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Transition of EMS workflow from radio to bell signals to shorten activation time in multiple casualty incident

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Multiple casualty incident (MCI) are critical situations mandating an immediate response. Traditionally, members of emergency medical services (EMS) are notified about MCI through radio signals. However, communication failures can lead to delays in activation time of EMS operations. The use of bell signals is proposed as a solution to address these issues. This study uses a retrospective pre-post design evaluating the impact of the bell and radio signal on activation times for EMS operation in MCI. Data were collected from January 2020 to December 2023 and divided into two phases: radio signal use during 2020–2021 (pre-design), and bell signal use during 2022–2023 (post-design). In the event of MCI, the bell or radio is used primarily to alert medical personnel. After the MCI was recognized during the pre-design phase, the dispatcher utilized the radio signal, calling out all EMS personnel twice via radio at 171.425 MHz, with a one-minute interval between communication to notify them of the incident. The ED staff would be informed of these incidents through radio or telephone communication by EMS personnel. In the post-design phase, the dispatcher utilized the bell signal, ringing it three times to alert all staff. Activation time and equipment used by EMS during MCI operations was recorded for both phases. A total of 105 MCI with EMS operations were recorded. In the bell signal group, 52.1% ($n = 199$) of the participants were male. Mass transportation incidents accounted for the most of the MCI, comprising 73.6% in the bell signal group and 73.1% in the radio signal group. The average activation time was significantly shorter for the bell signal (1.54 min) compared to the radio signal (3.60 min) ($P < 0.001$). The average response time for the bell signal was 13.20 min, while the radio signal response time averaged 16.10 min ($P = 0.042$). Early activation time (less than 2 min after EMS dispatch) was significantly more likely in the Bell signal group (adjusted odds ratio, 1.25; 95% confidence interval, 1.10–2.45) than in the Radio signal group. The activation and response times for EMS operations during MCI were significantly reduced by using bell signals to alert EMS staff.

Keywords Emergency medical services, Multiple casualty incidents, Communication, Activation time, Workflow

Abbreviations

MCI	Multiple casualty incident
EMS	Emergency medical services
ED	Emergency department
SD	Standard deviation
95%CI	95% Confidence interval

Multiple casualty incident (MCI) is defined as a critical situation involving several patients who require more medical resources than the hospital can provide, leading to an acute shortage of resources[1,2]. This shortage affects services in both the emergency medical system (EMS) and the emergency department (ED). Prompt activation

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of the EMS is essential in the medical management of MCI. Responding to such situations requires experienced or trained personnel to manage the incident in an organized and effective manner[3,4].

For the extensive scale of MCI, Thailand operates a National Disaster Command Headquarters, which serves as a central command and control facility responsible for directing, overseeing, and coordinating emergency management practices in major crisis incidents across all subordinate disaster management centers. The Minister of the Ministry of Interior has been appointed as the National Incident Commander, while the Permanent Secretary of the Ministry of Interior will serve as the Deputy National Incident Commander. At the city level, we also possess a Provincial Disaster Management Centre. In the case of a minor scale of MCI that can be managed by local organizations, the incident commander is the local EMS medical team that provide assistance in this scenario.

The EMS response to MCI is critically important, particularly in terms of the time it takes to reach the scene. Previous studies have shown that delays in reaching the scene can negatively impact survival rates and increase the likelihood of disability among injured individuals in MCI situations[5–7]. In Thailand, the standard EMS procedure begins with a phone call to the emergency number 1669. A preliminary history is then taken to assess the number of patients, the patient's symptoms and severity, along with providing pre-arrival instructions to assist while waiting for the ambulance. The command center subsequently dispatches the nearest ambulance unit to deliver emergency medical services and transport the patient to the designated hospital[8–10]. In the case of MCI, If a single EMS unit is unable to supply adequate ambulance or EMS personnel, the command center will collaborate with another EMS unit to augment resources.

The operational procedure for MCI differs from routine EMS responses, as it involves additional steps. These include reporting the incident to superiors, informing hospital personnel about the situation, organizing the necessary manpower, and ensuring the provision of medical equipment and supplies to manage a large number of patients. This also involves increasing the medical supplies on ambulances. These additional steps lengthen the time it takes for an ambulance to reach the scene. EMS personnel responding to MCI outside the hospital, including emergency physicians, nurses, paramedics, emergency medical technicians, and ambulance drivers, may be stationed in different areas of the hospital. In special situations, specific equipment is required, such as a chemical hazard protective suit with an oxygen tank for incidents involving chemical spills. This equipment is not typically found on regular emergency ambulances and must be retrieved from the medical device inventory, adding to the response time.

In this context, efficient communication between pre-hospital and hospital providers is an essential preliminary measure for system notification and cooperative situational awareness. Traditionally, EMS operations, particularly in resource-limited countries rely on radio communication or mobile phones for contact; however, these methods often face challenges, including communication delays or failures resulting from factors such as inadequate proficiency in radio communication among healthcare providers, sound disambiguation challenges, the constant noise in ER and EMS environments, or a lack of awareness regarding existing radio alerting protocols[11,12]. The implementation of bell signals has been introduced to address these issues. This system functions as a comprehensive alert for all tiers of medical personnels, including EMS and ED staff, aiming to reduce the time needed for emergency medical personnel to respond, leading to faster and more efficient MCI management outside the hospital.

Aim

The primary objective of this study was to compare the activation time between bell signals and radio signals for EMS operations in response to MCI. The secondary objective was to identify the equipment used by EMS during MCI.

Methods

Study design and setting

This retrospective pre-post design analysis utilized MCI event occurred at EMS units, Srinagarind Hospital in Thailand. With approximately 2,500 EMS operations conducted annually, the hospital serves as the region's primary hub for training emergency physicians and EMS professionals, as well as being a university-affiliated institution. The hospital's EMS unit is managed by a dispatch center that oversees six van ambulances, two motorcycle ambulances, and a telemedicine service, providing 24/7 online medical direction. Each EMS operation involves a team of three to five personnel, including emergency physicians, nurses, and emergency medical technicians.

Ethical considerations

Due to the retrospective nature of the study, the need to obtain the informed consent was waived by The Khon Kaen University Ethics Committee for Human Research (HE671457) to confirm that all methods were performed in accordance with the relevant guidelines and regulations.

Participants

This study included all patients admitted to our EMS unit from January 2020 to December 2023. The inclusion criteria for the study encompassed all patients who utilized our EMS services during MCI. Instances with insufficient data or considerable incident simulation practices were omitted from the study.

EMS operation workflow

During 2020–2021 (Pre-design), when MCI were identified by the dispatcher, EMS personnel at EMS unit were notified via radio signal. Upon identifying MCI, the dispatcher utilizes a frequency of 171.425 MHz to call all

EMS personnel twice, with a one-minute gap between each call. Subsequently, EMS personnel prepare, collect their equipment, and proceed to the ambulance to commence operations. The ED staff would be informed of these incidents through radio or telephone communication by EMS personnel, thereby alerting the hospital system and facilitating necessary preparations. The base station radio in this study was ICOM Inc. (Japan) model IC-F5123D with frequency coverage 136–174 MHz FM mode, Channel spacing 6.25/12.5/25 kHz. The 50 W output of this equipment was performed. The type of emission was 16K0F3E, 8K50F3E, 4K00F1E/F1D. Dimensions of radio was $150 \times 40 \times 167.5$ mm with weight 1.1 kg.

During 2022–2023 (Post-design), the EMS unit implemented a bell signal for MCI events, which the dispatcher rings the bell three times to simultaneously alert all EMS personnel and ED staff. The wired bell, model FBM023, is manufactured by Nohmi Bosai Limited (Tokyo, Japan) and produces a nominal sound level exceeding 90 db. The rated voltage was 24 VDC. The rated current was 10 mA. The sounding mechanism was motor driven with weight 420 gm. It is installed in the ED area, ensuring that the signal is audible in both the EMS and the ED.

Data collection

The data collection period was divided into two phases: the use of radio signals to activate EMS personnel in MCI situations during 2020–2021, and the use of bell signals during 2022–2023. Each incident was individually examined during the EMS operational period. The primary data collected focused on the activation time of EMS operations in response to MCI, overseen by three emergency physicians, each with over five years of EMS experience.

Definition

Activation time was defined as the period from EMS dispatch to when the vehicle was en route. Response time was defined as the time from receipt of the 1669-center call (the command-and-control center for EMS in Thailand) to the EMS unit's arrival at the scene. A single synchronized clock at the dispatch center was used to measure the time intervals in this study. The dispatcher monitored EMS operations via telemedicine, and a computer automatically recorded the duration of each process into the EMS database. MCI in this study was defined as a medical emergency situation in which the 1669-center reported more than five patients at the incident site.

Study size

The sample size for estimating an infinite population proportion was calculated using an estimated prevalence of 0.50[9] and a standard normal value of 1.96. The power analysis was performed with an alpha level of 0.05 and an absolute precision of 0.1[13]. Based on this, the authors determined that the required sample size would be 95.

Statistics

Statistical analysis was conducted using IBM SPSS for Windows, version 27.0, licensed from Khon Kaen University (Khon Kaen, Thailand) (IBM Corp.; Armonk, New York, USA). Categorical data were presented as frequencies and percentages, while continuous data were presented as means and standard deviations (SD). The chi-square test was used to evaluate the association between categorical variables, with statistical significance defined as a two-tailed P-value of < 0.05.

Results

Over the four-year study period, MCI occurred 122 events. 17 events were excluded due to incomplete data. A total of 105 MCI with EMS operations were collected from the database, as detailed in Table 1. In the bell signal group, 52.1% ($n = 199$) of the participants were male. The majority of MCI involved mass transportation incidents, accounting for 73.6% in the bell signal group and 73.1% in the radio signal group. Operations were most frequently conducted during the morning shifts in the bell signal group (41.5%). The most commonly used equipment in MCI for both groups were binoculars and portable lights.

The average activation times from dispatch to the vehicle being en route were 1.54 min for the bell signal and 3.60 min for the radio signal ($P < 0.001$; see Table 2). The average response time for the bell signal was 13.20 min, compared to 16.10 min for the radio signal ($P = 0.042$). In multiple logistic regression models adjusting for age, sex, type of MCI, and operation time, early activation time (less than 2 min after EMS dispatch) was significantly more likely in the Bell signal group (adjusted odds ratio, 1.25; 95% confidence interval, 1.10–2.45) than in the Radio signal group.

Discussion

Our study aimed to investigate the implementation of bell signals as a system, derived from the workflow development of the EMS unit, to notify EMS workers responding to MCI, substituting the conventional usage of radio communication. In this study, an MCI is defined as any incident involving more than five patients, which differs from other studies due to variations in MCI definitions across different EMS systems and countries[14–16]. At Srinagarind Hospital's EMS, the capacity to manage up to five patients simultaneously was used as the threshold for defining an MCI in this context.

The primary objective of this study was to compare the activation time of EMS operation pre and post implementation of bell signal. The study found that the use of signal bells significantly reduced both activation and response times compared to using radio communication to alert EMS personnel. The primary advantage of the signal bell is its ability to promptly alert personnel, as it produces a high-pitched audible alerting and a distinctive call that stands out against ambient noise, easily identified by healthcare providers in the area as an indication of MCI, being a widely recognized signal among EMS staff at all levels. This method helps minimize

Feature	Bell signal ($n=53$)	Radio signal ($n=52$)	*P* Value
Gender of all patients, N (%)			0.862
Male	199 (52.1)	187 (51.2)	
Female	183 (47.9)	178 (48.8)	
Age of all patients, Mean (SD), years	42.9 (5.6)	40.6 (4.9)	0.655
Type of MCI, N (%)			0.830
Mass-transportation	39 (73.6)	38 (73.1)	
Outbreak infection	8 (15.1)	7 (13.5)	
Fires or natural disasters	5 (9.4)	4 (7.7)	
Crime scene	1 (1.9)	3 (5.7)	
Operation Time, N (%)			0.752
Morning (8 AM–4 PM)	22 (41.5)	19 (36.5)	
Afternoon (4 PM–12 AM)	20 (37.7)	25 (48.1)	
Night (12 AM–8 AM)	11 (20.8)	8 (15.4)	
Equipment's used in MCI, N (%)			0.720
Binoculars	47 (88.7)	45 (86.5)	
Portable light	30 (56.6)	32 (61.5)	
Fire extinguisher	5 (9.4)	3 (5.8)	
Chemical protective clothing	1 (1.9)	1 (1.9)	
Mobile chemical decontamination	1 (1.9)	1 (1.9)	
Number of casualties, Mean (SD)	7.2 (2.0)	7.0 (1.8)	0.920

Table 1. Characteristics of the subjects ($N=105$).

Time	Bell signal (min) $N=53$		Radio signal (min) $N=52$		*P* Value
	Mean	95% CI	Mean	95% CI	
Activation time	1.54	(1.24–2.05)	3.60	(2.90–4.22)	< 0.001[a]
Response time	13.20	(11.25–16.01)	16.10	(15.40-17.22)	0.042[a]

Table 2. Comparing times between bell and radio signal in activation of EMS in multiple casualty incident. [a] Statistical significance.

communication errors that can occur with radio communication, such as poor signal reception or personnel reducing the radio volume, leading to missed information or misunderstanding of radio codes[17,18]. The signal bell system thus supports faster EMS response and improves the efficiency of emergency units in reaching the MCI scene quickly. While using a bell signal has advantages, it can also have some drawbacks, such as generating noise that may disturb operators in the ED area who are not involved in EMS operations. However, modifications have been made to the area where the signal bell is installed to ensure that the signal reaches the target group as clearly as possible. These adjustments help prevent interference with other personnel or patients in the ED, minimizing the impact of the noise.

The secondary objective of this study was to identify the equipment used by EMS during MCI. Our study demonstrated that binoculars and portable lights were the most commonly utilized, which corresponds with the types of MCI identified in this research. Mass-transportation accidents often require the use of binoculars to assess the scene situation, number of injured people or potential threats, such as fires or oil explosions especially at nighttime. Additionally, with the increasing use of electric cars in Thailand in recent years, EMS personnel must be prepared to respond in public areas. Binoculars are crucial for assessing the situation from a safe distance before providing assistance.

According to the study, male patients were most commonly associated with MCI. Previous studies have similarly found that MCI related to terrorism, mass traffic accidents, fire accidents, and natural disasters predominantly involve male patients[19,20].

Regarding the type of MCI, this study found that most MCI were caused by mass-transportation accidents, aligning with previous research showing that Thailand frequently experiences large-scale accidents due to road traffic issues[21,22]. Motorcycles are the leading cause of death in traffic accidents. The second most common cause of MCI was outbreaks of infectious diseases, with incidents occurring at secondary schools and police training centers due to food poisoning, leading to more than fifty casualties. This contrasts with other countries, where MCI are often driven by terrorism or the use of biological weapons[23–26].

In terms of the timing of MCI, most incidents occurred during the morning and afternoon shifts (08:00 AM – 12:00 AM). However, MCI that occur during the night shift are often more complex, as they are more likely to be related to crime scenes or fire-related incidents[27,28]. Night shifts typically have fewer EMS personnel on duty, which can lead to delayed responses. Therefore, ensuring adequate staffing and preparation of medical equipment and supplies during night shifts is crucial to prevent late responses.

This study aims to improve work processes for quicker patient access in the field of EMS in resource-limited country. By modifying the operational approach to be more simple, convenient, and cost-effective, the study supports the development of sustainable practices within the organization for the future[29–32].

Limitations of the study

This study's retrospective design presents a limitation, as it may lead to incomplete collection of variable factors. Additionally, data were gathered from only one EMS unit, and the response model may vary across different regions. Countries in the Asia–Pacific region possess distinct prehospital emergency care or EMS systems that differ from European or Anglo-American models. Most countries in Asia have established EMS in hospitals. There was a risk that the results might not be universally applicable. In terms of the type of MCI, most of the MCI in this study were related to mass-transportation accidents in Thailand, which may differ from the types of incidents seen in other areas. To enhance the comprehensiveness of the results, future studies should expand the scope to include other types of MCI, as well as examine the equipment and supplies needed to address various situations more effectively.

Conclusions

The implementation of bell signals to alert EMS members significantly shortened both activation and response times for EMS operations in MCI. Early activation time (under 2 min post-EMS dispatch) was much more prevalent in the Bell signal group. Binoculars and portable lights were the most commonly used equipment in EMS during these incidents.

Data availability

When a reasonable request is made, the corresponding author can provide the datasets used and/or analysed in this study.

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Author contributions
KI, KA, LWC, and MP participated in planning the study design. KI, MP, and KA took part in the data collection. KI, MP, and KA analyzed the data and drafted the first version of the manuscript. LWC helped with statistical testing and acted as Supervision. KI, MP, and KA made revised the manuscript. KI completed the final manuscript. All authors read and approved of the final manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
The Khon Kaen University Ethics Committee for Human Research (HE671457) granted ethical authorization. Since patient confidentiality was ensured by providing every individual with a unique study number rather than their name, the requirement for prior consent from the patients was prevented.

Consent for publication
Not applicable.

Additional information
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