Developing a geographic strategy for equal rapid response first aid

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Abstract

Background: All people have rights to take first aids equally because they have risk for sudden cardiac arrest at any time. Japan employs mainly two inclusive strategies for rapid response first aid. The first is public services such as fire trucks and ambulance response. The second is increasing the number of first responders. However, many residents are geographically unaware whether public services in their areas provide quick responses during emergencies, such as cardiac arrest. For this reason, they lack knowledge the necessity of mutual aid, which enables nearby neighbors who have undergone proper training to respond and provide first aid. Thus, the study aims to identify geographically specific areas where mutual aid is essential for rapid response first aid.

Methods: The study targeted 20 cities in Japan designated by government ordinance and to simulate response areas reachable by public service. The driving conditions with 3 min were simulated with the speed limits, which are obeyed by the Japanese Road Traffic Act. Also, the populations covered in the areas was calculated in each targeted city.

Results: The simulated map appears to render easy recognition of weak areas that may benefit from rapid response and may necessitate mutual aid. The maximum, minimum, and median population coverage rates are 65%, 22%, and 38.5%, respectively.

Conclusion: The study indicates that mutual aid for rapid response is essential to most of the targeted areas in the case of sudden cardiac arrest. Moreover, mutual aid can be implemented strategically by geographic visualization and numerical values for equal rapid response first aid.

Background

Most people wish to live have longer and they have rights to take first aids equally because they have risk for sudden cardiac arrest at any time. During a cardiac arrest, rapid response first aid, such as chest compression, is essential for resuscitation and positive neurological outcomes even in the absence of defibrillation.[1] However, the majority of people wait for emergency vehicles from the public service sector in Japan, such that the implementation rate of chest compression during cardiac arrest by layperson is 58% (14,789/25,560), out of which, only 5.1% (13,11/14,789) implement automated external defibrillation (AED).[2] In general, when a fire dispatch center receives an emergency call for cardiac arrest, responders verbally instruct callers on how to perform cardiopulmonary resuscitation (CPR) before the arrival of the emergency service on the scene. However, the response time of callers in initiating CPR, including AED, remains unknown. Thus, the study focuses on response time for CPR because it influences survival rates.[3,4]

In the past 10 years, the number of medical emergency calls has increased.[5] The Japanese emergency response system (EMS) operates on a “first-come first-serve” basis regardless of the nature of the complaint. Unfortunately, late emergency response occurs even for patients undergoing cardiac arrest. In

response, when EMS dispatchers detect a patient under critical conditions, they activate not only ambulance vehicles but also fire trucks or other emergency vehicles for rapid response. However, according to the Fire Disaster Management Agency in Japan, the national average of response time is 8.7 min as of 2019.[6] Thus, the survival rates of patients through public emergency services is expectedly low because the recommended AED deployment should be within 5 min according to the AED guidelines in Japan.[7]

As another method of rapid response, local EMSs aim to increase the number of first responders who provide basic life support within their vicinities. In 2019, local fire agencies conducted first aid classes, including refresher courses, for 1.9 million people.[8]

Currently, Japan employs two inclusive plans for rapid response. The first is the response of the public service sector, whereas the second includes chance bystanders. As a result, the hospital discharge rates increased from 6.9% in 2010 [9] to 9.0% in 2019,[9] which is higher compared with those of previous years. In the western context, however, the survival rate for witnessed cardiac arrest due to ventricular fibrillation in Seattle and King County was 59%.[10] In contrast, this rate is 37.8% in Japan,[11] which indicates room for improvement. One of the reasons underlying this scenario is that most residents lack knowledge about if their areas are geographically capable of receiving rapid response from public emergency services. Nevertheless, they continue to expect rapid emergency response for cases of cardiac arrest despite the expected low survival rates.

Rapid response first aid is essential for hospital discharge and for the rest of one's life. Therefore, residents should be aware of the limitations of public service and the necessity of mutual aid, which is a powerful life-saving tool before the arrival of EMS.[12,13] However, to the best of the author's knowledge, a geographically strategic plan for rapid response is lacking. Thus, the study aims to identify areas not covered by rapid response. As such, mutual aid is essential for these areas as a form of equal rapid response first aid. In addition, the study aims to quantify the areas covered by emergency services.

Methods

1.1 Target cities

The study identified 20 cities, namely, Sapporo, Sendai, Niigata, Chiba, Saitama, Yokohama, Kawasaki, Sagamihara, Nagoya, Shizuoka, Hamamatsu, Osaka, Sakai, Kyoto, Kobe, Okayama, Hiroshima, Kitakyushu, Fukuoka, and Kumamoto, which were designated by government ordinance.

1.2 Time setting

The AED guideline in Japan states that the preferable time for AED deployment is within 5 min.[7] This time frame is broken down as follows. The first minute is allocated for awareness via an emergency call. One minute is allocated for shifting from AED to the delivery of the first shock. The remaining 3 min is allocated for transportation to the emergency scene. There are varying speed limits on the streets of

Japan that are based on the Japanese Road Traffic Act. The driving conditions were simulated with the speed limits for 3 min.[14] Lastly, the covered areas are added to the population, and the population coverage rate is calculated per city.

1.3 Data management

The study plotted fire stations as starting points to determine the reachable areas per city (Fig. 1). The distance is then considered relative to the prescribed speed of emergency vehicles within 3 min, to simulate the real road setting speed on the map. Next, areas reachable by emergency vehicles are calculated from the fire stations. Lastly, the population is added to the reachable areas as areas of implementation of AED within 5 min. Analysis was conducted via ARCGIS by ESRI, a geography software. In addition, covered areas in several fire stations overlap with areas covered by other fire stations. In this case, the areas are set at half distances to avoid overlapping.

Results

Fig. 2 illustrates the necessity of mutual aid to rapid response through a geographical visualization (Supplementary material). Furthermore, Table 1 indicates that the maximum, minimum, and median coverage rates are 65% (Osaka), 22% (Okayama), and 38.5% (Kobe, Kitakyushu), respectively.

Table 1 Demographics and coverage rates

City	Area (km^2)	Population	Population density ($persons/km^2$)	Number of stations	Coverage rate (%)
Sapporo	1,121.26	1,970,057	1,757.00	52	60
Sendai	786.35	1,090,263	1,386.49	28	32
Saitama	217.43	1,307,931	6,015.41	26	25
Chiba	271.78	980,203	3,606.60	24	33
Yokohama	437.7	3,748,781	8,564.73	96	48
Kawasaki	143.01	1,530,457	10,701.75	36	61
Sagamihara	328.91	722,828	2,197.65	22	40
Niigata	726.45	796,500	1,096.43	34	36
Shizuoka	1,411.83	691,185	489.57	24	39
Hamamatsu	1,558.06	791,770	508.18	25	27
Nagoya	326.5	2,327,557	7,128.81	60	46
Kyoto	827.83	1,466,264	1,771.21	47	46
Osaka	225.3	2,740,202	12,162.46	89	65
Sakai	149.82	827,971	5,526.44	17	30
Kobe	557.01	1,522,944	2,734.14	29	39
Okayama	789.95	720,865	912.55	21	22
Hiroshima	906.68	1,199,359	1,322.80	32	47
Kitakyushu	491.95	940,141	1,911.05	29	38
Fukuoka	343.46	1,592,657	4,637.10	31	31
Kumamoto	390.32	739,393	1,894.33	22	30

Discussion

The geographical approach of extracting weak areas provides two major suggestions. The first is that public service is limited in terms of rapid response under maximum settings and when expressed as numerical information. The second is that mutual aid is indeed an essential component of AED deployment within 5 min in weak areas due to latency in the response of public emergency services. The study illustrates that although the maximum coverage rate is high at 65% in Osaka and minimum at 22% in Okayama, there is no valuable for the comparison. Each city is given specific areas and limited budget

per year. For example, the larger population, the more the fire stations, where the areas covered by public emergency services depend on the number of fire stations. In addition, the covered area is dependent on population density. If a fire station is set in the center of a densely populated city, then the covered areas experience better emergency services. Conversely, coverage of decentralized populations, such as rural areas, is difficult.

One of solutions for rapid response first aid is for emergency teams to standby in weak areas in anticipation of emergency calls. Large fire stations reserve extra emergency vehicles that specifically respond to medical calls for cardiac arrest. If surplus emergency vehicles in fire stations can afford to standby in other areas, then coverage area may be improved. Unfortunately, however, standing by on streets or large parking areas in Japan is prohibited due to opposition from residents.[15] Evidently, emergency services are required to respond to other emergency calls even if they are in other areas or are returning from hospitals.

Other solutions are constructing an emergency response system with mutual aid, especially in the case of a sudden cardiac arrest, which can happen to anyone at any time. Therefore, protecting yourself, your family, and neighbors in the area is a natural tendency. However, such areas and facilities come in many forms, such as residential, public utility and leisure areas; offices; and warehouses. Thus, attention should be given to the development of emergency systems in weak areas due to nature of each area and facility. For example, a stadium is obliged to protect its consumers. Out of this area, this obligation is null.

Moreover, the most of individuals may be accustomed to mutual aid within their environment. Iwami[16] reports that “cardiac arrests in public or in the work place had a higher chance of being found in ventricular fibrillation and survival than those at private residences.” In other words, the place to occur is under a person’s observation. The notion suggests that formulating an emergency response system with mutual aid that can be utilized in public or the work place is a viable option. Consequently, office workers are commendable as first aid responders for coworkers and customers.

However, approximately 70% of cases of cardiac arrests occur in private residences.[17] In this case, a rapid response system with mutual aids is required as soon as possible. Compared with the public or work place setting, cardiac arrest that occurs in residential areas may lead to cognitive loss among first responders. In fact, actions may be delayed until first responders are notified about the symptoms of cardiac arrest. Even when cardiac arrest occurs near someone inside the house, other family members rely on emergency services. Therefore, the expected implementation of this solution is particularly low in weak areas. As such, the solution continues to be efficient communication through text messages and mobile phone applications.[18,19] In addition, the 2020 care system guideline of the American Heart Association 2020 recommends that “notification of lay rescuers via mobile phone apps results in improved bystander response times, higher bystander CPR rates, shorter time to defibrillation, and higher rates of survival after hospital discharge.”[20]

Moreover, according to Kurn,[21] a local neighborhood volunteer can improve response time to a simulated cardiac arrest. The more rapid the response to the scene, the more the chance of survival for patients undergoing cardiac arrest.[22–25] In fact, the Kashiwa city fire department initiates a rapid response system for first responders through a mobile application.[26] Especially, the application is used for particular conditions, such as arrhythmia, VF, or pulseless ventricular tachycardia, because it can be treated with AED not only by healthcare providers but also by lay persons. However, the lay persons should be trained as first responders to obtain average-quality CPR.[27] Alternative, once a response system with mutual aid is established, then it can lead to potential improvement in weak areas in terms of recognition and response time for first aid.[28]

The study does not intend to arouse unnecessary public anxiety, but to geographically identify areas that require a strategy for rapid response. From the point of view of residents, they should geographically understand their areas and the necessity for mutual aids in the occurrence of cardiac arrest in their areas. Conversely, from the point of view of the public, cities should focus on inclusive strategies in terms of the number of first aid classes, which should be offered as frequently as possible. Moreover, cities should appeal for the appropriation of public funds for emergency care services to their residents. According to Weisfeldt,[29] “The incremental value of resuscitation strategies, such as the ready availability of an AED, may be related to the place where the arrest occurs.”

Lastly, each city should prioritize their areas with a geographic strategy to improve hospital discharge rates by formulating a rapid response system with mutual aid that is open to all residents. Moreover, the study suggests that calculating the population coverage rate is useful for evaluating public response and mutual aid as one of the numerous objectives for equal rights. In the future, the population coverage rate could become a standard evaluation for rapid response systems across cities.

Limitation

The study employs a simulation of emergency settings. Thus, the results may only represent the best possible areas covered by public emergency services. As such, certain public emergency services cannot respond to emergency situations due to increased number of emergency calls in Japan. In real life, response time is influenced by transportation conditions, such as vehicle accidents, road construction, and weather. Hence, these obstacles may minimize the areas covered by emergency services.

Conclusion

The study found that extracting weak areas reflects the potential weak areas that received delayed public response in each city. In addition, the calculated population coverage rates suggest limited public service in terms of rapid response and limited prioritization of emergency response systems for weak areas. In other words, the study expressed the necessity of mutual aid across cities. As such, weak areas should employ mutual aid as a priority and improve covered areas in the city. Furthermore, the population coverage rate can be used as an objective index for the rapid response system.

Abbreviations

AED: Automated External Defibrillation

CPR: Cardio Pulmonary Resuscitation

EMS: Emergency Medical System

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

KN-Conceptualization Methodology Writing- Original draft. SK- Project administration

KF- Study conception, local fire department information SO- Supervision, Writing- Reviewing and Editing HY- Supervision, Writing- Reviewing and Editing

All authors read and approved the final manuscript."

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Figures

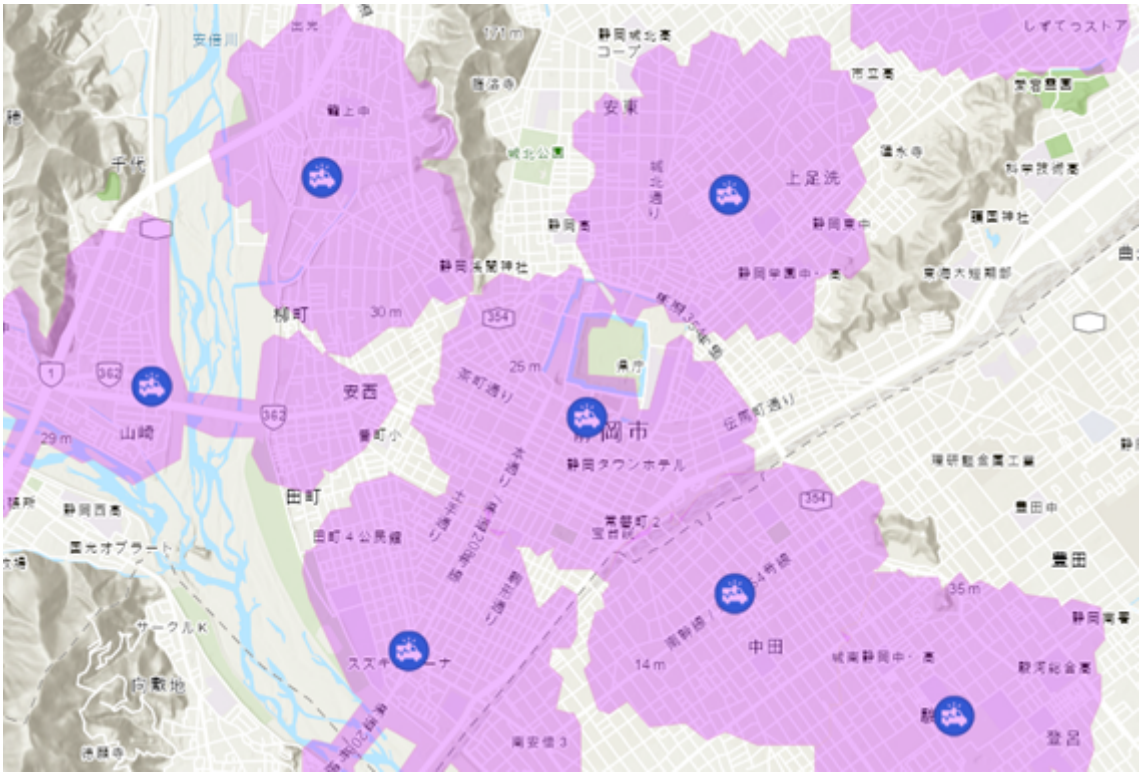

Figure 1

Areas reachable by emergency vehicles in Shizuoka (as an example) within 3 min

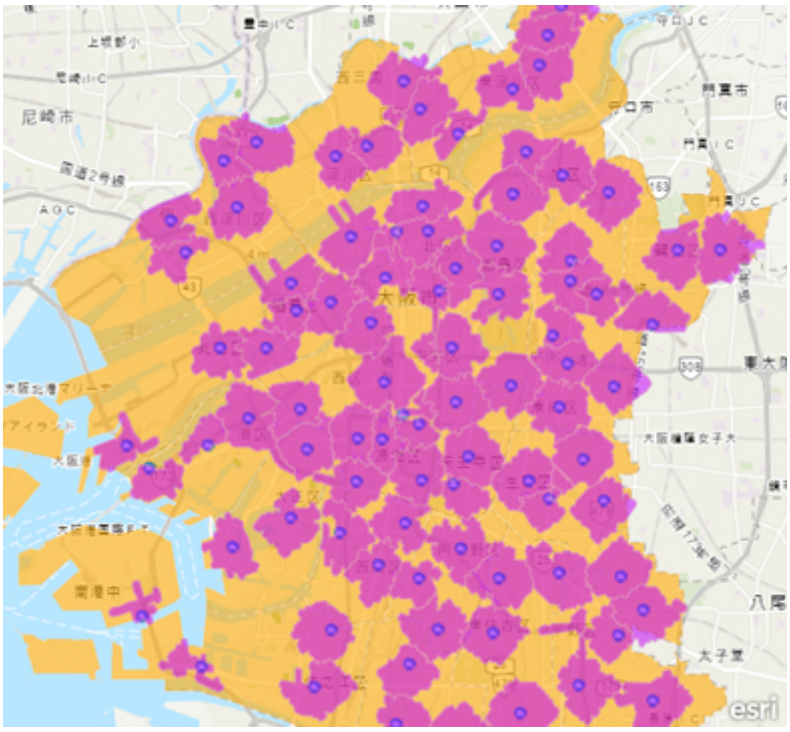

Figure 2

Areas that require mutual aid are in orange. This figure represents the city of Osaka.

Supplementary Files

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- Supplementfile1.docx