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Operational factors associated with response time in a 24/7 physician-staffed medical intervention car system: a retrospective observational study

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Abstract

Background

Specialized physician-staffed prehospital units must balance access to advanced interventions with continuous staffing demands. Evidence on hybrid systems combining on-site and home-based on-call deployment is limited. This study evaluated response time and its operational determinants in a 24/7 physician-staffed Medical Intervention Car (MIC) system.

Methods

This retrospective observational study included all MIC activations in a German emergency medical services system from 2 December 2024 to 1 December 2025. The primary outcome was response time among missions with confirmed patient contact. A prespecified multivariable linear regression model included travel distance, operational period, interregional dispatch, extracorporeal membrane oxygenation (ECMO)-related mission, and public-holiday status. Comparisons between on-site and on-call periods and clinical outcomes were secondary or exploratory.

Results

Among 493 activations, 342 (69.4%) involved confirmed patient contact and had a calculable response time; 151 (30.6%) were cancelled before MIC arrival. Mean response time among missions with confirmed patient contact was 16.4 (standard deviation 7.5) minutes and was longer during on-call than on-site periods (17.6 vs 14.3 minutes). After adjustment, each additional kilometre was associated with 27.6 seconds longer response time (95% confidence interval [CI] 22.9 to 32.2), and ECMO-related missions with 137.4 seconds longer response time (95% CI 65.3 to 209.6). The adjusted association with on-call operation was 35.1 seconds (95% CI -40.9 to 111.0). Cancellation before arrival was more frequent during on-call periods (35.2% vs 21.5%). Return of spontaneous circulation and survival to hospital admission were available only as exploratory early outcomes and did not materially differ between periods.

Conclusion

In this hybrid MIC system, response time among missions with confirmed patient contact was associated mainly with travel distance and ECMO-related mission logistics; the adjusted association with standby configuration was small and imprecise. These findings support evaluation of resource location and complex deployment pathways. Because operational period was inseparable from time of day and cancellations differed between periods, the results do not establish causal equivalence between standby models.

Introduction

Physician-staffed emergency medical services (EMS) provide advanced interventions and clinical expertise at the scene of time-critical emergencies. Timely access matters particularly in out-of-hospital cardiac arrest and major trauma, although the relationship between response time and outcome depends on the clinical condition, bystander actions, dispatch processes, and the wider EMS configuration [1–6]. Response time is therefore both a clinically relevant interval and a system-level performance measure.

Specialized non-transport units extend conventional EMS capabilities through procedures, equipment, or subspecialist expertise that cannot be maintained on every response vehicle. Continuous availability is difficult to staff, however. Fixed on-site deployment supports immediate mobilization, whereas home-based on-call deployment may facilitate 24/7 coverage but introduces variation in starting location and mission pathways. Published comparisons of deployment concepts remain limited and are difficult to interpret without accounting for geography and mission characteristics [7–9].

In December 2024, a 24/7 physician-staffed Medical Intervention Car (MIC) system combining hospital-based daytime service with home-based on-call coverage was introduced in Stuttgart, Germany. The primary objective of this study was to quantify response time and assess prespecified operational factors associated with it. Secondary objectives were to describe on-site and on-call periods, cancellations before arrival, and early clinical outcomes. The analysis was intended to inform deployment planning rather than estimate a causal effect of standby configuration.

Methods

Study design and setting

This retrospective observational cohort study included every MIC activation from 2 December 2024 to 1 December 2025. The study area was Stuttgart, Germany, a metropolitan region of approximately 635,000 inhabitants. Reporting followed the STROBE recommendations.

The MIC is a physician-staffed, non-transport unit integrated into the municipal EMS and dispatched for predefined high-acuity indications or at the request of personnel already on scene. It supplements standard ambulance and physician-staffed EMS resources rather than replacing them. Senior physicians in anaesthesiology and intensive care medicine provide advanced airway management, point-of-care ultrasound including transoesophageal echocardiography, blood product administration, invasive procedures, and prehospital extracorporeal cardiopulmonary resuscitation (ECPR). Subspecialists may join selected paediatric, neonatal, or ECPR missions. System capabilities are summarized in Supplementary Tables S1 and S2.

On weekdays from 08:00 to 17:00, the team, vehicle, and equipment were based at the hospital. At other times, including weekends and public holidays, the physician and vehicle were home-based within the

city. Selected on-call missions required an intermediate hospital stop to collect personnel or equipment. Only one MIC resource was available; consequently, operational period was predetermined by dispatch time and intrinsically coupled to time of day and day of week.

Participants and study population

An activation was defined as any MIC dispatch, irrespective of subsequent cancellation or patient contact. All 493 activations were included in descriptive analyses. Of these, 342 missions involved confirmed patient contact, whereas 151 were cancelled before MIC arrival. Cancelled missions had no arrival timestamp and therefore no calculable response time. The response-time analysis and the analysis of survival to hospital admission comprised the 342 missions with confirmed patient contact. ROSC was assessed only among the 177 cardiac-arrest missions with confirmed patient contact.

Turnout time was the interval from alarm to vehicle departure, driving time from departure to scene arrival, and response time from alarm to scene arrival. The primary outcome was response time. Secondary operational measures were turnout time, driving time, travel distance, cancellation before arrival, and mission characteristics. Exploratory early clinical outcomes were prehospital ROSC and survival to hospital admission. An ECMO-related mission comprised activation for possible prehospital ECPR or support of ECPR at another hospital, whether or not extracorporeal support was initiated.

Data sources and bias

Timestamps came directly from the computer-aided dispatch system and mission characteristics from structured fields in the electronic MIC record. No variables were abstracted from narrative records. Road-network distance was calculated from the actual starting location to the scene, including intermediate stops. Travel distance was available for all missions and turnout time for 475 (96.3%). Response and driving times were structurally unavailable for all 151 cancellations; no imputation was performed. Because cancellation was more frequent during on-call periods, comparisons of response time are conditional on confirmed patient contact and may be affected by differential selection.

Statistical analysis

Continuous data are reported as mean (standard deviation [SD]) or median (interquartile range [IQR]) according to their distribution and clinical interpretability; categorical data are reported as number (percentage). Distributional form and model suitability were assessed graphically. The primary analysis used multivariable linear regression with response time in seconds as the dependent variable. Travel distance, operational period, interregional dispatch, ECMO-related mission, and public-holiday status were specified before analysis based on operational plausibility. Model assumptions were assessed using residual plots, the Durbin-Watson statistic, variance inflation factors, tolerance, and condition

indices. An interaction between distance and operational period and sensitivity analyses excluding ECMO-related and interregional missions were exploratory.

Effect estimates are presented with 95% CIs. No adjustment for multiplicity was applied. The prespecified primary model was interpreted from the magnitude and precision of its coefficients; secondary and exploratory analyses were considered hypothesis-generating and were not interpreted solely from P values. No formal sample-size calculation was performed because all missions during the predefined period were included. Analyses used IBM SPSS Statistics version 30 (IBM Corp., Armonk, NY, USA).

During manuscript preparation, the authors used ChatGPT (OpenAI, San Francisco, CA, USA) for English-language editing and assistance with manuscript formatting. The tool was not used for data collection, statistical analysis, or interpretation of the results. All generated content was critically reviewed and edited by the authors, who take full responsibility for the final manuscript.

Results

Cohort and operational performance

The MIC was activated 493 times: 163 (33.1%) during on-site and 330 (66.9%) during on-call periods. Of the 493 MIC activations, 342 (69.4%) involved confirmed patient contact, whereas 151 (30.6%) were cancelled before MIC arrival (Fig. 1). Adult cardiac arrest accounted for 250 activations (50.7%), paediatric or neonatal emergencies for 86 (17.4%), and ECMO-related missions for 252 (51.1%). Mission and operational characteristics are shown in Table 1.

Table 1
Mission and operational characteristics during the study period. Values are n (%) or mean (SD). Response and driving times were structurally unavailable for missions cancelled before arrival. Group comparisons are descriptive; inferential estimates for response time are reported in Table 2.

Characteristic	Total	On-site	On-call
Activations	493	163	330
Confirmed patient contact	342 (69.4)	128 (78.5)	214 (64.8)
Cancelled before MIC arrival	151 (30.6)	35 (21.5)	116 (35.2)
Primary dispatch	366 (74.2)	124 (76.1)	242 (73.3)
Interregional dispatch	56 (11.4)	15 (9.2)	41 (12.4)
Adult cardiac arrest	250 (50.7)	82 (50.3)	168 (50.9)
Paediatric/neonatal emergency	86 (17.4)	38 (23.3)	48 (14.5)
ECMO-related mission	252 (51.1)	82 (50.3)	170 (51.5)
Prehospital ECPR	45 (9.1)	20 (12.3)	25 (7.6)
Travel distance, km	12.0 (10.1)	8.4 (8.2)	13.7 (10.5)
Turnout time, min	2.1 (1.6)	1.7 (1.3)	2.2 (1.7)
Driving time, min	14.4 (7.3)	12.7 (5.9)	15.4 (8.0)
Response time, min	16.4 (7.5)	14.3 (5.8)	17.6 (8.2)

Across the 342 missions with confirmed patient contact, mean response time was 982.0 (95% CI 934.0 to 1030.0; SD 452.4) seconds or 16.4 (SD 7.5) minutes. Mean response time was 855.7 (SD 346.3) seconds during on-site periods and 1057.5 (SD 490.7) seconds during on-call periods, an unadjusted difference of 201.9 seconds (95% CI 104.7 to 299.1). Mean travel distance was 7.8 (SD 7.3) km in the on-site and 13.8 (SD 10.7) km in the on-call response-time cohorts. Turnout time was available for 476 activations and averaged 104.9 (SD 78.3) seconds on site and 132.6 (SD 99.5) seconds on call. Cancellations occurred in 35/163 (21.5%) on-site and 116/330 (35.2%) on-call activations.

Factors associated with response time

The prespecified multivariable model explained 49.7% of response-time variance (adjusted R^2=0.489). Each additional kilometre was associated with 27.6 seconds longer response time (95% CI 22.9 to 32.2), and an ECMO-related mission with 137.4 seconds longer response time (95% CI 65.3 to 209.6). After adjustment, the estimate for on-call operation was 35.1 seconds (95% CI -40.9 to 111.0). Estimates for interregional dispatch and public-holiday status were imprecise and included no difference (Table 2). Variance inflation factors were below 2.

Table 2
Prespecified multivariable linear regression of factors associated with response time among missions with confirmed patient contact (n = 342). Coefficients represent differences in response time in seconds. The model explained 49.7% of the variance (adjusted R^2=0.489). Confidence intervals and P values were not adjusted for multiplicity.

Variable	Adjusted coefficient, s	Unadjusted 95% CI	P value
Travel distance, per km	27.6	22.9 to 32.2	< 0.001
On-call operational period	35.1	−40.9 to 111.0	0.364
Interregional dispatch	62.8	−67.2 to 192.7	0.343
ECMO-related mission	137.4	65.3 to 209.6	< 0.001
Public-holiday mission	−27.8	−197.9 to 142.2	0.748

There was no evidence that the association between travel distance and response time differed by operational period. The adjusted interaction estimate was 1.5 seconds per kilometre (unadjusted 95% CI − 7.3 to 10.4; P = 0.730; Supplementary Table S6). In sensitivity analyses, exclusion of ECMO-related missions or interregional dispatches did not materially change the association between travel distance and response time. The adjusted association with on-call operation remained small and imprecise in both models (Supplementary Table S7).

Exploratory clinical outcomes

Among 177 cardiac arrest missions with confirmed patient contact, ROSC occurred in 40/66 (60.6%) on-site and 57/111 (51.4%) on-call missions. Survival to hospital admission was documented in 107/128 (83.6%) on-site and 172/214 (80.4%) on-call missions with confirmed patient contact, respectively. These outcomes were neither designed nor powered to establish equivalence or a causal effect of operational period, and long-term outcomes were unavailable.

Discussion

Principal findings

In this complete one-year cohort of a 24/7 specialized physician-staffed response system, on-call missions with confirmed patient contact had a mean unadjusted response time approximately 3.4 minutes longer than corresponding on-site missions. Most of this difference was associated with longer travel routes and mission-specific logistics. After adjustment, the estimate attributed to operational period was small and imprecise, whereas distance and ECMO-related missions retained clear associations with response time. Cancellations were also more frequent during on-call periods; therefore, the response-time findings are conditional on confirmed patient contact.

Interpretation and implications

The distance-response time association is expected, but its operational implication is not trivial for a specialized resource whose starting location changes across the day. It shows that comparisons based only on standby category can misattribute spatial and pathway effects to staffing configuration. Previous EMS studies similarly identify geography, resource distribution, and deployment location as major determinants of response time [6–9]. The present study extends those observations to a continuously available unit that combines hospital-based and decentralized deployment and provides advanced procedures including ECPR. Earlier cardiac-arrest research also suggests that shorter access to definitive resuscitation, particularly defibrillation, may improve survival, although those data concern conventional EMS pathways rather than specialized add-on units [10, 11].

The additional time associated with ECMO-related missions persisted after adjustment for route length. Deployment structures differ across physician-staffed EMS systems and depend on regional geography, available resources, and organizational context [9, 12]. Intermediate hospital stops, specialist rendezvous, and mission-specific equipment preparation are plausible contributors. These findings identify two potentially modifiable components of system design: vehicle positioning and the organization of complex deployment pathways. Co-location of personnel and equipment, alternative decentralized bases, or proximity-based positioning could reduce delay, but their effects and resource implications require prospective evaluation.

The early outcome data provide clinical context but cannot demonstrate benefit or harm from either operational period. Conventional EMS resources were dispatched independently and could deliver established emergency care before MIC arrival; their arrival times were unavailable. The value proposition of a specialized MIC therefore cannot be inferred from response time alone. Future evaluation should combine operational intervals with interventions delivered, time to advanced treatment, patient-centred outcomes, and cost.

Limitations

This single-system study may not generalize to other geographies or EMS structures. Operational period was structurally coupled to time of day, day of week, starting location, and potentially traffic and workload; residual confounding precludes causal comparison of standby models. Response time was observable only for missions with confirmed patient contact. Because cancellation occurred more frequently during on-call periods, the response-time comparison is conditional on patient contact and may be affected by differential selection. Detailed traffic, weather, concurrent resource availability, and arrival times of standard EMS units were unavailable. Patient physiology and long-term outcomes were not collected, and the clinical analyses were underpowered. Finally, confidence intervals and P values were not adjusted for multiplicity; secondary and exploratory analyses should therefore be interpreted as hypothesis-generating.

Conclusion

Within this hybrid 24/7 MIC system, response time among missions with confirmed patient contact was associated mainly with travel distance and ECMO-related mission logistics. After adjustment for measured operational factors, the association between operational period and response time was small and imprecise. These findings support evaluation of resource location and complex deployment pathways when organizing continuous access to specialized prehospital care, but they do not establish causal equivalence between on-site and on-call models.

Abbreviations

CI
Confidence interval
ECMO
Extracorporeal membrane oxygenation
ECPR
Extracorporeal cardiopulmonary resuscitation
EMS
Emergency medical services
IQR
Interquartile range
MIC
Medical Intervention Car
ROSC
Return of spontaneous circulation
SD
Standard deviation

Declarations

Ethics approval and consent to participate

The study was submitted to the Ethics Committee of the State Medical Association of Baden-Württemberg (Landesärztekammer Baden-Württemberg; reference F-2025-134). The committee determined that formal ethical review or approval was not required because the analysis used a pseudonymized routine operational dataset without directly identifying information or linkage to additional hospital records. The requirement for informed consent was waived because of the retrospective design and use of pseudonymized data.

Consent for publication

Not applicable.

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Author Contribution

MB contributed to the conceptualization and design of the study, development of the methodology, data curation, formal analysis, visualization, project administration, and preparation of the original manuscript draft.DR contributed to the investigation, acquisition and validation of operational data, clinical interpretation of the findings, and critical review and editing of the manuscript.JoS contributed to the investigation, operational implementation of the MIC system, acquisition and validation of operational data, and critical review and editing of the manuscript.JeS contributed to the investigation, operational implementation of the MIC system, acquisition and validation of operational data, and critical review and editing of the manuscript.MO contributed to the investigation, acquisition and validation of clinical data, clinical interpretation of the findings, and critical review and editing of the manuscript.AW contributed to the study methodology, supervision of the project, interpretation of the findings, and critical review and editing of the manuscript.MM contributed to the clinical interpretation of the findings, particularly regarding paediatric and congenital cardiac care, and critical review and editing of the manuscript.NR contributed to the clinical interpretation of the findings, particularly regarding neonatal and paediatric emergency care, and critical review and editing of the manuscript.CW contributed to the study methodology, supervision of the project, interpretation of the findings, and critical review and editing of the manuscript.All authors read and approved the final manuscript, agreed to be personally accountable for their own contributions, and agreed to ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Data Availability

The datasets used and analysed during the current study are not publicly available because they contain operational emergency-service data subject to institutional and data-protection requirements, but are available from the corresponding author on reasonable request and with the necessary institutional permissions.

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Figures

Figures

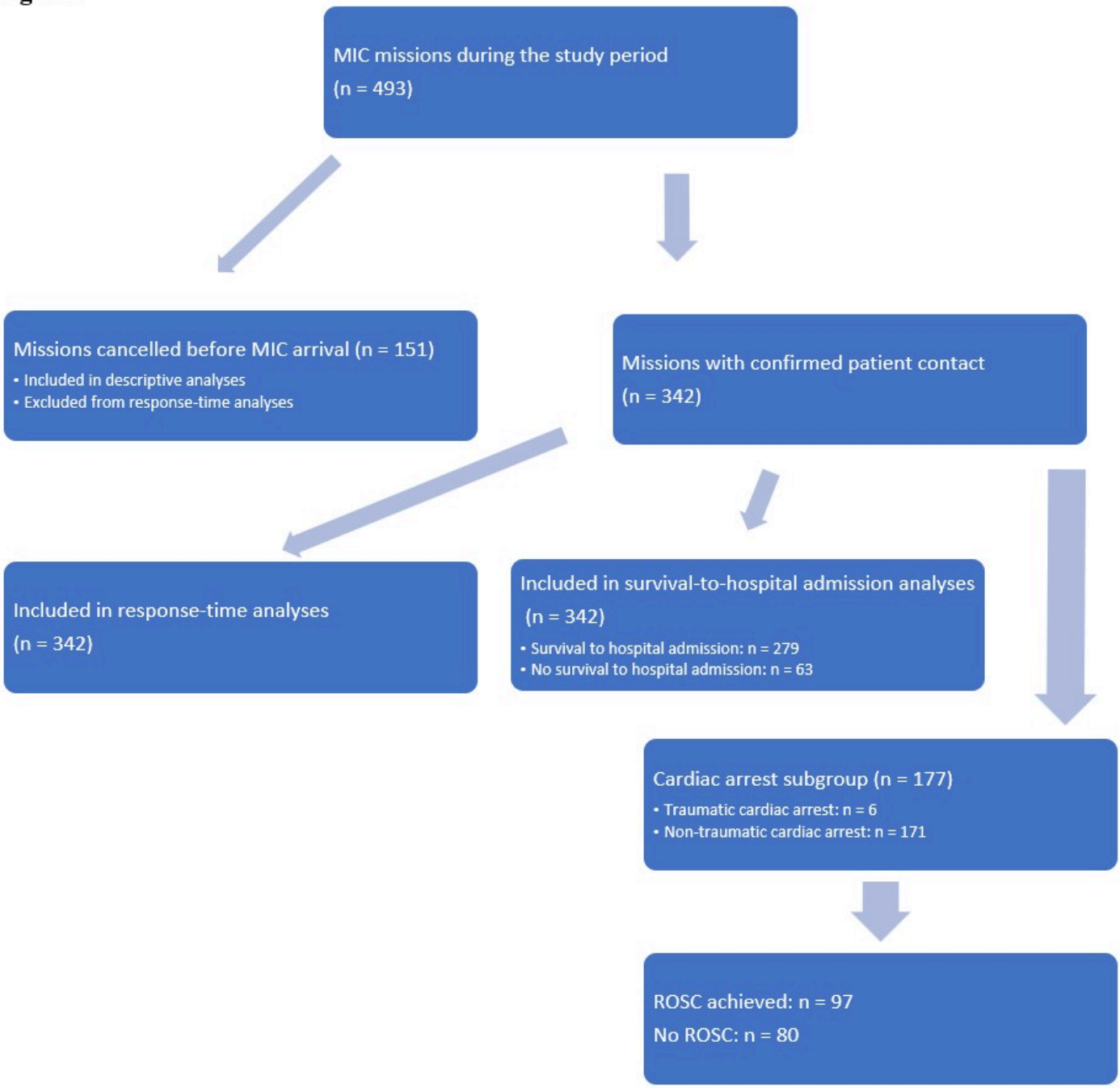


Figure 1

Flow of MIC activations through the operational and clinical analyses. All 493 activations were included in descriptive analyses. Response time and survival to hospital admission were assessed among the 342 missions with confirmed patient contact. ROSC was assessed among the 177 cardiac-arrest missions with confirmed patient contact.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryMICOPIJEM.docx