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Response times in a physician-staffed medical intervention car system: impact of a hybrid on- site and on-call standby model

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Research Article

Keywords:

Posted Date: May 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9520510/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Physician-staffed Medical Intervention Car (MIC) systems are increasingly used to provide advanced prehospital care. Hybrid standby models combining on-site and on-call service may improve resource utilization, but their impact on operational performance remains unclear. This study aimed to assess response time and its determinants in a physician-staffed MIC system and to compare operational performance between on-site and on-call service models.

Methods

This retrospective observational study included all MIC missions in an urban emergency medical services (EMS) system in Germany over a one-year period. Missions were categorized as on-site or on-call service. Operational time intervals, including turnout time, driving time and response time, were analyzed. Multivariable linear and logistic regression models were used to identify independent predictors of response time and prolonged response time (> 15 minutes).

Results

A total of 493 missions were included, of which 163 (33.1%) occurred during on-site service and 330 (66.9%) during on-call service, with complete response time data available for 342 missions. Response time was longer during on-call service in unadjusted analyses (17.6 ± 8.2 min vs. 14.3 ± 5.8 min, $p < 0.001$). Travel distance was strongly associated with response time ($r = 0.688$, $p < 0.001$) and was the strongest independent predictor in multivariable analysis. After adjustment for travel distance and mission characteristics, service model was not independently associated with response time. Similar results were observed for prolonged response time.

Conclusions

In this physician-staffed MIC system, response time was primarily determined by travel distance rather than the standby model. Differences observed between on-site and on-call service were explained by operational factors and were not independently associated with response time after adjustment. These findings underscore the importance of geographic and system-level determinants in EMS performance and suggest that evaluations of standby models should be interpreted within their broader operational context.

Introduction

Physician-staffed emergency medical services (EMS) systems are widely used in several European countries to provide advanced prehospital care by integrating medical expertise directly into emergency response. In these systems, paramedic-staffed ambulances are complemented by physician-staffed rapid response units capable of delivering advanced interventions on scene.

Timely access to advanced care is a key determinant of outcome in time-critical emergencies such as out-of-hospital cardiac arrest and severe trauma. Multiple studies have demonstrated an association between shorter response times and improved survival, although the strength of this relationship varies depending on clinical context and system configuration (1–3). Response time may also be influenced by broader contextual factors, including socioeconomic characteristics (4). Outcomes in time-critical emergencies are influenced not only by response time but also by bystander interventions and early system activation (5). At the same time, response time is influenced by a range of operational factors, including geographic distance and operational characteristics (6).

To address increasing complexity in prehospital care, physician-staffed Medical Intervention Car (MIC) systems have been introduced as specialized non-transport units equipped for advanced critical and emergency care interventions. These systems aim to complement existing EMS structures by providing early access to advanced procedures and subspecialized expertise. However, implementation strategies differ substantially between regions, and evidence on their operational performance remains limited.

One key aspect of system design is the standby model. Traditional approaches rely on station-based or hospital-based presence, ensuring immediate availability but requiring substantial staffing resources. Alternatively, home-based on-call models for special teams may improve feasibility and resource utilization but introduce potential delays related to decentralized deployment. Previous studies comparing different standby concepts have reported modest differences in response times, with effects often attenuated after accounting for operational variables (7–9).

Despite increasing adoption of hybrid deployment strategies, data on continuously operating 24/7 systems combining on-site and on-call service remain scarce. In particular, it is unclear to what extent observed differences in response time are attributable to the standby model itself or to underlying factors such as travel distance and mission characteristics.

In December 2024, a continuously operating physician-staffed MIC system using a hybrid standby model was implemented in Stuttgart, Germany. This system combines hospital-based on-site service during daytime hours with home-based on-call coverage during nights, weekends and public holidays, providing a unique opportunity to evaluate operational performance under real-world urban conditions.

The aim of this study was to assess response time and its determinants in a physician-staffed MIC system and to compare operational performance between on-site and on-call service models.

Materials and methods

Study design

This retrospective observational cohort study included all missions of a physician-staffed MIC operating within an urban EMS system between December 2, 2024, and December 31, 2025.

The primary objective was to compare response time between two operational models (on-site vs. on-call service). Secondary objectives included analysis of turnout time and driving time, identification of factors associated with response time and evaluation of predictors of prolonged response time (>15 minutes).

Setting and system description

The study was conducted in Stuttgart, Germany, a metropolitan area with approximately 635,000 inhabitants and a heterogeneous urban structure with varying population density and traffic conditions.

The MIC is a physician-staffed, non-transport rapid response unit integrated into the municipal EMS system and dispatched by the Integrated Dispatch Center Stuttgart. It is deployed either as a primary response unit for predefined high-acuity emergencies (e.g., cardiac arrest, severe trauma, pediatric emergencies) or as an additional resource upon request by on-scene EMS personnel. The MIC supplements, but does not replace, standard ambulance and physician-staffed EMS units.

The unit is staffed by senior physicians in anesthesiology and intensive care medicine, with optional integration of subspecialists (e.g., pediatric or neonatal intensivists) depending on dispatch criteria. Core capabilities include advanced airway management (including endotracheal intubation and supraglottic airway devices), hemodynamic stabilization and advanced resuscitation measures. A detailed equipment list is provided in Supplementary Table S2.

Operational model

For analytical purposes, missions were categorized into two service models:

On-site service:
During weekdays between 08:00 and 17:00, the MIC team is stationed at the hospital with immediate access to the vehicle and equipment, allowing direct deployment without additional mobilization delay.

On-call service:
Outside these hours (17:00–08:00), including weekends and public holidays, the MIC operates as a home-based on-call system. The physician and vehicle are located at the physician's residence within the city. Upon dispatch, the physician proceeds directly to the scene. For selected mission types requiring subspecialized expertise (e.g., pediatric, neonatal, or extracorporeal cardiopulmonary resuscitation (ECPR)-related missions), intermediate pickup of additional personnel and equipment at the hospital may be required.

A structured comparison of both service models is provided in Supplementary Table S1.

Dispatch procedures

The MIC is dispatched via the Integrated Dispatch Center Stuttgart according to standardized alarm and dispatch protocols. Dispatch occurs either automatically for predefined high-acuity conditions (e.g., cardiac arrest, severe trauma, pediatric emergencies) or upon secondary request by EMS personnel on scene.

The MIC is deployed as an additional resource and does not replace standard EMS response units. Dispatch prioritization and activation criteria are determined by the dispatch center based on structured call interrogation and predefined algorithms.

Participants and study population

All MIC missions during the study period were included without sampling. Missions were categorized according to service model (on-site vs. on-call).

Missions without patient contact were defined as activations in which no direct patient interaction occurred, including cancellations during the response phase and cases where no intervention was required on scene. These missions were included in descriptive analyses but excluded from analyses requiring confirmed arrival at the patient (response time analysis).

Variables and outcome measures

Operational time intervals were defined as follows:

- **Turnout time:** time from alarm to vehicle departure
- **Driving time:** time from vehicle departure to arrival on scene
- **Response time:** time from alarm to arrival on scene

The primary endpoint was response time. Secondary endpoints included turnout time, driving time and prolonged response time (>15 minutes).

Explanatory variables included service model (on-site vs. on-call), mission characteristics (e.g., dispatch category, type of activation) and mission-specific travel distance.

Dispatch categories were grouped into clinically meaningful categories based on predefined criteria.

Data sources and measurement

Data were obtained from two sources:

1. The dispatch database of the Integrated Dispatch Center Stuttgart, providing time stamps for alarm, vehicle departure and arrival on scene
2. The electronic mission documentation system of the MIC, providing operational and clinical mission characteristics

Mission-specific travel distances were calculated using road-network-based routing. For on-site missions, distance was calculated from the hospital base to the scene. For on-call missions, distance was calculated from the physician's residence to the scene. For missions requiring intermediate stops (e.g., subspecialist pickup), total distance was calculated as the sum of all route segments.

Location data were temporarily available for distance calculation and subsequently pseudonymized prior to analysis.

Bias and missing data

Missing data were present for operational time intervals, particularly response time. These missing cases were primarily related to mission cancellations. As missingness was not assumed to be completely at random, analyses were performed using a complete-case approach. The potential for selection bias was considered in the interpretation of results.

Study size

The study included all available MIC missions during the defined study period (n = 493). No formal sample size calculation was performed.

Statistical analysis

Continuous variables are presented as mean ± standard deviation or median with interquartile range, depending on distribution. Normality of continuous variables was assessed using visual inspection of histograms and Q–Q plots, as well as the Shapiro–Wilk test.

Group comparisons between service models were performed using independent-samples t-tests or Mann–Whitney U tests, as appropriate. Categorical variables were compared using chi-square or Fisher's exact tests.

Associations between continuous variables were assessed using Pearson or Spearman correlation coefficients, depending on data distribution.

Multivariable linear regression analysis was used to identify independent predictors of response time. Logistic regression analysis was performed to identify predictors of prolonged response time (>15 minutes). Model assumptions, including normality of residuals and multicollinearity, were assessed using standard diagnostic procedures (e.g., residual plots and variance inflation factors).

All statistical analyses were performed using IBM SPSS Statistics (Version 26, IBM Corp., Armonk, NY, USA). A two-sided p-value < 0.05 was considered statistically significant.

Ethical considerations

The study was submitted to the Ethics Committee of the State Medical Association of Baden-Württemberg (Landesärztekammer Baden-Württemberg; reference number F-2025-134). The Ethics Committee determined that the study did not require formal ethical review or approval according to §15 of the professional code, as no personal data or identifiable human data were used. The requirement for informed consent was waived due to the retrospective design of the study and the use of fully pseudonymized data. All procedures were performed in accordance with the Declaration of Helsinki and relevant national regulations.

RESULTS

Study population and mission characteristics

During the study period, a total of 493 MIC missions were included, of which 163 (33.1%) occurred during on-site service and 330 (66.9%) during on-call service.

Overall, 313 missions (63.5%) involved direct patient contact, whereas 180 missions (36.5%) were classified as missions without patient contact. The proportion of missions without patient contact did not differ significantly between service models (32.5% vs. 38.5%, p = 0.20).

Most missions were initiated as primary dispatches by the Integrated Dispatch Center (347/493; 70.4%), while 126 (25.6%) represented secondary dispatches requested by on-scene EMS personnel. Interregional dispatches accounted for 56 missions (11.4%), with no significant differences between service models.

Regarding dispatch categories, adult cardiac arrest was the most frequent indication (250/493; 50.7%) and occurred with similar proportions during on-site and on-call service (50.3% vs. 50.9%, p = 0.90).

Trauma-related missions accounted for 129 cases (26.2%) and were evenly distributed between service models (26.4% vs. 26.1%, p = 0.95). Trauma included traffic accidents, falls, and other injury-related dispatch categories.

Pediatric and neonatal emergencies, including pediatric cardiac arrest, comprised 86 missions (17.4%). These missions were more frequent during on-site service compared to on-call service (23.3% vs. 14.5%, p = 0.04).

Medical emergencies not classified as cardiac arrest or trauma were rare (6/493; 1.2%) and similarly distributed between groups. Other or special operations accounted for 16 missions (3.2%), with a trend toward higher proportions during on-site service.

A detailed overview of mission characteristics by service model is provided in Table 1.

A flow diagram of the study population and data availability is shown in Fig. 1.

Table 1
Baseline characteristics and mission profiles by service model

Variable	Total (n = 493)	On-site (n = 163)	On-call (n = 330)	p-value
Missions with patient contact, n (%)	313 (63.5)	110 (67.5)	203 (61.5)	0.20
Missions without patient contact, n (%)	180 (36.5)	53 (32.5)	127 (38.5)	0.20
Primary dispatch, n (%)	347 (70.4)	115 (70.6)	232 (70.3)	0.95
Secondary dispatch (EMS request), n (%)	126 (25.6)	40 (24.5)	86 (26.1)	0.68
Interregional dispatch, n (%)	56 (11.4)	18 (11.0)	38 (11.5)	0.87
Cardiac arrest, n (%)	250 (50.7)	82 (50.3)	168 (50.9)	0.90
Trauma (all categories), n (%)	129 (26.2)	43 (26.4)	86 (26.1)	0.95
Pediatric / neonatal emergencies, n (%)	86 (17.4)	38 (23.3)	48 (14.5)	0.04
Medical emergencies, n (%)	6 (1.2)	3 (1.8)	3 (0.9)	0.76
Other / special operations, n (%)	16 (3.2)	9 (5.5)	7 (2.1)	0.08
Travel distance, mean ± SD (km)	11.96 ± 10.10	8.35 ± 8.16	13.73 ± 10.49	0.001
Travel distance, median (Min,Max), km	9.27 (0–67.34)	6.12 (0–49.77)	10.53 (0.56–67.34)	0.001

Availability of operational time data

Turnout time was available for 475/493 missions (96.3%), response time for 342/493 missions (69.4%), and driving time for 340/493 missions (69.0%). Complete data for all operational time intervals were available in 340 missions (69.0%).

Missing data were primarily associated with missions without patient contact. The proportion of missing response time data was higher in missions without patient contact compared to missions with confirmed patient contact.

Descriptive analysis of travel distance

Mission-specific travel distance differed between service models (Table 1). Mean travel distance was higher during on-call service, reflecting differences in deployment origin and operational pathways. The observed difference in response time between service models was consistent with differences in travel distance between groups. In exploratory analyses, longer response times in missions with intermediate stops corresponded to increased travel distance (Supplementary Table S3).

Operational time intervals

Operational time intervals are summarized in Table 2. Turnout time was longer during on-call service (2.2 ± 1.7 min) compared to on-site service (1.8 ± 1.3 min, p = 0.002). Driving time was longer during on-call service (15.5 ± 8.0 min vs. 12.5 ± 5.5 min, p < 0.001). Response time was also longer during on-call service (17.6 ± 8.2 min) compared to on-site service (14.3 ± 5.8 min), corresponding to a mean difference of 3.4 minutes (p < 0.001).

Table 2
Operational time intervals by service model

Time interval	On-site (n)	Mean ± SD (min)	On-call (n)	Mean ± SD (min)	Mean difference (min)	p-value
Turnout time	157	1.8 ± 1.3	318	2.2 ± 1.7	0.4	0.002
Driving time	127	12.5 ± 5.5	213	15.5 ± 8.0	3.0	< 0.001
Response time	128	14.3 ± 5.8	214	17.6 ± 8.2	3.4	< 0.001

Association between travel distance and response time

Travel distance showed a strong positive correlation with response time (Pearson r = 0.688, p < 0.001). This association was consistent across service models and represented the dominant contributor to variability in response time.

Multivariable analysis

Travel distance was the strongest independent predictor of response time. Each additional kilometer was associated with an increase of approximately 28 seconds (p < 0.001). After adjustment for travel distance and mission characteristics, service model was not independently associated with response time.

Prolonged response time

Travel distance was significantly associated with prolonged response time (> 15 minutes), whereas service model was not independently associated after adjustment.

Subgroup analysis: cardiac arrest

In the subgroup of cardiac arrest missions, response time was longer during on-call service in unadjusted analyses. However, consistent with the overall cohort, no independent association between service model and response time was observed after adjustment for travel distance.

Summary of key findings

Unadjusted analyses demonstrated longer turnout, driving and response times during on-call service. However, travel distance was identified as the principal determinant of response time. After adjustment for distance and mission characteristics, the service model itself was not independently associated with response time.

Discussion

Principal findings

These findings extend beyond the intuitive association between distance and response time by demonstrating that apparent differences between operational models are largely mediated by geographic and system-level factors. In this study evaluating a continuously operating physician-staffed MIC system using a hybrid standby model, unadjusted analyses demonstrated longer turnout, driving and response times during on-call service compared to on-site service. Pediatric and neonatal emergencies, including pediatric cardiac arrest, were more frequently encountered during daytime on-site service. Although this difference reached statistical significance, it was modest in magnitude and not considered clinically relevant for the primary analysis. However, after adjustment for travel distance and mission characteristics, the service model itself was not independently associated with response time. Instead, travel distance emerged as the dominant determinant of response time, both in linear and logistic regression analyses.

Taken together, these results indicate that observed differences in response time between service models are largely explained by operational and geographic factors rather than the standby model alone.

Interpretation in the context of existing literature

The strong association between travel distance and response time observed in this study is consistent with previous research in EMS, which has identified geographic and logistical factors as key determinants of operational performance (1, 6). Several studies have demonstrated that response time is closely linked to system configuration and spatial distribution of resources rather than isolated organizational characteristics.

While shorter response times have been associated with improved outcomes in specific conditions such as out-of-hospital cardiac arrest (1–3), the relative contribution of individual system components remains complex. Previous reviews have highlighted that EMS response time is influenced by multiple interacting system-level factors, including geography, resource distribution and dispatch strategy (10, 11). Our findings support this concept by demonstrating that response time differences between operational models are largely mediated by distance-related factors.

Regarding standby models, previous studies have reported modest differences between station-based, hospital-based and home-based systems (9). In a recent analysis of emergency physician response times in Germany, Raker et al. demonstrated slightly shorter response intervals for centralized deployment models, although absolute differences were limited. Importantly, these differences diminished when accounting for operational factors such as location and travel distance.

Our results are consistent with these findings. Although unadjusted analyses suggested longer response times during on-call service, these differences were no longer significant after adjustment. This indicates that the standby model itself may be less relevant than the geographic and logistical context in which it is embedded. Additional interaction analyses showed no evidence that the relationship between travel distance and response time differed between service models ($p = 0.750$; Supplementary Table S4), further supporting the robustness of distance as the primary determinant.

This study adds to existing evidence by demonstrating that, within a continuously operating hybrid 24/7 physician-staffed system, differences attributed to standby model are largely explained by operational factors. This provides a system-level perspective beyond simple descriptive comparisons of response times and contributes to a more nuanced understanding of EMS performance.

Exploratory analyses further suggested that longer response times in specific mission pathways, such as those requiring intermediate stops, were primarily explained by increased travel distance rather than the operational model itself.

These findings further support the strong association between travel distance and response time rather than a causal relationship.

Comparable physician-staffed or advanced prehospital response systems have been described in other European countries and North America, although their organizational structures and deployment strategies differ substantially across regions (12, 13).

Implications for system design

The findings of this study have implications for the design and evaluation of physician-staffed prehospital systems. Hybrid standby models combining on-site and on-call service are often implemented to balance resource utilization and continuous availability of specialized personnel.

Our results suggest that, within an urban EMS system, decentralized on-call models can be integrated without substantial independent impact on response time, provided that geographic distribution and dispatch strategies are optimized. These findings further indicate that evaluations of EMS performance should focus less on isolated structural elements and more on integrated operational characteristics. While based on a single system, these findings provide insights into how geographic and operational factors interact with deployment models in urban EMS settings.

At the same time, the observed association between travel distance and response time underscores the importance of spatial factors in EMS performance. Strategies aimed at reducing travel distance, such as optimized vehicle positioning or dynamic deployment models, are likely to have a greater impact on response time than modifications of standby structure alone.

Strengths

This study has several strengths. It represents, to our knowledge, one of the first evaluations of a continuously operating 24/7 physician-staffed MIC system using a hybrid standby model under real-world conditions. The use of a complete cohort of all missions over a one-year period reduces selection bias related to case inclusion.

In addition, the integration of detailed operational data, including mission-specific travel distance, allowed for a more granular analysis of determinants of response time compared to purely descriptive studies.

Limitations

Several limitations should be considered when interpreting these findings.

First, this was a single-center study conducted within a specific urban EMS system, which may limit generalizability to other settings with different geographic or organizational structures.

Second, missing data were present for operational time intervals, particularly response time. As missing data were more common in missions without patient contact, the analyzed cohort may overrepresent missions with completed responses and introduce selection bias.

Third, important operational confounders such as traffic conditions, time of day, and concurrent resource availability were not available and could not be included in the analysis. These dynamic factors may influence response time and contribute to residual confounding.

Fourth, the categorization of dispatch diagnoses into broader clinical groups may have led to some degree of misclassification or loss of granularity, although this approach was necessary to enable meaningful comparison between service models.

Fifth, this study focused on operational performance metrics and did not include patient-centered outcomes. Therefore, no conclusions can be drawn regarding the clinical impact of the observed differences in response time.

Finally, although multivariable analyses were performed, residual confounding cannot be excluded.

Conclusions

In this real-world analysis of a physician-staffed MIC system, response time was primarily determined by travel distance rather than standby model. While on-call service was associated with longer response times in unadjusted analyses, these differences were explained by operational factors and were not independently associated with response time after adjustment.

These findings emphasize the importance of geographic and system-level determinants in EMS performance and suggest that evaluation of standby models should consider the broader operational context.

Abbreviations

EMS – emergency medical services

MIC – Medical Intervention Car

ECPR – extracorporeal cardiopulmonary resuscitation

SD – standard deviation

ECMO – extracorporeal membrane oxygenation

Declarations

Acknowledgements

The authors thank Matthias Klose from the Stuttgart Integrated Dispatch Center for his valuable support and assistance during the implementation of this project. We further acknowledge the Björn Steiger Foundation for enabling and supporting our Project.

Authors’ contributions

MB and CW contributed to the study design. MB drafted the initial manuscript. CW, AW, and MB contributed to the interpretation of the data. AW, MB, and DR contributed to the discussion of the results.

All authors critically revised the manuscript for important intellectual content and approved the final manuscript.

Funding

No funding was received for this study.

Data availability

Data are available from the corresponding author upon reasonable request.

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 number F-2025-134). The Ethics Committee determined that the study did not require formal ethical review or approval according to §15 of the professional code, as no personal data or identifiable human data were used. The requirement for informed consent was waived due to the retrospective design of the study and the use of fully pseudonymized data. All procedures were performed in accordance with the Declaration of Helsinki and relevant national regulations.

Competing interests

The authors declare that they have no competing interests.

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Figures

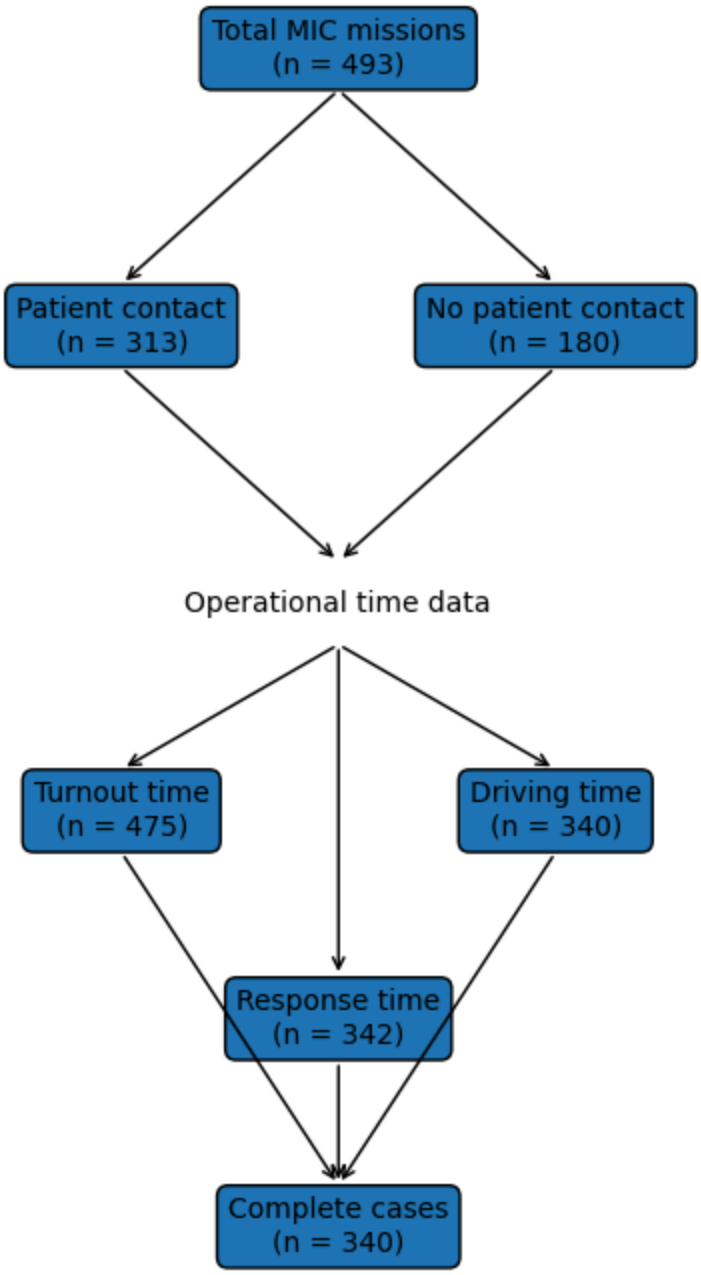


Figure 1

Flow diagram of study population and data availability

Supplementary Files

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

- SupplementaryMICDET.docx