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Increased number of dispatches in emergency medical services correlates to response time extension

Natsuko Ishikawa[1] | Keisuke Tomita[1] | Takashi Shimazui[1] | Yoko Tochigi[2] | Taka-aki Nakada[1,2]

[1]Department of Emergency and Critical Care Medicine, Chiba University Graduate School of Medicine, Chiba, Japan
[2]Smart119 Inc., Chiba, Japan

Correspondence
Taka-aki Nakada, Department of Emergency and Critical Care Medicine, Chiba University Graduate School of Medicine, 1-8-1 Inohana, Chuo-ku, Chiba 260-8677, Japan.
Email: taka.nakada@nifty.com

Abstract

Aim: This study investigated the correlation between the number of emergency medical service (EMS) dispatches and response time extension. In addition, we conducted a simulation to assess the potential for reducing response times by relocating the ambulance based on the number of dispatches.

Methods: This retrospective observational study analyzed data on patients treated with EMS between May 1 and June 25, 2021, in an urban area (Chiba City, Japan). Spearman's rank correlation tests were used to analyze the correlations among the number of dispatches, response time extension, and ambulance distance. We created a heat map to visualize the number of dispatches and distribution of emergency case occurrences, and simulated the relocation of the EMS team with the lowest number of dispatches to the closest EMS team with the highest number of dispatches.

Results: In total, 7915 emergency cases were included. The median response time across all dispatches was 9 min, whereas that for the response time extension cases was 12 min. There was a significant positive correlation between the increased number of dispatches, response time extension ($r = 0.94$, $p < 0.0001$), and ambulance distance ($r = 0.95$, $p < 0.0001$). The relocation simulation significantly shortened the average response time from 13 min and 30 s to 12 min and 11 s (9.9% decrease, $p < 0.0001$).

Conclusion: An increased number of dispatches significantly increased the response time extension cases and ambulance distance. Our simulation suggests that EMS relocation can potentially shorten the response time. While increased dispatches influence the response time extension, optimal EMS allocation may improve response times.

KEYWORDS
computer simulation, dispatch, emergency medical services, response time

INTRODUCTION

The number of emergency case dispatches has increased substantially in recent years.[1–3] This surge in dispatch has strained medical resources, notably affecting emergency medical services (EMS). While the norm involves the closest EMS responding to handle emergency cases in their jurisdiction, they are sometimes occupied with ongoing activities, necessitating the dispatch of another EMS from a distant location.[4,5] Such situations require ambulances to cover long distances, consequently extending the response time, which is defined as the time from the emergency call to the arrival of an ambulance at the scene.[6–8]

Response time is a component of prehospital time and has been reported to be associated with patient outcomes. A previous report suggested that increased prehospital time is associated with increased mortality in patients with out-of-hospital cardiac arrest.[4] Another report on patients with penetrating trauma suggested worsened mortality.[9] Clarifying the factors associated with increased prehospital time or its components will contribute to the future improvement of these issues and may subsequently improve patient outcomes. Given the observed increase in response times with increased dispatches, a plausible association between these factors may exist. However, to the best of our knowledge, no previous study has examined this association. In addition, because the response time independently depends on patient conditions or transferring hospital situations, optimization of emergency systems may shorten the response time. Exploring a possible way to shorten response time may contribute to advancing prehospital care practices.

In this study, we tested the hypothesis that an increased number of dispatches extends response time and ambulance distance, using prehospital data from a Japanese urban area. In addition, we conducted a relocation simulation of the EMS to examine whether optimized EMS relocation based on the number of dispatches could shorten the response time.

METHODS

Patients

The study was conducted in an urban area of Japan (Chiba City, the 12th largest city in Japan, with 1 million people). Patients treated by EMS in Chiba City were enrolled in this study. We focused on emergency dispatch data in Chiba City from May 1 to June 25, 2021 (for 8 weeks), as the period contained typical weekdays/weekends and national holidays in Japan (37 weekdays and 19 weekends/national holidays during the 8 weeks); thus, the results can be generalized as typical emergency dispatch activities. In addition, while the coronavirus pandemic affected recent emergency dispatches, this period was the interval of outbreaks,[10] and the dispatches were not significantly affected by the pandemic.

The EMS was dispatched from the Chiba City Fire Department, which covers the entire Chiba City, with 26 EMS teams for approximately 53,000 emergency cases by 2021. Among the EMS teams, one used a helicopter rather than an ambulance for their activities. Thus, from a total of 7917 patients who were treated by the EMS during the study period, regardless of whether the patients were transferred between hospitals ($n = 788$) or not transported to hospitals ($n = 1066$), we excluded this team's activity ($n = 2$). Finally, 7915 patients who were treated by 25 EMS teams were enrolled in this study.

Data collection and definition

Data were retrieved from emergency activity records for each dispatch described by the EMS teams. We retrieved data on the name of the EMS team, times (emergency call, ambulance arrival at the scene, departure from the scene, and hospital arrival), patient age and sex, accident type, injury severity, and ambulance distance from the fire station to the scene. The Ethics Committee of Chiba University School of Medicine waived the ethical review and approval for the study since the study used only an anonymized database throughout the investigations. This study was conducted with careful consideration of the provisions of the Declaration of Helsinki. Time was retrieved from hourly segments. In addition, we divided the day into two time periods, daytime (8:00 a.m. to 7:59 p.m.) and nighttime (8:00 p.m. to 7:59 a.m.) according to the previous reports,[11,12] and business hour (9:00 a.m. to 4:59 p.m.) and non-business hour (5:00 p.m. to 8:59 a.m.) according to general hospital business hours in Japan, to confirm the differences in the number of dispatches between the time periods.

Ambulance distance was defined as the distance between the scene and the ambulance location at the time the ambulance was dispatched. Response time was defined as the time from the emergency call to ambulance arrival at the scene. The EMS activity times including response times for each patch were calculated. We defined the top quartile of response time (more than or equal to 11 min) across all dispatches as the response time extension; the top quartile of the time from ambulance arrival at the scene to departure (more than or equal to 27 min) across all dispatches as the prolonged patient care; the top quartile of the time from ambulance departure to arrival at the hospital (more than or equal to 18 min) across all dispatches as the prolonged transport. In the EMS relocation simulation, the EMS team relocated from the base with the lowest dispatch, defined as the relocated EMS.

EMS relocation simulation

In the EMS relocation simulation, the EMS team with the lowest number of dispatches (relocated EMS) was relocated to the base nearest to the EMS team with the highest number of dispatches (busiest EMS dispatched for 485/7915 cases during the study period). The relocated EMS was dispatched from the base of the busiest EMS instead of its original location. As real-world prehospital activities involve time, we assumed that each EMS dispatch would take at least 1 h to complete its ongoing activity. In the case of a subsequent call during an ongoing activity, we assumed that other EMS teams would be dispatched. This simulation focused on 836 cases that geographically should have been treated by the busiest EMS but were handled by other EMS teams. We did not analyze cases handled by the relocated EMS because the number was small (83/7915 cases). We compared the response times before and after EMS relocation in these cases. We used the Matrix API of Mapbox for the EMS relocation simulation, and the Mann–Whitney *U* test was used to compare the response time before and after the relocation of the EMS.

Statistical analysis

The primary outcome was response time extension. The secondary outcome was ambulance distance. To clarify the hypothesis that increased dispatches extend the response time and ambulance distance, we examined the correlation between the total number of dispatches and outcomes.

For further examination, we assessed the correlations between response time extension and prolonged patient care or prolonged transport. Moreover, we created a heat map to visualize the number of dispatches of each EMS and the distribution of emergency case occurrences. After determining the distribution, we simulated the relocation of the EMS to improve response time.

Correlations were analyzed using Spearman's rank correlation coefficients. The Mann–Whitney *U* test was used for comparisons between groups. Data are described as median and interquartile range (IQR) for continuous variables and as number and percentage (%) for categorical variables. Two-tailed *p*-values of <0.05 were considered statistically significant. Analyses were performed using the Python 3.11.0 (Python Software Foundation, State of Delaware, USA) SciPy statistical software package.

RESULTS

Among 7915 patients, the median age was 66 years old (IQR 39–81), and 53.1% were male. The median response time was 9 min (IQR 7–11), and the ambulance distance was 2.2 km (IQR 1.4–3.2) (Table 1).

TABLE 1 Baseline characteristics for patient data and dispatched EMS units.

	($n = 7915$)
Patient characteristics	
Age, years	66 (39–81)
Male sex, *n* (%)	4202 (53.1)
Type, *n* (%)	
Disease	5962 (75.3)
Injury	741 (9.4)
Transfer to a different hospital	788 (10.0)
Others	424 (5.3)
Admitted after hospital transport, *n* (%)	3385 (42.8)
Not admitted after hospital transport, *n* (%)	3464 (43.8)
EMS data	
Number of dispatches by time of day, *n* (%)	
8:00 a.m.–7:59 p.m.	5311 (67.1)
8:00 p.m.–7:59 a.m.	2604 (32.9)
Response time (min)	9 (7–11)
Ambulance distance to the scene (km)	2.2 (1.4–3.2)

Note: Data are presented as median and interquartile range (IQR) for continuous variables and as percentages (%) for categorical variables. Response time is the time from emergency call to ambulance arrival at the scene. Ambulance distance to the scene, distance from the fire station where EMS teams were on standby to the scene where the injury or illness occurred.

Abbreviation: EMS, emergency medical services.

Association between response time extension and number of dispatches

There was a significant positive correlation between the response time extension and number of dispatches ($r = 0.94$, $p < 0.0001$) (Figure 1). In addition, the scatter plots between the response time extension and the number of dispatches showed that the response time extension was disproportionately distributed during the daytime (8:00 a.m. to 7:59 p.m.) (Figure 1). The scatter plot for business hours versus non-business hours clearly illustrated that the response time extension is specifically biased during the morning of business hours (Figure S1).

Association between ambulance distance and number of dispatches

Next, we evaluated the association between ambulance distance and number of dispatches. There was a significant positive correlation between ambulance distance and number of dispatches ($r = 0.95$, $p < 0.0001$) (Figure 2). Patients with longer ambulance distances were disproportionately distributed in the daytime, similar to the response time extension (8:00 a.m. to 7:59 p.m.) (Figure 2). The scatter plot for business hours versus non-business hours clearly illustrated that the longer ambulance distance is specifically biased during the morning of business hours (Figure S2).

Associations between response time extension and prolonged patient care and prolonged transport

When we assessed the correlations between response time extension and EMS activity times, we found a significant positive correlation between the response time extension and the number of prolonged patient care cases ($r = 0.70$, $p < 0.0001$) (Figure S3) as well as a significant positive correlation between the response time extension and the number of prolonged transport cases ($r = 0.84$, $p < 0.0001$) (Figure S4).

Dispatch heat map and EMS team relocation simulation

To explore ways to improve the response time, we first created a heat map to determine the occurrence of emergencies in Chiba City (Figure 3A). Area 1 is an urban area with a large population along the railroad, and the number of emergency cases was high in this area (Figure 3A). The EMS teams in Area 1 had a higher number of dispatches than the EMS teams located in other areas (Figure 3B). However, an extended response time was frequently observed in the EMS teams surrounding Area 1 (Figure 3C). Over the study period, the EMS team with the highest number of dispatches handled 485 cases (8.6 cases/day) while the EMS team with the lowest number of dispatches handled 83 cases (1.5 cases/day) (Figure 3B).

The EMS relocation simulation was conducted based on the distributions of the number of emergency cases, EMS

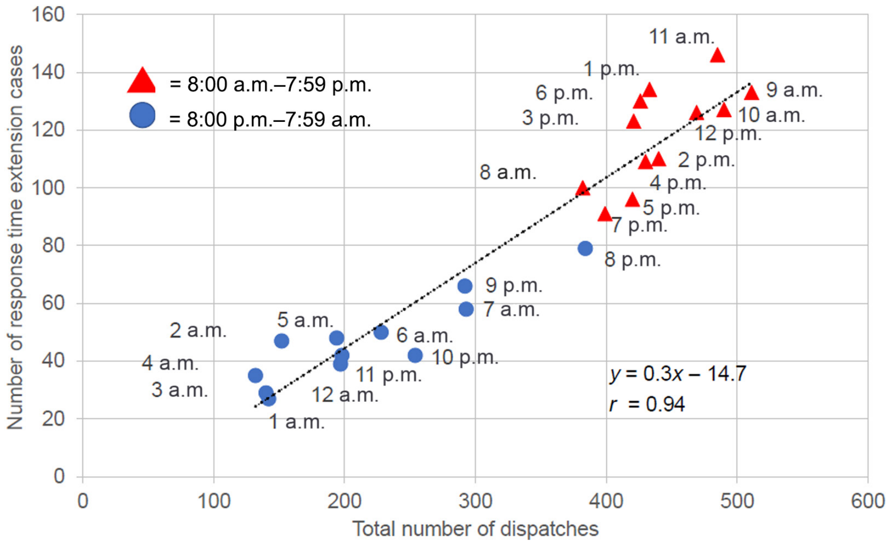


FIGURE 1 Correlation between the number of dispatches and response time extension cases. There was a significant positive correlation between the number of dispatches and the. response-time extension cases ($r=0.94$, $p<0.0001$). The scatter plots indicate the following: The response time extension disproportionately happened in the daytime. Red triangles indicate daytime (8:00 a.m. to 7:59 p.m.). Blue circles indicate nighttime (8:00 p.m. to 7:59 a.m.).

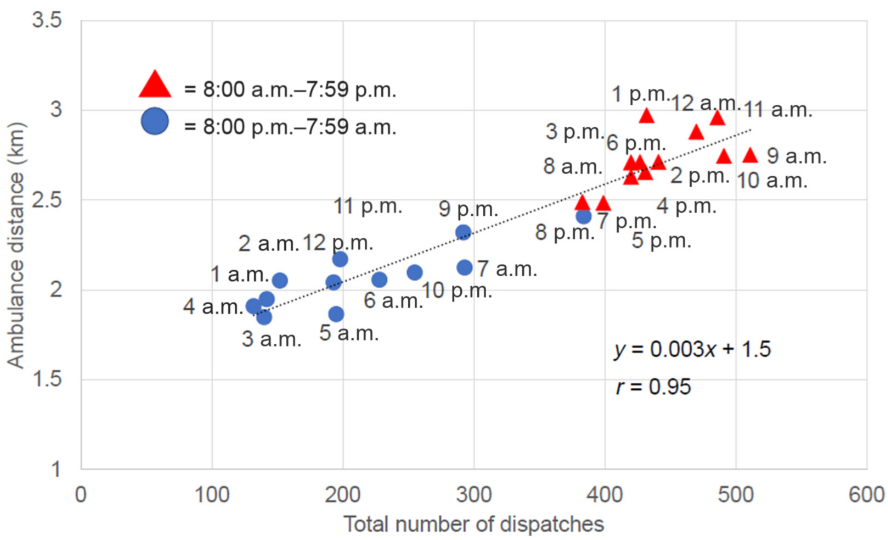
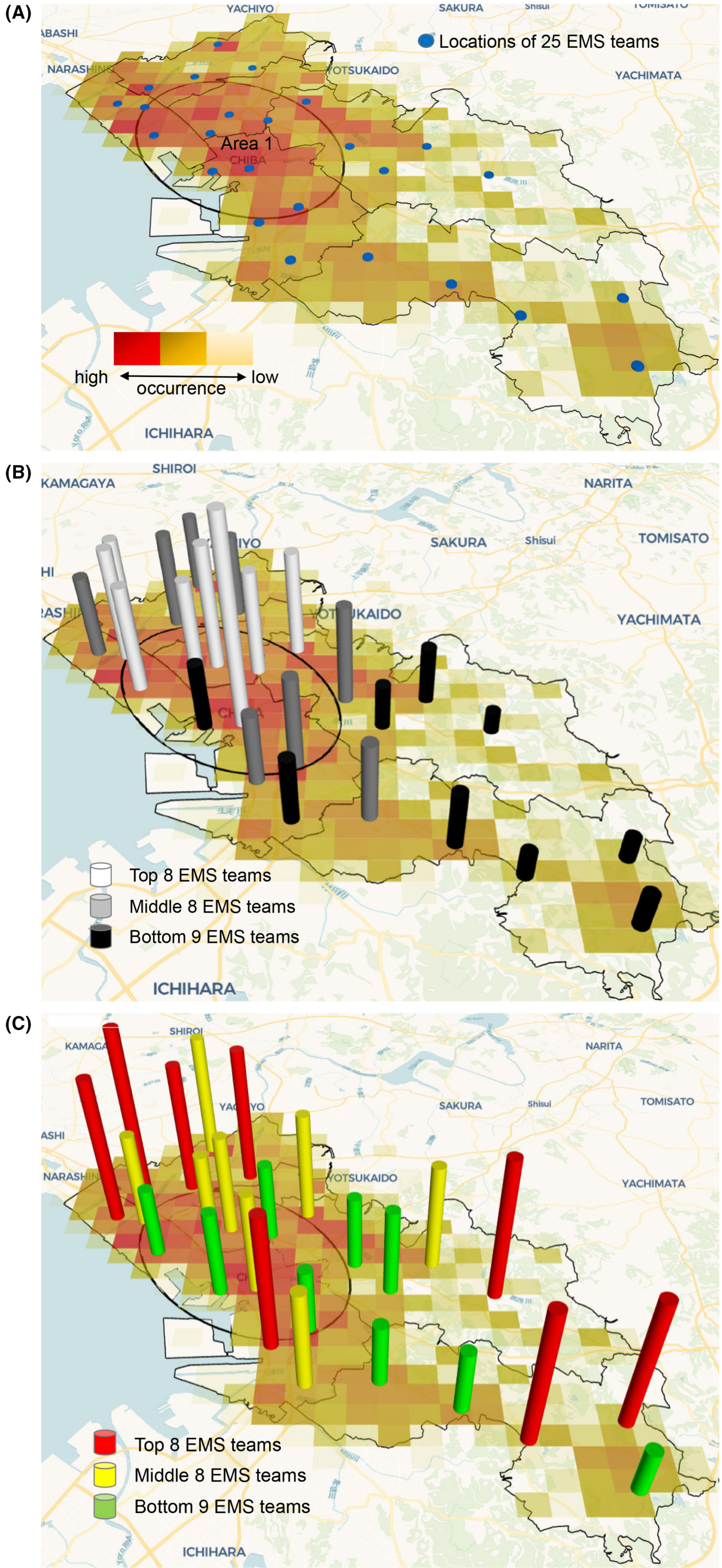


FIGURE 2 Correlation between the number of dispatches and ambulance distance. There was a significant positive correlation between the number of dispatches and ambulance distance ($r=0.95$, $p<0.0001$). The scatter plots indicate that cases with longer ambulance distances were disproportionately distributed during the daytime. Red triangles indicate daytime (8:00 a.m. to 7:59 p.m.). Blue circles indicate nighttime (8:00 p.m. to 7:59 a.m.).

FIGURE 3 (A) Heat map for emergency case occurrences in Chiba City and the location of 25 emergency medical service (EMS) teams. Area 1 had a high number of emergency case occurrences in Chiba City. Blue circles indicate the locations of 25 EMS teams. (B) Number of dispatches of each emergency medical service (EMS) team. The 25 EMS teams were divided into 3 groups according to the number of dispatches. White bars indicate the top eight EMS teams, gray bars indicate the middle eight teams, and black bars indicate the bottom nine teams. (C) Frequency of response time extension cases handled by each emergency medical services (EMS) team. The 25 EMS teams were divided into three groups according to the percentage of response time extension cases. The red bars indicate the top eight EMS teams, yellow bars indicate the middle eight teams, and green bars indicate the bottom nine teams.


(A)
Locations of 25 EMS teams
Area 1
high
occurrence
low
YACHIYO
SAKURA
NARASHINO
YOTSUKAIDO
YACHIMATA
CHIBA
ICHIHARA
(B)
SHIROI
KAMAGAYA
NARITA
SAKURA
Shisui
TOMISATO
YACHIMATA
Top 8 EMS teams
Middle 8 EMS teams
Bottom 9 EMS teams
ICHIHARA
(C)
SHIROI
NARITA
SAKURA
Shisui
TOMISATO
YOTSUKAIDO
YACHIMATA
Top 8 EMS teams
Middle 8 EMS teams
Bottom 9 EMS teams
ICHIHARA

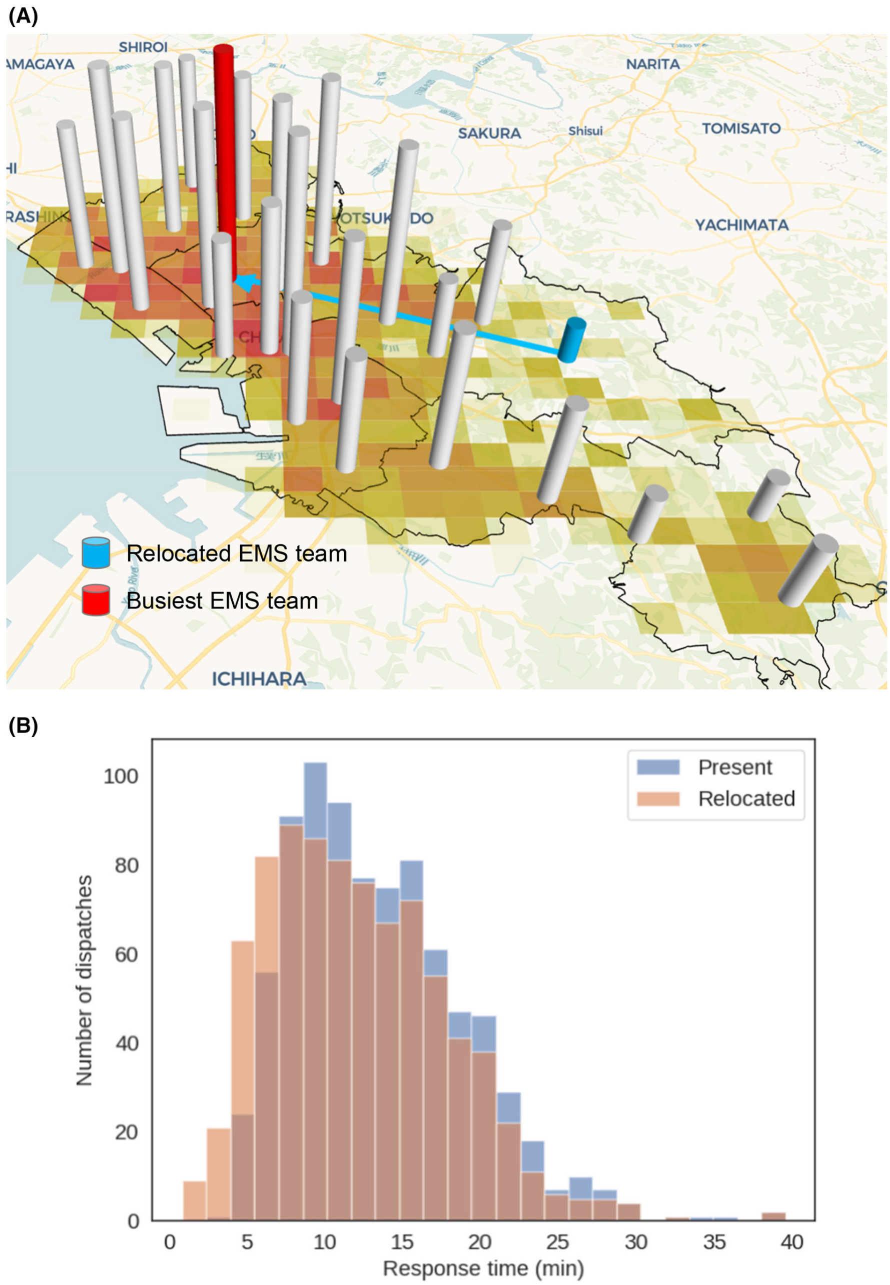


FIGURE 4 (A) Relocation simulation of the emergency medical services (EMS) team. The EMS team with the lowest number of dispatches (relocated EMS) was deployed at the base of the EMS team with the highest number of dispatches and was nearest to the relocated EMS (busiest EMS). The blue bar indicates the relocated EMS and the red bar indicates the busiest EMS. (B) Histograms of the association between the number of dispatches and response time in the cases focused on the relocation simulation. Relocation of the EMS significantly shortened the response time compared to the present study (from 13 min and 30 s to 12 min and 11 s, a 9.9% decrease, $p < 0.0001$).

dispatches, and response time extension cases (Figure 4A). After the relocation, the average response time was significantly shortened from 13 min and 30 s to 12 min and 11 s (9.9% decrease, $p < 0.0001$) (Figure 4B).

DISCUSSION

In this study, an increased number of dispatches was significantly correlated with the response time extension and ambulance distance. In addition, the EMS relocation simulation based on the number of dispatches successfully reduced response time.

The demand for ambulances is increasing worldwide because of aging and growing populations.[1–3] With an increasing number of dispatches, prehospital time also increases.[8,13] Prehospital time comprises several components. Among these components, the time from the emergency call to the arrival of an ambulance at the scene is called the response time. A systematic review of global response times indicates the mean response times were Asia 7.2 min, Europe 11.1 min, America 9 min, Oceania 8 min, and Africa 19.5 min.[14] The average response time in Japan was reported as 9.4 min,[8] which is similar to our median response time (9 min). However, as the World Health Organization suggests that the ideal response time is equivalent to or less than 8 min,[15] this time should be shortened.

In the Japanese EMS system, medical resources, such as EMS teams and ambulances, are allocated according to the population, aging rate, and dispatch status.[16] Upon receiving an EMS call, the nearest available EMS team is dispatched.[4] However, if the nearest team engages in an ongoing activity, the next nearest available team is dispatched. Hence, as the number of dispatches increases, there is a trend toward an increase in the need for distant EMS teams, which may extend the response time. In addition, ambulances in Japan cannot go to the nearest hospital when the hospital rejects the request for patient acceptance.[17,18] This specific EMS system may require ambulances to transport patients to more distant hospitals, which requires more transport time and potentially impacts response time extensions. The present study showed a significant positive correlation between the number of dispatches and response time extension cases (Figure 1). In addition, ambulance distance is an independent factor that defines response time,[19] and our study also determined a significant positive correlation between ambulance distance and response time (Figure 2). The number of dispatches was disproportionately distributed across time zones, particularly in the morning during business hours showing the highest number of dispatches (Figures 1, 2, S1, and S2). These results may help to consider the appropriate distribution of the medical resources in the Japanese EMS systems.

The response time is the duration from when the ambulance is dispatched until it reaches the scene. While the response time is independent of the duration of patient care in individual cases, our analyses found that it was statistically affected by the duration of patient care or transport time to the hospital across entire EMS activities. In addition, biased requirements for a specific EMS may make them continuously engage in an activity and lead to the absence of an EMS in a specific location. This requires another EMS from a distant location and causes a response time extension. Thus, the optimal allocation of EMS has the potential to reduce response time. In this study, we first determined the biases of emergency cases and actual dispatches of EMS. A heat map showed that the areas with the highest number of emergency cases overlapped in an urban area with a large population in Chiba City (Area 1 in Figure 3A), which is similar to a previous report that showed a correlation between population and the number of dispatches.[20,21] In contrast, the dispatches with the highest number of response time extensions were distributed in the area surrounding Area 1 (Figure 3C). One possible reason for this is that an increased number of dispatches would require a distant EMS team for assistance. Our simulation successfully indicated a shortening of the response time after relocation (decreased by 1 min and 19 s) (Figure 4B). A previous study conducted in Iran showed that the relocation of 8 out of 24 EMS bases to new locations chosen according to the number of dispatches, traffic congestion, and distance to the nearest hospital reduced the response time by 2 min.[22] This study involved eight EMS bases requiring the establishment of new bases. However, by focusing on the large disparity in the number of emergency dispatches, our simulation reduced the response time by simply relocating one EMS to another existing EMS base, which required fewer medical resources and was easier to perform. Our results indicate that optimizing the number of dispatches could be a solution to shorten response time.

This study had several limitations. First, the number of patients and the duration of evaluation were limited. This study covered approximately 8000 emergency cases in only one Japanese city (population of approximately 0.98 million) during the 8 weeks. The study was conducted during the coronavirus epidemic, and the dispatches may be impacted by the disease. Although we chose the interval period between outbreaks, the epidemic may still have affected the dispatches. Furthermore, while the number of emergency dispatches generally exhibits seasonal variations, with increased dispatches in summer or winter compared to spring,[17,18] and ambulances may encounter more public health problems during busier seasons, our study was conducted during the spring season. The correlations observed in this study might differ in the other seasons. Second, although we performed the simulation, we did not conduct a demonstration experiment. Third, we excluded cases from the simulation that were handled by the relocated EMS. However, the number was small (83/7915 cases, 1.5 cases/day) and only 1.0% across all the dispatches. This may have had little effect on our results. Fourth, because of the differences in the EMS system and the traffic environment, our results could not always be adapted to EMS activity in other locations. Fifth, our study did not evaluate the patients' prognoses. Improving the prognosis is the ultimate goal of the medical research. Further study is needed to assess how the response time impacts the prognosis.

CONCLUSION

The increased number of dispatches was significantly correlated with response time extension and ambulance distance. In addition, our simulation showed a possible improvement in response time after optimal EMS relocation. By focusing on the number of dispatches, strategic EMS allocation may shorten the response time.

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CONFLICT OF INTEREST STATEMENT

T. Nakada is the CEO of Smart119 Inc. and Y. Tochigi is the employee of Smart119 Inc. The funding source had no role in the design, practice or analysis of this study.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

ETHICS STATEMENT

Approval of the research protocol: N/A.
Informed Consent: N/A.
Registry and the Registration no. of the Study/Trial: N/A.
Animal Studies: N/A.

ORCID

Natsuko Ishikawa https://orcid.org/0009-0008-9757-9536
Yoko Tochigi https://orcid.org/0009-0007-3021-5888
Taka-aki Nakada https://orcid.org/0000-0002-4480-556X

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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