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Association Between Emergency Medical Services Crew Composition and Return of Spontaneous Circulation Following Out-of-Hospital Cardiac Arrest: A National Retrospective Cohort Study from Saudi Arabia

Abdullah Alharbi

harbiabdulla@ksau-hs.edu.sa

King Saud bin Abdulaziz University for Health Sciences

Yasir Almukalfi

King Saud bin Abdulaziz University for Health Sciences

Faris Shahat

Saudi Red Crescent Authority (SRCA)

Bander Sultan Alanazi

King Saud bin Abdulaziz University for Health Sciences

Ahmed Basim

King Saud bin Abdulaziz University for Health Sciences

Anas Khalid Alghamdi

King Saud bin Abdulaziz University for Health Sciences

Omar Amer Alansari

King Saud bin Abdulaziz University for Health Sciences

Mohammed Ali Alqabsani

King Saud bin Abdulaziz University for Health Sciences

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Abstract

Background

The optimal composition of Emergency Medical Services (EMS) crews for out-of-hospital cardiac arrest (OHCA) remains uncertain. This study examined the association between EMS crew size, crew configuration, and return of spontaneous circulation (ROSC) in Saudi Arabia.

Methods

A retrospective cohort study was conducted using Saudi Red Crescent Authority registry data. Adult patients who underwent prehospital resuscitation with documented crew composition and ROSC status were included. Three multivariable logistic regression models evaluated the associations between crew size, crew configuration, and the number of Advanced Life Support (ALS) providers with ROSC after adjustment for age, sex, EMS response time, and initial cardiac rhythm.

Results

Among 1,511 patients, 446 (29.5%) achieved ROSC. Crew size was not independently associated with ROSC. Compared with two-provider crews, three-provider crews (adjusted OR 0.81, 95% CI 0.53–1.22; *P* = 0.330) and crews with ≥ 4 providers (adjusted OR 1.34, 95% CI 0.78–2.25; *P* = 0.274) showed no significant association. In contrast, ALS-only crews had significantly greater odds of ROSC than the BLS + BLS reference configuration (adjusted OR 1.87, 95% CI 1.13–3.05; *P* = 0.014). Each additional ALS provider demonstrated a borderline positive association with ROSC (adjusted OR 1.20, 95% CI 1.00–1.44; *P* = 0.054). Shockable initial rhythm remained the strongest predictor of ROSC.

Conclusions

Crew size alone was not independently associated with ROSC following OHCA. In contrast, ALS-only crew configuration was associated with significantly greater odds of ROSC, suggesting that provider qualifications may be more influential than crew size in prehospital resuscitation. Optimising ALS capability within EMS crews may represent a more effective staffing strategy than increasing crew size alone.

1. Introduction

Out-of-hospital cardiac arrest (OHCA) remains one of the leading causes of mortality worldwide, with survival rates varying considerably between emergency medical service (EMS) systems despite advances in resuscitation science and prehospital care [1–3]. Improving outcomes following OHCA requires optimisation of modifiable components of the chain of survival, including the organisation and

delivery of EMS [4]. Among these potentially modifiable factors, EMS crew composition has received increasing attention because of its potential influence on resuscitation performance and patient outcomes [5, 6].

There is currently no internationally accepted standard for EMS crew composition. Ambulance crews differ considerably across EMS systems in both the number of responding personnel (crew size) and the clinical qualifications of those personnel (crew configuration). Larger crews may facilitate the simultaneous performance of critical resuscitation tasks, including high-quality cardiopulmonary resuscitation (CPR), airway management, defibrillation, vascular access, medication administration, and patient transport [7]. In contrast, crews with a greater proportion of Advanced Life Support (ALS)-trained providers may improve clinical decision-making and enable the delivery of advanced interventions, potentially resulting in better patient outcomes.

Previous studies have investigated the relationship between EMS crew composition and OHCA outcomes, the available evidence remains inconsistent [8–15]. Some observational studies have reported improved return of spontaneous circulation (ROSC), survival, and neurological outcomes with higher proportions of ALS-trained personnel [9, 10, 11, 14]. Whereas others have found little or no additional benefit after adjustment for patient and event characteristics [16, 17]. Similarly, simulation studies have suggested that crews comprising three or more providers perform resuscitation tasks more efficiently and deliver higher-quality CPR than two-person crews [12, 18]. However, simulation findings may not accurately reflect the operational complexity encountered in real-world prehospital practice [15, 19, 20].

Determining the optimal balance between crew size and provider qualifications has important implications for workforce planning, resource allocation, and EMS system performance. Understanding whether additional personnel or a greater proportion of ALS providers contributes more substantially to resuscitation success could inform evidence-based staffing policies while maximizing the use of limited healthcare resources.

Therefore, this study aimed to evaluate the association between EMS crew size and crew configuration and return of spontaneous circulation following prehospital resuscitation in Saudi Arabia using a large retrospective cohort of patients attended by the Saudi Red Crescent Authority. We hypothesized that EMS crew configuration, particularly the presence of a greater proportion of ALS-trained providers, would demonstrate a stronger association with ROSC than crew size alone after adjustment for patient characteristics and EMS response time.

1.1 Aim

To determine the association between EMS crew size and crew configuration and return of spontaneous circulation among patients receiving prehospital resuscitation by the Saudi Red Crescent Authority.

- *1.2 Objectives*

- To evaluate the association between EMS crew size and return of spontaneous circulation.
- To evaluate the association between EMS crew configuration and return of spontaneous circulation.
- To determine whether the number of ALS providers is a stronger predictor of ROSC than crew size after adjustment for potential confounders

2. Methods

2.1 Study Design

A retrospective cohort study was conducted using routinely collected data from the Saudi Red Crescent Authority (SRCA) national Emergency Medical Services (EMS) registry. The study included eligible prehospital resuscitation cases attended by SRCA between **1** January 2025 and 31 December 2025. The SRCA provides prehospital emergency medical services throughout Saudi Arabia using an Anglo-American paramedic-led model. Ambulance crew staffing varies according to operational requirements and workforce availability and may include Basic Life Support (BLS) providers, Advanced Life Support (ALS) providers, or combinations of both. During the study period, responding crews varied in both the number and clinical qualifications of attending personnel, enabling the evaluation of EMS crew size and crew configuration in relation to return of spontaneous circulation (ROSC).

The study was approved by the Saudi Red Crescent Authority Institutional Review Board (IRB approval No. IRB-25-0036S) under expedited review. The requirement for informed consent was waived by the Institutional Review Board because the study involved retrospective analysis of routinely collected, de-identified registry data. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Reporting of the study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) recommendations [21].

2.2 Data Source and Collection

Data were obtained from the Saudi Red Crescent Authority (SRCA) national EMS registry, which contains routinely collected information on prehospital emergency responses. The dataset included patient demographic characteristics, resuscitation characteristics, EMS response intervals, initial cardiac rhythm, crew composition, prehospital interventions, and resuscitation outcomes. Crew composition data included the number and qualification level of EMS personnel attending each case, allowing crew size, crew configuration, and the number of Advanced Life Support (ALS) providers to be derived for analysis.

Data for cases attended between 1 January and 31 December 2025 were extracted and compiled by members of the research team, including BA, AB, AA, OA, and M A, using data recorded within the SRCA EMS registry. The data were de-identified prior to analysis and subsequently cleaned and prepared for statistical analysis. Data preparation included identification and removal of duplicate records, standardisation and recoding of relevant variables, derivation of EMS crew composition variables, and

assessment of missing data. No directly identifiable patient information was included in the analytical dataset.

2.3 Study Population

Patients who underwent prehospital resuscitation and were attended by SRCA EMS between 1 January and 31 December 2025 were assessed for eligibility. Cases were included if they had documented prehospital resuscitation, EMS crew composition, and return of spontaneous circulation (ROSC) status. Interfacility transfers, duplicate records, and cases with missing information required to determine crew composition or the primary outcome were excluded.

Following application of the eligibility criteria, 1,511 patients were included in the study cohort. Of these, 1,508 (99.8%) had complete data for all covariates required for the multivariable regression analyses and were included in the adjusted models.

2.4 Study Variables

The primary exposures of interest were three measures of EMS crew composition: crew size, crew configuration, and the number of Advanced Life Support (ALS) providers. These exposures were evaluated separately because they represent related but distinct characteristics of EMS staffing.

Crew size was defined as the total number of EMS personnel assigned to the responding crew and was categorised as two, three, or four or more providers. Two-provider crews were used as the reference category in the regression analysis.

Crew configuration represented the combination of Basic Life Support (BLS)- and ALS-qualified personnel within the responding crew. Crew configurations were categorised as BLS, BLS + BLS, ALS, ALS + BLS, or ALS + ALS, according to the number and qualification level of personnel documented for each case. The BLS + BLS configuration was used as the reference category in the regression analysis.

The number of ALS providers was derived from the documented crew composition and represented the number of ALS-qualified personnel attending each case. This variable was modelled as the number of ALS providers, with increasing values representing greater ALS representation within the responding crew.

The three exposure measures were evaluated in separate multivariable regression models to avoid simultaneously including closely related measures of EMS staffing composition in the same model.

2.5 Outcomes Variable

The primary outcome was prehospital return of spontaneous circulation (ROSC). ROSC status was obtained from the SRCA EMS registry and recorded as a binary outcome (ROSC achieved or not achieved) based on documentation by the attending EMS crew. For statistical analysis, ROSC was coded as a binary variable, with patients who achieved ROSC compared with those who did not achieve ROSC during prehospital resuscitation.

2.6 Covariates and Potential Confounders

Potential confounders included age, sex, EMS response time, and initial cardiac rhythm. These variables were selected a priori based on their established clinical relevance to out-of-hospital cardiac arrest outcomes and their potential to influence the association between EMS crew composition and return of spontaneous circulation (ROSC).

Age was analysed as a continuous variable in years, and sex was categorised as female or male, with female used as the reference category. EMS response time was analysed as a continuous variable in minutes and represented the interval from incident notification to EMS arrival at the scene. Initial cardiac rhythm was categorised as shockable or non-shockable, with non-shockable rhythm used as the reference category. Shockable rhythms included ventricular fibrillation and pulseless ventricular tachycardia, where documented, while other cardiac arrest rhythms were classified as non-shockable.

All four covariates were included consistently across the three multivariable logistic regression models to obtain adjusted estimates of the associations between crew size, crew configuration, number of ALS providers, and ROS

2.7 Statistical Analysis

Continuous variables were summarised as means with standard deviations (SDs) or medians with interquartile ranges (IQRs), as appropriate according to their distribution. Categorical variables were summarised as frequencies and percentages. Baseline characteristics were compared between patients who achieved return of spontaneous circulation (ROSC) and those who did not. Welch's two-sample t-test was used to compare continuous variables, and Pearson's chi-squared test was used to compare categorical variables.

Three separate multivariable logistic regression models were fitted to evaluate the independent associations between EMS crew composition and ROSC. Separate models were used because crew size, crew configuration, and the number of Advanced Life Support (ALS) providers represent closely related measures of EMS workforce composition and were therefore not entered simultaneously into the same model. Model 1 evaluated crew size, with two-provider crews as the reference category. Model 2 evaluated crew configuration, with BLS + BLS crews as the reference category. Model 3 evaluated the number of ALS providers. All three models were adjusted for age, sex, EMS response time, and initial cardiac rhythm. Female sex and non-shockable initial rhythm were used as the respective reference categories.

Associations are reported as adjusted odds ratios (ORs) with 95% confidence intervals (CIs) and corresponding P values. Adjusted predicted probabilities of ROSC according to crew size and crew configuration were estimated from the respective multivariable logistic regression models using empirical marginal standardisation with the ggeffects package.

Multivariable analyses were conducted using complete-case analysis. Of the 1,511 patients included in the study cohort, 1,508 (99.8%) had complete data for all variables required for the multivariable analyses and were included in the regression models. Three patients with missing covariate data were excluded from these analyses.

Multicollinearity was assessed using variance inflation factors (VIFs). Model calibration was assessed using the Hosmer–Lemeshow goodness-of-fit test, and model discrimination was evaluated using the area under the receiver operating characteristic curve (AUROC) with 95% confidence intervals (CIs).

All statistical analyses were performed using R version 4.5.1 (R Foundation for Statistical Computing, Vienna, Austria). All statistical tests were two-sided, and a P value < 0.05 was considered statistically significant [22].

2.8 Ethics Approval

This study was approved by the Saudi Red Crescent Authority (SRCA) Institutional Review Board (IRB approval No. IRB-25-0036S) under expedited review. The study used routinely collected, de-identified registry data, and the requirement for informed consent was waived by the Institutional Review Board because of the retrospective nature of the study. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

3. Results

3.1 Study Population

A total of 1,511 patients met the inclusion criteria and were included in the final analysis. Of these, 446 (29.5%) achieved ROSC and 1,065 (70.5%) did not.

3.2 Baseline Characteristics

Among the 1,511 patients included in the analysis, 446 (29.5%) achieved ROSC, while 1,065 (70.5%) did not. The mean age was similar between the no ROSC and ROSC groups (59.5 ± 29.9 vs. 59.7 ± 21.6 years, P = 0.90). A significantly greater proportion of patients who achieved ROSC were female (40.7% vs. 34.1%), whereas males were less represented in the ROSC group (59.3% vs. 65.9%; *P* = 0.019). Mean EMS response time did not differ significantly between groups (9.6 ± 6.4 vs. 10.1 ± 6.6 minutes, *P* = 0.20). Baseline characteristics of the study population according to ROSC status are presented in Table 1

[Insert Table 1 here]

Table 1: Baseline characteristics of the study population according to return of spontaneous circulation (ROSC).

Characteristic	No ROSC (n = 1,065)	ROSC (n = 446)	P value
Age, years	59.5 ± 29.9	59.7 ± 21.6	0.90
Sex			0.019
Female	363 (34.1%)	181 (40.7%)	
Male	700 (65.9%)	264 (59.3%)	
EMS response time, min	10.1 ± 6.6	9.6 ± 6.4	0.20
Crew size	**0.30**		
2 providers	921 (86.5)	390 (87.4)	
3 providers	100 (9.4)	33 (7.4)	
≥4 providers	44 (4.1)	23 (5.2)	
Crew configuration	**0.007**		
BLS	616 (57.8)	251 (56.3)	
Mixed (ALS+BLS)	398 (37.4)	155 (34.8)	
ALS	51 (4.8)	40 (9.0)	
Number of ALS providers	**0.007**		
0	616 (57.8)	251 (56.3)	
1	398 (37.4)	155 (34.8)	
2	51 (4.8)	40 (9.0)	
Initial rhythm	**<0.001**		
Non-shockable	948 (89.0)	356 (79.8)	
Shockable	117 (11.0)	90 (20.2)	

Crew size was not significantly associated with ROSC on univariable comparison (*P* = 0.30), with two-provider crews attending 86.5% of patients without ROSC and 87.4% of those with ROSC, three-provider crews attending 9.4% and 7.4%, respectively, and crews with ≥4 providers attending 4.1% and 5.2% of cases. In contrast, crew configuration differed significantly between groups (*P* = 0.007), with all-ALS crews being more common among patients who achieved ROSC (9.0% vs. 4.8%), while BLS-only crews accounted for 56.3% versus 57.8% and mixed ALS/BLS crews for 34.8% versus 37.4% of ROSC and no ROSC cases, respectively. Similarly, the number of ALS providers differed significantly (*P* = 0.007), with two ALS providers present in 9.0% of ROSC cases compared with 4.8% of no ROSC cases. Initial

shockable rhythm was substantially more common among patients who achieved ROSC (20.2% vs. 11.0%, $P < 0.001$) and represented the strongest clinical predictor.

3.3 Association Between Crew Size and ROSC

Of the 1,511 eligible patients, 1,508 (99.8%) had complete data for all variables included in the multivariable analyses. Three patients with missing covariate data were excluded from the regression models. In the adjusted logistic regression model, crew size was not independently associated with ROSC. Compared with two-provider crews, three-provider crews (adjusted OR 0.81, 95% CI 0.53–1.22; P=0.330) and crews with four or more providers (adjusted OR 1.34, 95% CI 0.78–2.25; P=0.274) showed no statistically significant association. Male sex remained associated with lower odds of ROSC, whereas an initial shockable rhythm was independently associated with increased odds of ROSC. Adjusted odds ratios and 95% confidence intervals from the three multivariable models are presented in Figure. 1

[Insert Fig. 1 here]

Figure 1: Adjusted odds ratios for the association between EMS crew composition and return of spontaneous circulation (ROSC). Forest plot showing adjusted odds ratios (ORs) and 95% confidence intervals (CIs) from the three multivariable logistic regression models. All models were adjusted for age, sex, EMS response time, and initial cardiac rhythm.

3.4 Association Between Crew Configuration and ROSC

Compared with the BLS+BLS reference configuration, ALS-only crews demonstrated significantly greater odds of ROSC (adjusted OR 1.87, 95% CI 1.13–3.05; P=0.014). ALS+BLS, ALS+ALS, and BLS-only crews were not significantly associated with ROSC after adjustment. Adjusted predicted probabilities of ROSC according to crew configuration are presented in Fig. 2, with the highest predicted probability observed among ALS-only crews, although confidence intervals overlapped.

[Insert Fig. 2 here]

Figure 2: Adjusted predicted probability of return of spontaneous circulation according to EMS crew configuration. Predicted probabilities of ROSC estimated from the adjusted logistic regression model evaluating crew configuration. Error bars represent 95% confidence intervals.

3.5 Association Between Number of ALS Providers and ROSC

Each additional ALS provider demonstrated a borderline positive association with ROSC (adjusted OR 1.20, 95% CI 1.00–1.44; P=0.054). Although not statistically significant, the direction of effect suggests that increasing ALS provider availability may improve resuscitation outcomes. The results of all three multivariable logistic regression models are presented in Table 2.

[Insert Table 2 here]

Table 2: Multivariable logistic regression models evaluating the association between EMS crew composition and return of spontaneous circulation (ROSC) (n = 1,508 complete cases).

Variable	Model 1OR (95% CI)	P value	Model 2OR (95% CI)	P value	Model 3OR (95% CI)	P value
Crew size						
3 vs 2 providers	0.81 (0.53–1.22)	0.330	—	—	—	—
≥4 vs 2 providers	1.34 (0.78–2.25)	0.274	—	—	—	—
Crew configuration						
ALS vs BLS+BLS	—	—	**1.87 (1.13–3.05)**	**0.014**	—	—
ALS+ALS vs BLS+BLS	—	—	1.26 (0.61–2.50)	0.517	—	—
ALS+BLS vs BLS+BLS	—	—	1.13 (0.87–1.49)	0.366	—	—
BLS vs BLS+BLS	—	—	1.07 (0.75–1.52)	0.697	—	—
Number of ALS providers						
Per additional ALS provider	—	—	—	—	1.20 (1.00–1.44)	0.054
Covariates						
Age (years)	1.00 (1.00–1.00)	0.913	1.00 (1.00–1.00)	0.787	1.00 (1.00–1.00)	0.805
Male sex	**0.73 (0.58–0.91)**	**0.007**	**0.73 (0.58–0.92)**	**0.007**	**0.72 (0.57–0.91)**	**0.006**
EMS response time (minutes)	0.99 (0.97–1.01)	0.194	0.99 (0.97–1.01)	0.175	0.99 (0.97–1.01)	0.266
Shockable rhythm	**2.11 (1.55–2.85)**	**<0.001**	**2.16 (1.59–2.93)**	**<0.001**	**2.14 (1.57–2.89)**	**<0.001[1]**

Abbreviations: ALS, Advanced Life Support; BLS, Basic Life Support; CI, confidence interval; EMS, Emergency Medical Services; OR, odds ratio; ROSC, return of spontaneous circulation.

No evidence of problematic multicollinearity was identified across the three models, with all VIFs ≤1.06. The Hosmer–Lemeshow goodness-of-fit test indicated no evidence of poor model fit for Model 1 (P=0.972), Model 2 (P=0.615), or Model 3 (P=0.830). Model discrimination was limited, with AUROCs of 0.584 (95% CI 0.552–0.616), 0.597 (95% CI 0.565–0.628), and 0.590 (95% CI 0.558–0.621) for Models 1, 2, and 3, respectively..

3.6 Adjusted Predicted Probabilities

Adjusted predicted probabilities by crew size are presented in Figure 3. Predicted probabilities varied modestly across crew-size categories and confidence intervals overlapped, supporting the regression findings that increasing crew size alone was not independently associated with ROSC.

[1]1. Model 1 evaluated crew size.

2. Model 2 evaluated crew configuration.

3. Model 3 evaluated the number of ALS providers.

4. All models were adjusted for age, sex, EMS response time, and initial cardiac rhythm.

5. Reference categories were: crew size = 2 providers; crew configuration = BLS+BLS; sex = female; initial rhythm = non-shockable

4. Discussion

This study evaluated the association between EMS crew composition and return of ROSC among patients with OHCA. The principal finding was that crew size alone was not independently associated with ROSC after adjustment for patient demographics and arrest characteristics. In contrast, crew configuration demonstrated a stronger association with ROSC, with ALS-only crews having significantly greater odds of ROSC compared with the reference BLS+BLS configuration. Furthermore, each additional ALS provider demonstrated a borderline positive association with ROSC. Collectively, these findings suggest that the clinical qualifications of responding personnel may be more important than the absolute number of providers attending an OHCA.

Several registry-based studies have similarly reported that increasing crew size alone does not necessarily improve survival after OHCA. Fang et al. demonstrated that a higher proportion of EMT-Paramedics was independently associated with sustained ROSC and favourable neurological outcomes, whereas total crew headcount was not predictive of survival [9]. Likewise, Kim et al. reported that ALS representation at first patient contact was associated with improved ROSC and neurological outcomes after adjustment for confounding variables [10]. Comparable findings were observed by Sun et al., who found that survival was associated with the proportion of ALS-qualified providers rather than the total number of responders [17]. More recently, Wang et al.'s systematic review and meta-analysis concluded

that crews with more than 50% ALS-trained personnel were associated with improved ROSC, survival, and neurological outcomes, although the certainty of evidence was considered low [11].

Our findings closely mirror these observations. Neither three-provider crews nor crews comprising four or more personnel demonstrated significantly greater odds of ROSC compared with standard two-provider crews. Conversely, ALS-only crews demonstrated nearly twice the odds of achieving ROSC compared with the BLS+BLS reference group. This consistency across multiple EMS systems strengthens the hypothesis that workforce capability, rather than workforce size alone, is the primary determinant of successful prehospital resuscitation.

Several mechanisms may explain why crew configuration demonstrated a stronger association with ROSC than crew size. ALS-trained providers possess advanced competencies in rhythm recognition, airway management, vascular access, medication administration, and team leadership during resuscitation. These advanced clinical skills may facilitate more rapid recognition of reversible causes of cardiac arrest and improve adherence to evidence-based resuscitation protocols. Consequently, the observed benefit likely reflects greater clinical capability rather than simply increasing the number of personnel attending the scene.

The present findings are also consistent with current international resuscitation guidelines, which emphasis the timely delivery of advanced life support interventions alongside uninterrupted high-quality CPR [23,24]. Although chest compressions remain the cornerstone of cardiac arrest management, ALS interventions become increasingly important during prolonged resuscitation and in selected shockable and non-shockable arrest rhythms.

Simulation studies have consistently demonstrated that larger EMS crews perform resuscitation tasks more efficiently than smaller teams. Tsai et al. reported that crews of four or more providers achieved higher chest compression fractions and shorter times to epinephrine administration and endotracheal intubation [12]. Similarly, Robakowska et al. found that three-person crews delivered higher-quality CPR, shorter interruptions in chest compressions, faster defibrillation, and earlier drug administration than two-person teams [18]. More recently, Yoon et al. demonstrated that three-person EMS crews were more likely to achieve guideline-recommended chest compression rates, although no significant differences were observed in compression depth or chest compression flow time. Importantly, the Yoon study did not evaluate clinical outcomes such as ROSC or survival [25].

Despite these improvements in procedural performance, our study did not demonstrate an independent association between larger crew size and ROSC. This apparent discrepancy likely reflects the complex nature of OHCA outcomes. While larger teams may improve technical aspects of resuscitation, survival is also influenced by numerous patient- and system-level factors, including witnessed arrest, bystander CPR, initial rhythm, arrest aetiology, EMS response intervals, and post-resuscitation hospital care. Improvements in procedural efficiency alone may therefore be insufficient to produce measurable improvements in patient survival.

Consistent with previous OHCA literature, an initial shockable rhythm remained the strongest independent predictor of ROSC across all three regression models, approximately doubling the odds of successful resuscitation. This finding aligns with numerous international registry studies demonstrating superior outcomes among patients presenting with ventricular fibrillation or pulseless ventricular tachycardia [9-11]. In contrast, age and EMS response time were not independently associated with ROSC after adjustment, suggesting that arrest-specific characteristics may exert a greater influence on immediate resuscitation outcomes than demographic factors alone. Interestingly, male patients demonstrated significantly lower odds of ROSC than females, although the reasons underlying this association remain uncertain and warrant further investigation.

This study has several strengths. It represents the first investigation of EMS crew composition and ROSC within Saudi Arabia and utilised a large multicentre cohort derived from routinely collected SRCA registry data. Separate multivariable regression models were developed to evaluate crew size, crew configuration, and ALS provider numbers independently, thereby avoiding multicollinearity between closely related workforce variables. All analyses were adjusted for clinically important confounders, including age, sex, EMS response time, and initial cardiac rhythm.

Several limitations should also be acknowledged. First, the retrospective observational design precludes causal inference, and residual confounding cannot be excluded. Important predictors of OHCA outcome, including bystander CPR, public access defibrillation, dispatcher-assisted CPR, arrest location, arrest aetiology, duration of resuscitation, CPR quality, and post-resuscitation hospital care, were unavailable within the registry. Second, ROSC was the only patient outcome evaluated; survival to hospital discharge and neurological outcomes were not available. Finally, these findings reflect a single national EMS system and may not be directly generalisable to EMS systems operating under different staffing models or dispatch structures.

5. Conclusions

In this large retrospective cohort study, EMS crew size was not independently associated with return of spontaneous circulation (ROSC) following out-of-hospital cardiac arrest after adjustment for important confounding variables. In contrast, ALS-only crew configuration was associated with significantly greater odds of ROSC, while increasing numbers of ALS providers demonstrated a positive, although not statistically significant, association with improved outcomes. These findings suggest that the clinical qualifications of EMS personnel may be more influential than crew size alone in determining prehospital resuscitation success. For EMS systems such as the Saudi Red Crescent Authority, optimising the proportion of ALS-qualified providers within ambulance crews may represent a more effective workforce strategy than simply increasing crew size. Prospective multicentre studies are needed to confirm these findings and evaluate their impact on survival to hospital discharge and long-term neurological outcomes.

Declarations

Data Availability

The datasets analyzed during the current study are not publicly available because they contain confidential patient information owned by the Saudi Red Crescent Authority but are available from the corresponding author upon reasonable request and with permission from the Saudi Red Crescent Authority.

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Conflicts of Interest

The authors declare no conflicts of interest.

Generative AI Disclosure

During the preparation of this manuscript, the authors used ChatGPT (OpenAI, GPT-5.5) to assist with language refinement, manuscript organisation, and improvement of clarity and readability. The authors reviewed and revised all AI-assisted content and take full responsibility for the accuracy, integrity, and final content of the manuscript.

Author Contributions

Abdullah Alharbi (Principal Investigator): Conceived and designed the study, developed the study protocol, obtained ethical approval, supervised the project, performed the statistical analysis with Yasir Almukalfi, interpreted the data, and drafted the manuscript.

Fares Shahata (Co-Principal Investigator): Contributed to study conception and design, co-developed the study protocol, obtained ethical approval, coordinated data acquisition, and critically revised the manuscript.

Yasir Almukalfi (Co-Principal Investigator): Contributed to study design, supervised the statistical analysis, interpreted the findings, and critically revised the manuscript.

Bander Alanazi: Contributed to study design, collected study data and critically revised the manuscript.

Ahmed Basim, Anas Alghamdi, Omar Alansari, and Mohammed Alqabsani: Collected and curated the study data and critically reviewed the manuscript.

All authors contributed to the interpretation of the findings, critically revised the manuscript for important intellectual content, approved the final version of the manuscript, and agree to be accountable for all aspects of the work.

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Figures

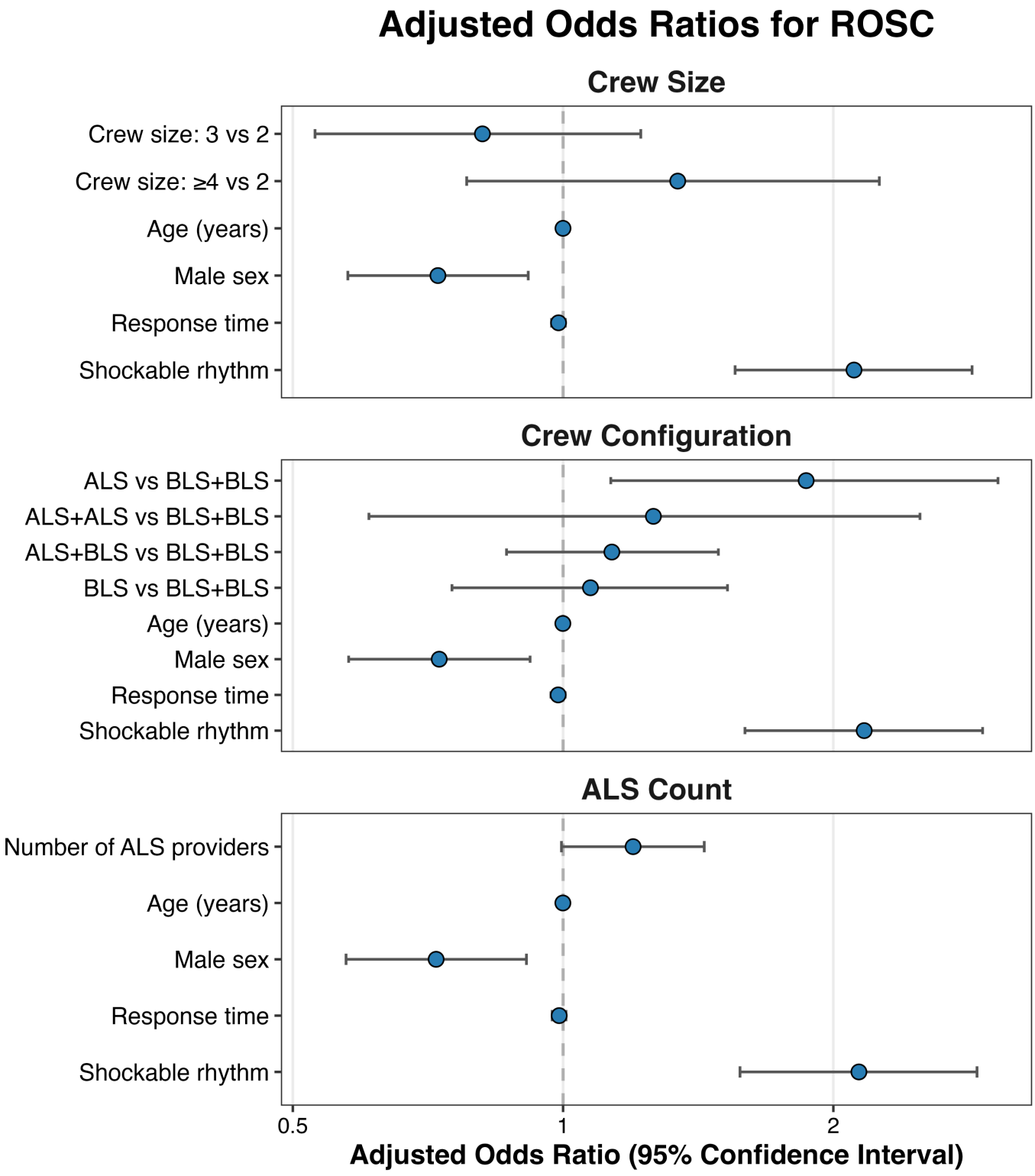


Figure 1

Adjusted odds ratios for the association between EMS crew composition and return of spontaneous circulation (ROSC). Forest plot showing adjusted odds ratios (ORs) and 95% confidence intervals (CIs) from the three multivariable logistic regression models. All models were adjusted for age, sex, EMS response time, and initial cardiac rhythm.

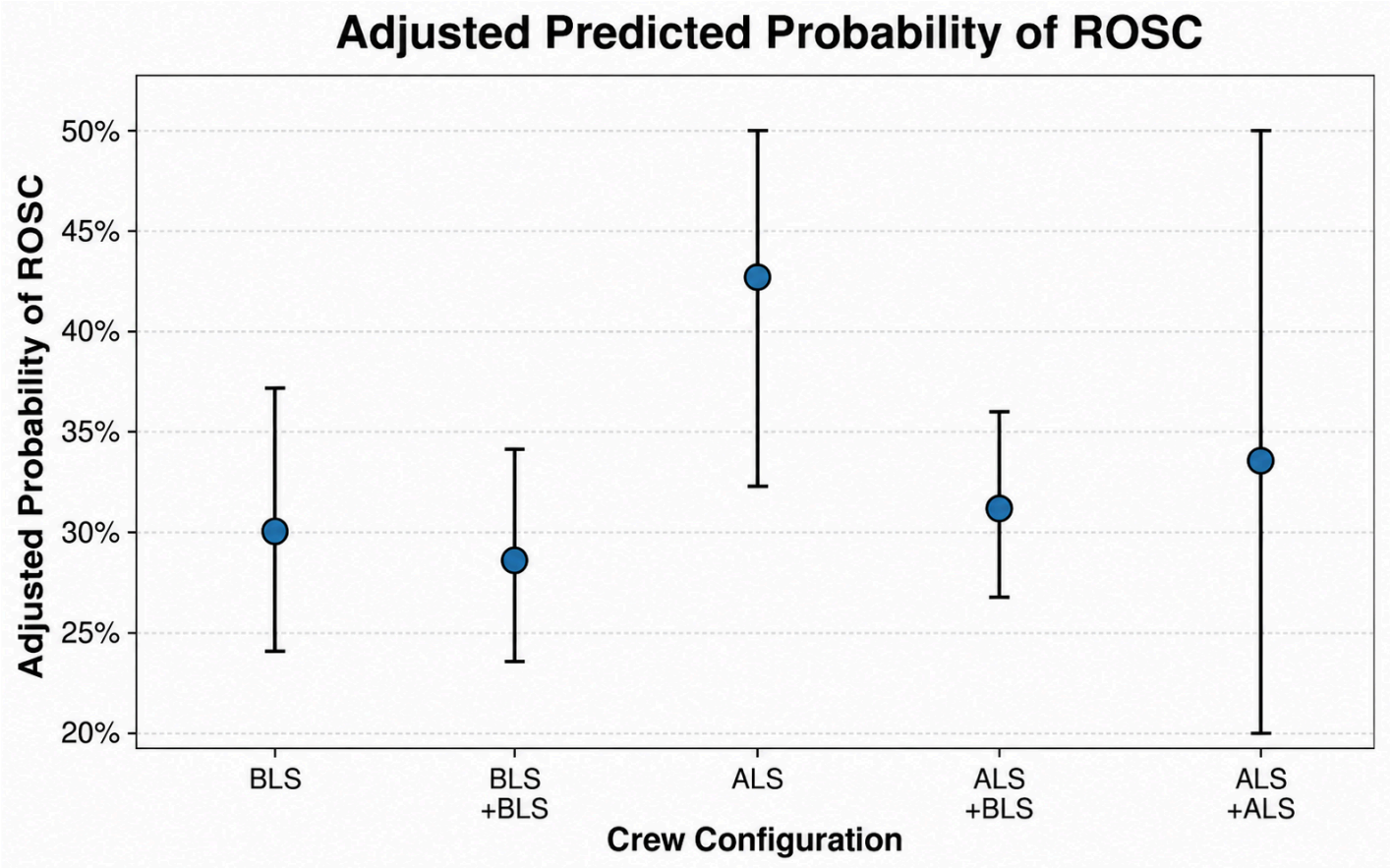


Figure 2

Adjusted predicted probability of return of spontaneous circulation according to EMS crew configuration. Predicted probabilities of ROSC estimated from the adjusted logistic regression model evaluating crew configuration. Error bars represent 95% confidence intervals.

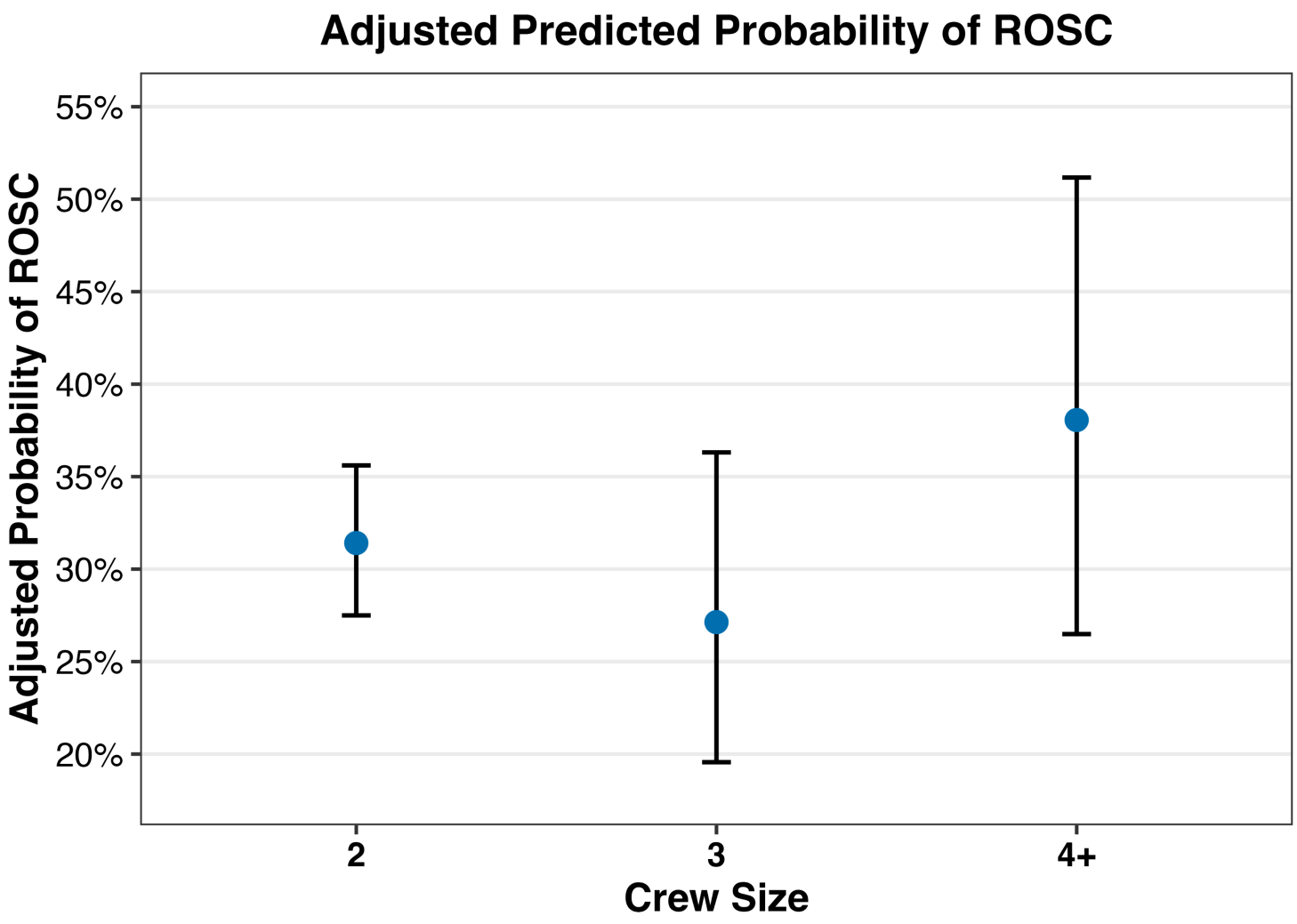


Figure 3

Adjusted predicted probability of return of spontaneous circulation according to EMS crew size. Predicted probabilities of ROSC estimated from the adjusted logistic regression model evaluating crew size. Error bars represent 95% confidence intervals.