillation.

Mechanical chest compressions, though not routinely recommended, can free up rescuers' hands for other tasks in understaffed conditions and challenging locations. Pre-filled syringes appear practical, but questions about spatial storage, distribution, and color differentiation in ambulances and rescue bags[39] are yet to be resolved. The use of intraosseous access as a universal procedure during OHCA is debatable, but it is a quick and time-saving intervention. The use of disposable electrodes and metronomes in field defibrillators and monitors is currently accepted.[4,16]

Although international ALS CPR guidelines are created through a very careful and rigorous process aimed at assessing patient outcomes, less attention is paid to the deliverability of individual steps under certain conditions.[4,16] No comprehensive work has yet been published that would establish a protocol for a two-member crew, optimizing all major approaches described above in line with current recommendations. Adapting disposable equipment for the two-member crew OHCA ALS CPR is also necessary. Crew training should encompass not only algorithm steps but also movement around the patient. It's clear that a well-trained professional with in-depth procedure knowledge according to their role must proceed in a precisely structured manner.

The data indicates that this is an underexplored issue, despite being a common scenario for the often first-arriving two-member ambulance crew at an OHCA site. However, the clinical recommendations from the presented outcomes are currently weak. Therefore, it is essential to create robust, methodologically sound randomized simulation studies addressing most of the topics mentioned during

ALS CPR, including modifications for shockable and non-shockable OHCA rhythms. These studies could serve as a background for future clinical studies. The research questions of such studies could address the knowledge gaps such as prioritisation of the ALS procedures that are linked with improved outcomes and freeing hands of rescuers, equipment choices and ergonomics during ALS CPR by two-member teams.

Limitations

The chosen time interval from 2005 was selected to align with publications reflecting recommendations similar to current ERC guidelines.[4] To refine our objectives and the potential generalization of findings, articles on CPR in paediatric patients or special circumstances were excluded.

The outcomes of the selected studies were not determined a priori, in accordance with methodological guidance for scoping reviews.[17]

The objectives and methodologies of the identified studies varied. High-quality, detailed qualitative analyses are missing, and no randomized prospective controlled clinical trials with systematic clinical outcome measurements exist.

Not all studies explicitly stated a focus on two-member teams in their titles or objectives. Some studies used two-member teams to test various interventions but did not state the aim to study two-member teams specifically. The heterogeneity of the included studies was significant. Most were simulation studies with varying interventions, currently incomparable and collectively only providing partial insight into the complexity of the issue.

Additionally, all assessed studies were conducted based on recommendations older than the current ones.[4] It is evident that numerous local protocols in emergency medical services worldwide address the two-member crew approach to providing high-quality, protocol-adherent ALS, which cannot be exhaustively traced.

Conclusion

Based on the currently identified evidence, no specific adaptations within the ALS structure for two-member teams responding to OHCA can be recommended. This underscores the need for more comprehensive and robust studies in this area.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT-4, OpenAI in order to improve language and readibility without changing the context. This tool was used after the text was drafted and the authors reviewed and edited the content as needed and take full responsibility for the content of the publication

CRediT authorship contribution statement

Miroslav Keselica: Writing – review & editing, Writing – original draft, Methodology, Investigation. **David Peřan:** Writing – review & editing, Methodology, Investigation. **Metoděj Renza:** Writing – review & editing, Writing – original draft, Investigation. **František Duška:** Writing – review & editing, Supervision, Conceptualization. **David Omáčka:** Writing – review & editing, Methodology, Investigation. **Sebastian Schnaubelt:** Writing – review & editing, Conceptualization. **Ileana Lulic:** Writing – review & editing, Conceptualization. **Roman Sýkora:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

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Appendix A. Supplementary material

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REFERENCES

1. Kurz MC, Schmicker RH, Leroux B, et al. Advanced vs. basic life support in the treatment of out-of-hospital cardiopulmonary arrest in the resuscitation outcomes consortium. Resuscitation 2018;128:132–7. https://doi.org/10.1016/j.resuscitation.2018.04.031.

2. Dick WF. Anglo-American vs. Franco-German emergency medical services system. Prehosp Disaster Med 2003;18:29–35. https://doi.org/10.1017/s1049023x00000650.
3. Dabrowski M, Sip M, Dabrowska, et al. It is impossible to follow the ERC algorithm in a two-paramedics ambulance team. Resuscitation 2017;118:e43. https://doi.org/10.1016/j.resuscitation.2017.
4. Soar J, Böttiger BW, Carli P, et al. European Resuscitation Council Guidelines 2021: adult advanced life support. Resuscitation 2021;161:115–51. https://doi.org/10.1016/j.resuscitation.2021.02.010.
5. Brucke M, Helm M, Schwartz A, Lampl L. Two rescuer resuscitation–mission impossible? A pilot study using a manikin setting. Resuscitation 2007;74:317–24. https://doi.org/10.1016/j.resuscitation.2006.12.013.
6. Ventzke MM, Gässler H, Brucke M, Helm M. Modifizierter Zweihelferreanimationsalgorithmus. Alternative im Auslandseinsatz der Bundeswehr! [Modified two-rescuer resuscitation algorithm. Alternative for international missions of the German Armed Forces!]. Anaesthesist 2011;60:49–56. https://doi.org/10.1007/s00101-010-1778-7.
7. Kłosiewicz T, Puślecki M, Zalewski R, Sip M, Perek B. Analysis of the quality of chest compressions during resuscitation in an understaffed team — randomised crossover manikin study. Disaster Emerg Med J 2020;5:24–9. https://doi.org/10.5603/DEMJ.a2020.0008.
8. Kłosiewicz T, Puślecki M, Szarpak L, Daôbrowski M, Perek B. Automatic compression improves adherence to advanced life support protocol in two-paramedic team. A randomized simulation study. Signa Vitae 2021;17. https://doi.org/10.22514/sv.2020.16.0110.
9. Guyette FX, Rittenberger JC, Platt T, Suffoletto B, Hostler D, Wang HE. Feasibility of basic emergency medical technicians to perform selected advanced life support interventions. Prehosp Emerg Care 2006;10:518–21. https://doi.org/10.1080/10903120600726015.
10. Schröder J, Bucher M, Meyer O. Effect of the laryngeal tube on the no-flow-time in a simulated two rescuer basic life support setting with inexperienced users. Auswirkung des Larynx-Tubus auf die No-Flow-Zeit in einem simulierten zwei-Helfer Basic Life Support Szenario mit unerfahrenen Anwendern. Med Klin Intensivmed Notfmed 2016;111:493–500. https://doi.org/10.1007/s00063-015-0088-x.
11. Asselin N, Choi B, Pettit CC, et al. Comparative analysis of emergency medical service provider workload during simulated out-of-hospital cardiac arrest resuscitation using standard versus experimental protocols and equipment. Simul Healthc 2018;13:376–86. https://doi.org/10.1097/SIH.0000000000000339.
12. Harari Y, Riemer R, Jaffe E, Wacht O, Bitan Y. Paramedic equipment bags: How their position during out-of-hospital cardiopulmonary resuscitation (CPR) affect paramedic ergonomics and performance. Appl Ergon 2020;82, 102977. https://doi.org/10.1016/j.apergo.2019.102977.
13. Choi B, Asselin N, Pettit CC, et al. Simulation-based randomized comparative assessment of out-of-hospital cardiac arrest resuscitation bundle completion by emergency medical service teams using standard life support or an experimental automation-assisted approach. Simul Healthc 2016;11:365–75. https://doi.org/10.1097/SIH.0000000000000178.
14. Eschmann NM, Pirrallo RG, Aufderheide TP, Lerner EB. The association between emergency medical services staffing patterns and out-of-hospital cardiac arrest survival. Prehosp Emerg Care 2010;14:71–7. https://doi.org/10.3109/10903120903349820.
15. Nichol G, Detsky AS, Stiell IG, O'Rourke K, Wells G, Laupacis A. Effectiveness of emergency medical services for victims of out-of-hospital cardiac arrest: a metaanalysis. Ann Emerg Med 1996;27:700–10. https://doi.org/10.1016/s0196-0644(96)70187-7.
16. Berg KM, Bray JE, Ng KC, et al. 2023 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: Summary From the Basic Life Support; Advanced Life Support; Pediatric Life Support; Neonatal Life Support; Education, Implementation, and Teams; and First Aid Task Forces. Circulation 2023. https://doi.org/10.1161/CIR.0000000000001179.
17. Peters MDJ, Marnie C, Tricco AC, et al. Updated methodological guidance for the conduct of scoping reviews. JBI Evid Synth 2020;18:2119–26.
18. Tricco AC, Lillie E, Zarin W, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and Explanation. Ann Intern Med 2018;169:467–73.
19. Sykora R, Keselica M, Peran D. Adaptation of advanced life support recommendation for two-member ambulance crew: a scoping review protocol. Registration. Open Science Framework. https://osf.io/vx34z.
20. Tsai BM, Sun JT, Hsieh MJ, et al. Optimal paramedic numbers in resuscitation of patients with out-of-hospital cardiac arrest: a randomized controlled study in a simulation setting. PLoS One 2020;15.
21. Krzyżanowski K, Śleôzak K, Daôbrowski S, et al. Comparative analysis of the effectiveness of performing advanced resuscitation procedures undertaken by two- and three- person basic medical rescue teams in adults under simulated conditions. Int J Environ Res Public Health 2021;18:4834. https://doi.org/10.3390/ijerph18094834.
22. Robakowska M, Śleôzak D, Żuratyński P, et al. Management decisions: the effectiveness and size of the emergency medical team. Int J Environ Res Public Health 2022;19:3753. https://doi.org/10.3390/ijerph19073753.
23. Martin-Gill C, Guyette FX, Rittenberger JC. Effect of crew size on objective measures of resuscitation for out-of-hospital cardiac arrest. Prehosp Emerg Care 2010;14:229–34. https://doi.org/10.3109/10903120903572293.
24. Bayley R, Weinger M, Meador S, Slovis C. Impact of ambulance crew configuration on simulated cardiac arrest resuscitation. Prehosp Emerg Care 2008;12:62–8. https://doi.org/10.1080/10903120701708011.
25. Dundar ZD, Ayranci MK, Kocak S, Girisgin AS. Bag-valve-mask versus laryngeal mask airway ventilation in cardiopulmonary resuscitation with continuous compressions: a simulation study. Prehosp Disaster Med 2021 Apr;36:189–94. https://doi.org/10.1017/S1049023X21000054.
26. Siebers C, Müßig B, Huppertz T, Kanz KG. Atemwegsmanagement in der Initialphase der Reanimation. Notfall + Rettungsmedizin 2009;12:277–82. https://doi.org/10.1007/s10049-009-1149-6.
27. Robak O, Pruc M, Malysz M, et al. Pre-filled syringes with adrenaline during cardiopulmonary resuscitation in nonshockable rhythms. Pilot randomised crossover simulation study. Disaster. Emerg Med J 2020;5:79–84. https://doi.org/10.5603/DEMJ.a2020.0025.
28. Zalewski R, Puslecki M, Klosiewicz T, Sip M, Perek B. The use of prefilled adrenaline syringes improves cardiopulmonary resuscitation quality-high-fidelity simulator-based study. J Thorac Dis 2020;12:2105–12. Available from: https://doi.org/10.21037/jtd.2020.04.33.
29. Zalewski R, Telec W, Puslecki M, Dabrowski M, Perek B, Szarpak L. Sudden cardiac arrest pharmacotherapy with prefilled syringes improves adherence to Advanced Life Support protocol in understaffed resuscitation pre-hospital care teams. Signa Vitae 2020;17:69–74. https://doi.org/10.22514/sv.2020.16.0098.
30. Zalewski R, Puślecki M, Szarpak Ł, Kłosiewicz T, Daôbrowski M, Perek B. Impact of Application of Multifunction Electrode (MFE) Pads on Cardiopulmonary Resuscitation Quality. Emerg Med Int 2020;19:2675214. https://doi.org/10.1155/2020/2675214.
31. Kern KB, Stickney RE, Gallison L, Smith RE. Metronome improves compression and ventilation rates during CPR on a manikin in a randomized trial. Resuscitation 2010;81:206–10. https://doi.org/10.1016/j.resuscitation.2009.10.015.
32. Nitzschke R, Doehn C, Kersten JF, et al. Effect of an interactive cardiopulmonary resuscitation assist device with an automated

external defibrillator synchronised with a ventilator on the CPR performance of emergency medical service staff: a randomised simulation study. Scand J Trauma Resusc Emerg Med 2017;25:36. https://doi.org/10.1186/s13049-017-0379-8.
33. Carlson JN, Colella MR, Daya MR, et al. Prehospital cardiac arrest airway management: an NAEMSP position statement and resource document. Prehosp Emerg Care 2022;26:54–63. https://doi.org/10.1080/10903127.2021.1971349.
34. Benger JR, Kirby K, Black S, et al. Supraglottic airway device versus tracheal intubation in the initial airway management of out-of-hospital cardiac arrest: the AIRWAYS-2 cluster RCT. Health Technol Assess 2022;26:1–158. https://doi.org/10.3310/VHOH9034.
35. Forestell B, Ramsden S, Sharif S, et al. Supraglottic airway versus tracheal intubation for airway management in out-of-hospital cardiac arrest: a systematic review, meta-analysis, and trial sequential analysis of randomized controlled trials. Crit Care Med 2024;52(2):e89–99. https://doi.org/10.1097/CCM.0000000000006112.
36. Penketh J, Nolan JP. Airway management during cardiac arrest. Curr Opin Crit Care 2023;29:175–80. https://doi.org/10.1097/MCC.0000000000001033.
37. Stuby L, Jampen L, Sierro J, et al. Effect of early supraglottic airway device insertion on chest compression fraction during simulated out-of-hospital cardiac arrest: randomised controlled trial. J Clin Med 2021;11:217. https://doi.org/10.3390/jcm11010217.
38. Stuby L, Suppan L, Jampen L, Thurre D. Impact of the over-the-head position with a supraglottic airway device on chest compression depth and rate: a post hoc analysis of a randomized controlled trial. Healthcare (Basel) 2022;10:718. https://doi.org/10.3390/healthcare10040718.
39. Stevens AD, Hernandez C, Jones S, et al. Color-coded prefilled medication syringes decrease time to delivery and dosing errors in simulated prehospital pediatric resuscitations: a randomized crossover trial. Resuscitation. 2015;96:85–91. https://doi.org/10.1016/j.resuscitation.2015.07.035.