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Bag size for manual ventilation during cardiopulmonary resuscitation in adult cardiac arrest: a systematic review

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Abstract

Background: Smaller-capacity self-inflating bags have been proposed to limit delivered tidal volume during adult cardiopulmonary resuscitation (CPR). This review evaluates whether using smaller-capacity self-inflating bags, compared with standard-size adult bags, for manual ventilation during CPR affects patient and ventilation outcomes.

Methods: We conducted a systematic review using the ILCOR Continuous Evidence Evaluation approach, searching MEDLINE, Embase, Web of Science, and CENTRAL from inception to May 7, 2026 (PROSPERO CRD420251266387). Eligible studies included randomized and non-randomized designs in humans and simulation. Critical outcomes were survival to discharge or 30 days with and without favorable neurological outcome. Important outcomes included survived event, return of spontaneous circulation (ROSC), tidal volume, ventilation rate, and adverse events. Certainty of evidence was assessed using GRADE.

Results: No randomized trials were identified. Evidence comprised one before-and-after observational study (n = 1994 out-of-hospital cardiac arrest patients with advanced airways) and two cross-over simulation studies. The observational study compared periods using smaller ventilation bags (450–700 mL) with standard adult bags (1000–1685 mL). Compared with the standard-bag period, the smaller-bag period was associated with lower survival with favorable neurological outcome (AOR 0.65, 95% CI 0.43–0.99) and lower event survival (adjusted odds ratio [AOR] 0.73, 95% CI 0.60–0.90). Survival to discharge and ROSC did not differ significantly. Simulation studies demonstrated inconsistent effects of bag size on guideline-consistent tidal volume delivery. The certainty of evidence was very low for all outcomes.

Conclusions: Although evidence is very limited and of very-low certainty, smaller bags may influence delivered tidal volume and worsen patient outcomes. Routine substitution of standard adult bags with small bags during CPR is not supported.

Keywords: Cardiac arrest, CPR, Ventilation, Bag-valve-mask, Tidal volume, Hyperventilation

Introduction

Effective ventilation during cardiopulmonary resuscitation (CPR) requires balancing adequate oxygenation and carbon dioxide clearance with avoidance of excessive intrathoracic pressure.[1] Hyperventilation during cardiac arrest increases intrathoracic pressure, which reduces venous return and raises pulmonary vascular resistance.(2) This leads to decreased cardiac output and reduced coronary and cerebral perfusion, and is associated with worse resuscitation outcomes.[2,3] Experimental and clinical observations suggest that excessive ventilation may reduce return of spontaneous circulation (ROSC) and survival.[4]

Standard adult self-inflating resuscitation bags typically have capacities of 1.5 L (L). Even partial compression can deliver tidal volumes exceeding guideline recommendations. Observational and

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simulation studies have demonstrated that excessive tidal volumes and ventilation rates are common during manual ventilation, particularly in high-stress resuscitation environments.[5,6]

Smaller-capacity manual resuscitation bags (e.g., pediatric-sized bags, approximately 0.5–0.7 L) have been proposed as a strategy to reduce delivered tidal volume and mitigate hyperventilation. Simulation and crossover studies have suggested that smaller-capacity ventilation bags may influence delivered tidal volume and ventilation rate compared with standard adult bags, although findings have been inconsistent.[7,8] These studies, however, were not designed to assess clinical outcomes. Whether such physiologic effects translate into improved patient-centered outcomes remains uncertain. As part of the International Liaison Committee on Resuscitation (ILCOR) Consensus of Science and Treatment Recommendations, we conducted a systematic review to evaluate the association between ventilation bag size and clinical outcomes during adult CPR.

Methods

This systematic review was prospectively registered on the International Prospective Register of Systemic Reviews (PROSPERO; CRD420251266387), complies with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting framework.[9] Guidelines (Checklist in Supplement 1). The ILCOR evidence evaluation process for systematic reviews was followed.[10]

Eligibility criteria

Studies were included if they involved adults with in-hospital or out-of-hospital cardiac arrest who received manual ventilation during CPR and compared a smaller-capacity self-inflating bag (e.g., a pediatric-sized bag used for adult ventilation) with a standard-size adult self-inflating bag (approximately 1.5 L) examining prespecified outcomes. The primary critical outcomes were survival to hospital discharge or 30 days and survival with favorable neurological outcome at hospital discharge or 30 days, measured using the Cerebral Performance Category (CPC), modified Rankin Scale (mRS), or an equivalent validated neurological score. Secondary important outcomes included survived event survival (survival to hospital admission,[11] return of spontaneous circulation (ROSC), tidal volume delivered, ventilation rate, and adverse events.

Randomized controlled trials (RCTs) and eligible non-randomized studies (including non-randomized controlled trials, interrupted time series, controlled before-and-after studies, and cohort studies) were included. As prespecified in the PROSPERO-registered protocol, randomized manikin, simulation, and cadaver studies were eligible for inclusion if clinical evidence was insufficient. Following study selection, only one eligible clinical observational study and no randomized clinical trials met the inclusion criteria; therefore, simulation studies were included in the final review. Studies were excluded if they were unpublished (e.g., conference abstracts or trial protocols), non-randomized manikin/simulation/cadaver studies, narrative reviews, editorials, or opinion pieces without primary data. Only studies published in English were eligible for inclusion.

Information sources and search strategy

We searched the following electronic databases from inception to May 7, 2026: MEDLINE, Embase, Web of Science, and the Cochrane Central Register of Controlled Trials (CENTRAL). The search strategy was developed using terms related to cardiac arrest, cardiopulmonary resuscitation (CPR), bag-valve-mask ventilation, self-inflating bags, and tidal volume. The full search strategy is available from the authors upon request, with the MEDLINE search provided in Supplement 2. Backward citation searching (reference list review), forward citation searching of included studies, and searches of trial and study registries were also performed.

Study selection

All citations were imported into Covidence, and duplicates were removed. Two reviewers independently screened titles and abstracts using pre-defined eligibility criteria (MD, NJ). Full-text articles of potentially eligible studies were then assessed independently by two reviewers (MD, NJ). Disagreements at any stage were resolved through discussion and consensus by a third reviewer (JB).

Data collection and items

A standardized data extraction form was used to extract study design, study setting, participant characteristics, intervention and comparator details, and outcome measures. A standardized data extraction form was used to extract study design, study setting, participant characteristics, intervention and comparator details, outcome measures, and relevant statistical information. Initial data extraction was performed by a single author (MD) and independently verified (JB). Where possible, missing values (e.g., standard deviations) were calculated from reported p-values, t-values, confidence intervals, or standard errors. Discrepancies were resolved through discussion and consensus among the review team.

Risk of bias and certainty of evidence

Risk of bias for each study was assessed by two reviewers using the Cochranes ROB2 tool for randomized studies[12] and ROBINS-I for non-randomized studies.[13] Disagreements were resolved by discussion and consensus. Certainty of evidence for each outcome was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.[14] The certainty of evidence was evaluated considering risk of bias, inconsistency, indirectness, imprecision, publication bias, and, where applicable, factors that may increase certainty of evidence. Evidence profiles were developed for all critical and important outcomes.

Synthesis of findings

Given the limited number of eligible studies and substantial clinical and methodological heterogeneity (differences in study design, airway type, ventilation technique, provider population, and study setting), meta-analysis was not performed. Findings were synthesized narratively using synthesis without meta-analysis (SWiM) methodology.[15]

Studies were grouped by prespecified critical and important outcomes and are presented separately by study design. Effect estimates were reported as presented in the original studies, with adjusted estimates preferentially described for clinical outcomes when available.

Results

Study selection

The PRISMA flowchart is provided in Fig. 1. Of 608 citations, three studies met inclusion criteria: one before-and-after observational clinical study[16] and two cross-over simulation studies[7,8] (Table 1). An additional small observational pilot study ($n = 50$) was identified,[17] but was excluded because the study did not provide analyzable data comparing the prespecified intervention and comparator among patients receiving manual ventilation during CPR.

Study characteristics

The included clinical study was a before-and-after observational study of 1994 OHCA patients with advanced airways (supraglottic or endotracheal) managed by emergency medical technicians and advanced life support paramedics.[16] The study compared a period of time using standard adult ventilation bags (1000–1685 ml [mL]) to a period of time using smaller-volume ventilation bags (450–700 mL). The smaller-bag period overlapped with the COVID-19 pandemic.

The two included cross-over simulation studies evaluated manual ventilation in adult cardiac arrest scenarios.[7,8] In one study, third-year paramedic students ventilated a manikin with an advanced airway during two-minute scenarios comparing 1600 mL volume bag to a 1000 mL volume bag[8] In the other, registered nurses or emergency medical technicians ventilated a manikin via adult facemask during ten-minute scenarios in a moving ambulance comparing a 1600 mL volume bag to a 500 mL volume bag.[7]

Due to differences in study design, ventilation techniques, airway type, provider populations, and co-interventions, meta-analysis was not performed.

Risk of bias

The observational before-and-after study was judged to have serious risk of bias due to its non-randomized design, temporal confounding (including overlap with the COVID-19 pandemic during the smaller bag period), and potential unmeasured co-interventions.[16] Both randomized crossover simulation studies were judged to have low risk of bias using RoB2 (Fig. 2). However, the certainty of evidence from these studies was downgraded because of indirectness, inconsistency, and imprecision.[7,8]

Effects of interventions

The certainty of evidence was rated as very low for all critical and important outcomes. Clinical observational evidence was downgraded for serious risk of bias and imprecision. Simulation evidence was additionally downgraded for indirectness and inconsistency.

Survival to hospital discharge or 30 days with favorable neurological outcome

For this critical outcome, very low-certainty evidence (downgraded for serious risk of bias and imprecision) was identified from one before-and-after observational study ($n = 1994$).[16] Survival with favorable neurological outcome (Cerebral Performance Category 1–2) was lower during the smaller-bag period (63/1331, 5%) compared with the larger-bag period (49/663, 7%) (adjusted odds ratio [AOR] 0.65, 95% CI 0.43 to 0.99).

Survival to hospital discharge or 30 days

For this critical outcome, very low-certainty evidence (downgraded for serious risk of bias and imprecision) was identified from one observational study ($n = 1994$).[16] There was no statistically significant difference in survival to discharge between the smaller-bag period (125/1331, 9%) and the larger-bag period (80/663, 12%) (AOR 0.79, 95% CI 0.57–1.09).

Event survival

For this important outcome, very low-certainty evidence (downgraded for serious risk of bias and imprecision) was identified from one observational study ($n = 1994$).[16] Event survival was lower during the smaller-bag period (460/1331, 35%) than during the larger-bag period (276/663, 42%) (AOR 0.73, 95% CI 0.60–0.90).

Return of spontaneous circulation

For this important outcome, very low-certainty evidence (downgraded for serious risk of bias and imprecision) was identified from one observational study ($n = 1994$).[16] There was no statistically significant difference in ROSC between the smaller-bag period (625/1331, 47%) and the larger-bag period (341/663, 51%) (AOR 0.85, 95% CI 0.70–1.03).

Delivered tidal volume

For delivered tidal volume, a physiologic outcome, very low-certainty evidence (downgraded for serious risk of bias, inconsistency, indirectness, and imprecision) was identified from two randomized cross-over simulation studies.[7,8]

Overall, simulation data suggest that smaller bags may reduce excessive tidal volume delivery, but they may also increase the risk of delivering tidal volumes below guideline recommendations, particularly when very small bags are used (400–600 mL or 6–7 mL/kg for adults) (Table 1). One study reported higher compliance with the larger (1600 mL) bag (52% vs 0%, $p < 0.001$), with all tidal volumes being less than 400 mL when the smaller (500 mL) bag was used.[7] The other study reported higher compliance with the smaller (1000 mL) bag (30% vs 3%, $p = 0.02$), with more frequent excessive tidal volumes in the larger (1600 mL) bag group.[8]

Ventilation rate

For ventilation rate, very low-certainty evidence was identified from one observational study (19) and two simulation studies.[7,8] The observational study ($n = 1994$) reported no statistically significant difference in mean ventilation rate between larger- and smaller-bag periods (11.9 ± 5.3 vs 12.0 ± 4.8 breaths/min, $p = 0.60$).[16] Guideline adherence (9–11 breaths/min) was marginally higher in the smaller-bag period.

One simulation study reported no statistically significant difference in compliance between bag sizes, with high rates of hyperventilation in both groups.[8] The other reported significantly fewer ventilations over 10 min when using the smaller (500 mL) bag compared with the larger (1600 mL) bag (29.2 ± 12.4 vs 43.8 ± 9.3, $p < 0.001$).[7]

Adverse events

No clinical studies directly compared rates of emesis, aspiration, barotrauma, or other adverse events according to ventilation bag size.

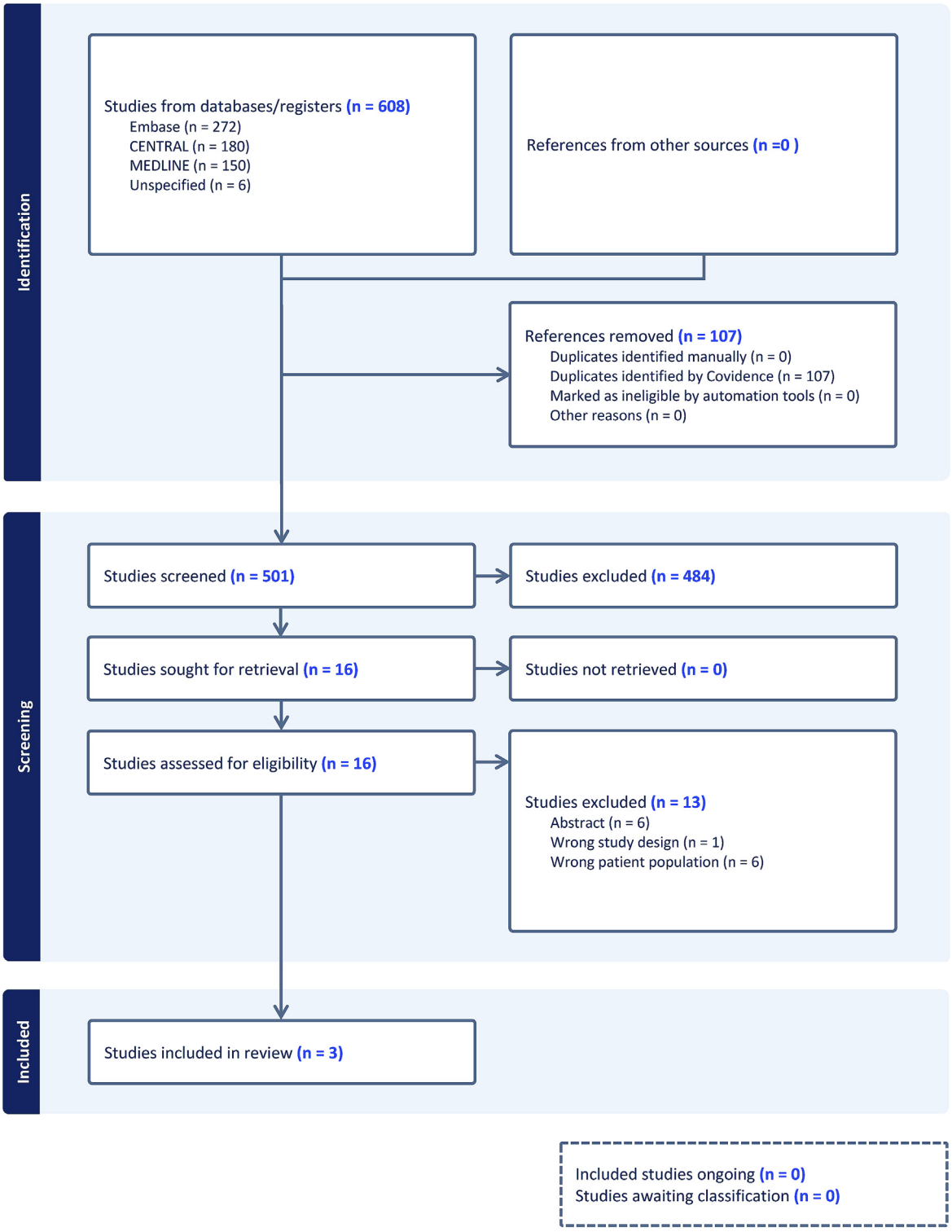

Fig. 1 – PRIMSA flowchart of search results.

Discussion

This systematic review was conducted in response to emerging observational data evaluating the impact of manual resuscitation bag size on ventilation delivery and outcomes during adult cardiac arrest. No randomized controlled trials were identified. The available evidence consisted of one observational before-and-after clinical study[16] and two cross-over simulation studies.[7,8] All outcomes were rated as very low certainty of evidence due to serious risk of bias, inconsistency, indirectness, and imprecision.

Effective ventilation during CPR is essential to optimize oxygen delivery and carbon dioxide elimination while minimizing harm from

Table 1 – Systematic review studies for manual bag ventilation size.

Author, year	Design/country of origin	Population/exposure	Participant characteristics	Intervention/control	Outcomes
Clinical studies					
Snyder 2023	Retrospective observational cohort study/ United States	OHCA with Advanced Airway $N = 1994$ Patients	Adult patients with an advanced airway (iGel or ETT) during non-traumatic OHCA 2015–2021	Small Adult CPR-2 Bag, Mercury Medical, 1000 mL, TV 450–725 ml/Standard CPR-2 Bag Mercury Medical, 1685 mL, TV 700–1040	Intervention = 1331, control = 663 Survival with Discharge with Good Neuro Outcome 5% vs, 7%, AOR 0.65, 95% CU 0.43–0.99 Survival to Discharge 9% vs.12%, AOR 0.79, 95% CI 0.57–1.09 Survival to Admission 35% vs. 42%, AOR 0.73, 95% CI 0.60–0.90 ROSC 47% vs. 51%, AOR 0.85, 95% CI 0.70–1.03 Guideline-consistence ventilation rate (10 breaths/min) 31.2% vs. 28.4% End-Tidal CO_2 36.9 ± 19.2 vs. 33.2 ± 17.2, $p < 0.001$
Simulation studies					
Riyapan 2021	Simulation randomized crossover study/ Thailand	Mannikin Adult OHCA scenario in moving ambulance with BVM $N = 52$	EMS registered nurses and basic EMTs	Pediatric-sized bag (500 ml) intervention/Adult-sized bag (1600 ml) control	$N = 52$ (intervention vs. control) Guideline-consistent Tidal Volume (400–600 ml) 0.0% vs. 52.1% ($p < 0.001$) High Tidal Volume (>600 ml) 0.0% vs. 11.4% ($p < 0.001$) Low Tidal Volume (<400 ml) 100.0% vs. 36.5% ($p < 0.001$) Mean Tidal Volume 239.0 vs. 444.5 ($p < 0.001$)
Nehme 2009	Simulation randomized crossover study/ Australia	Mannikin Adult OHCA scenario with advanced airway $N = 30$	Undergraduate third year paramedic students	1000 ml bag intervention/ 1600 ml bag control	$N = 30$ (intervention vs. control) Guideline-Consistent Ventilation Rate: 30% vs. 23% ($p = 0.55$) Guideline-Consistent Tidal Volume 30% vs. 3% ($p = 0.015$) Guideline-Consistent Minute Volumes 30% vs. 7% ($p = 0.045$)

ROSC: Return of Spontaneous Circulation, IQR: Interquartile Range, BV: Bag valve, OHCA: out-of-hospital cardiac arrest, ALS: Advanced Life Support, BLS: Basic life support, EMT: Emergency Medical Technician.

excessive ventilation. Hyperventilation during CPR has been associated with lower cardiac output and lower rates of ROSC and survival.[2,3] Cardiac arrest survivors are also at risk for pulmonary complications, including aspiration, pulmonary edema, barotrauma, and acute respiratory distress syndrome (ARDS), which are associated with worse clinical outcomes.[18,19] Although excessive tidal volumes and airways pressures are recognized contributors to ventilator-induced lung injury during mechanical ventilation, there

a. Cochranes RoB2 Tool

Study	Randomization Process	Deviation from Intended Intervention	Missing Outcome Data	Measurement of Outcome	Selection of Reported Results	Overall
Nehme 2009	Low	Low	Low	Low	Low	Low
Riyapan 2021	High	Low	Low	Low	Low	Some Concerns

b. ROBINS-I RoB Tool

Study	Confounding	Selection of Participants	Classification of Interventions	Deviation from Intended Interventions	Missing Data	Measurement of Outcomes	Selection of Reported Results	Overall
Snyder 2023	Serious	Moderate	Low	Moderate	Moderate	Low	Low	Serious

Fig. 2 – Risk of bias assessments in randomized controlled trials (a) and non-randomized studies.

are limited data directly linking intra-arrest ventilation practices or ventilation bag size to the subsequent development of ARDS. These physiologic principles provide a rationale for avoiding excessive ventilation during CPR, but the impact of ventilation bag size on pulmonary complications remains uncertain.

In current practice, standard adult self-inflating resuscitation bags typically have nominal volumes of approximately 1.5 L. Even partial compression of these devices may generate tidal volumes that exceed guideline recommendations of approximately 6–10 mL/kg (typically 400–600 mL for an adult).[20] This is especially likely during high-stress cardiac arrest scenarios where providers may inadvertently deliver rapid and forceful ventilations. Smaller-capacity ventilation bags have been proposed to mitigate this risk, with the concept that smaller bag volume may physically constrain insufflation volume.

The single observational study in this review suggested lower rates of favorable neurological outcome and survival to hospital admission during the smaller-bag period, without statistically significant differences in survival to discharge or ROSC.[16] However, interpretation of these findings is limited. The study's non-randomized design introduces potential confounding, including differences in case mix, provider experience, and temporal trends between periods. Importantly, the smaller-bag period overlapped with the COVID-19 pandemic, which may have influenced patient presentations, airway management protocols, and resource availability. In addition, the study did not report whether the proportion of patients managed with endotracheal intubation versus supraglottic airway devices, differed between the periods. Differences in airway management could have affected ventilation delivery and outcomes independent of bag size. Unmeasured co-interventions or system changes during this time could have impacted outcomes independently of bag size. These limitations contributed to serious downgrading for risk of bias and imprecision in the certainty assessment.

Simulation studies provided evidence regarding physiologic parameters, but findings were inconsistent.[7,8] Larger bags were generally associated with tidal volumes above recommended limits, while smaller bags were more often associated with tidal volumes below those limits. Compliance with guideline-recommended tidal volume varied substantially between the simulation studies, with no consistent finding as to which bag size optimizes ventilation delivery. Ventilation rate was also inconsistent across bag sizes, with high rates commonly observed regardless of device size. Simulation research offers useful mechanistic insight but lacks the physiological complexity, environmental stressors, and temporal constraints of real-world cardiac arrest, limiting extrapolation of results to patient care.

Taken together, the available data do not support a clinical advantage to smaller-capacity manual resuscitation bags during adult cardiac arrest. Although smaller bags may help to limit delivered tidal volumes, they may also risk hypoventilation, particularly if providers fail to fully compress the bag or ventilate adequately for taller patients. The balance between preventing hyperventilation and avoiding hypoventilation remains uncertain, and current findings do not establish that equipment change alone will reliably improve patient-centered outcomes.

Limitations

No randomized controlled trials were identified. The available evidence consisted of single non-randomized observational study with potential confounding and two simulation studies, limiting both the certainty and direct applicability of the findings to clinical practice. In the observational study, delivered tidal volumes were not measured, making it unclear whether differences in outcomes were attributable to ventilation bag size or to differences in actual ventilation delivered. Clinical and methodological heterogeneity, including differences in study design, ventilation bag sizes, airway management, ventilation techniques, provider population, and study settings limited comparability and precluded meta-analysis. Finally, the small number of studies and limited sample sizes contributed to imprecision, resulting in very low-certainty evidence for all outcomes.

Conclusion

Current evidence does not demonstrate improved clinical outcomes with smaller ventilation bags, though data are limited and of very low certainty. No randomized trials were identified, and available observational and simulation data are indirect and inconsistent. Given this

uncertainty, continued use of standard adult manual resuscitation bags remains appropriate pending higher-quality evidence.

Disclosure statement

Given her role as Associate Editor, Janet Bray, had no involvement in the peer-review of this article and has no access to information regarding its peer-review. Full responsibility for the editorial process for this article was delegated to another journal editor. JEB is an Editorial Board Member of Resuscitation. SM is an Editorial Board Member of Resuscitation Plus.

CRediT authorship contribution statement

Maya L. Dewan: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nicholas J. Johnson:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Siobhan Masterson:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Janet E. Bray:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization.

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Data availability statement

The review protocol and GRADE evidence tables are provided as supplementary materials. The complete MEDLINE search strategy is included in the Supplementary Materials. Additional review materials, including search strategies for the remaining databases, are available from the corresponding author upon reasonable request.

Declaration of competing interest

Dr. Janet E. Bray is an Associate Editor for Resuscitation and had no involvement in the peer-review or editorial decision-making process for this manuscript. Full responsibility for the editorial process was delegated to another journal editor. Dr. Bray is also an Editorial Board Member of Resuscitation. Dr. Siobhan Masterson is an Editorial Board Member of Resuscitation Plus.

The remaining authors declare no competing interests.

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Non-author Task Force member collaborators

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Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.resplu.2026.101422.

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