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Spatial analysis and data mining techniques for identifying risk factors of Out-of-Hospital Cardiac Arrest

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ABSTRACT

Out-of-Hospital Cardiac Arrest (OHCA) is a critical issue of emergency medical service (EMS). In addition to the first aids given to OHCA patients by witnesses or bystanders, time factors such as arrival of ambulance and transportation from site to EMS are also important. Comprehensive coverage of EMS, especially enhanced by ubiquitous computing technologies, could significantly improve the survival rate of OHCA patients. However, it heavily challenges the resource allocation and management policy in the public health system of a metropolis.

Objectives: In this study, we first used spatial analysis techniques with a finer granularity to identify high risk areas of OHCA in a metropolis. We then used data mining techniques to elucidate the effects of patients' characteristics, pre-hospital resuscitation treatments, and spatial factors on post-OHCA survivability. With this information, public health institutions can enhance the EMS by allocating properly first-aid resources at the right places to improve the survival rate of OHCA patients.

Methods: We used New Taipei City, Taiwan as the scope of this study. Data of all registered OHCA cases in New Taipei City in 2011 were reviewed retrospectively. The dataset was combined with the National Doorplate Database to enhance the granularity of spatial analyses. Global and local spatial analyses based on Global Moran's Index, Local Moran's Index, and Getis-Ord Gi* statistic were performed to cluster high risk districts for OHCA in New Taipei City. Statistical methods such as Chi-square test, logistic regression, and decision tree were then adopted to analyze factors influencing 2-h survivability after OHCA.

Results: Significant spatial clustering of OHCA events was found ($p < 0.05$) in the western side of New Taipei City. We found that the 2-h survival rate after OHCA was significantly correlated ($p < 0.05$) with type of OHCA, EMT-P (Emergency Medical Technicians-Paramedic) dispatch, intubation, drug administration, onsite ROSC (Return of Spontaneous Circulation), AED (Automated External Defibrillator) usage, bystander witnessing, AED initial cardiac rhythm, cardiac rhythm recovery before admission, and past histories of diabetes and renal disease.

Conclusions: Based on the finding of this study, several important factors of OHCA can be improved to enhance the quality of the EMS service. With the spatial analysis of OHCA hotspots, public health institutions can manage the first-aid resources more efficiently and make EMS policies more effectively. As a result, the survival rate of OHCA patients can be improved.

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1. Introduction

Out-of-Hospital Cardiac Arrest (OHCA) is a critical issue of emergency medical service (EMS). In the United States, annually approximately 420,000 OHCA cases occurred (Go, Mozaffarian, & Roger, 2014). Researches have revealed that the survival rate of OHCA patients is related to the location of the OHCA events (Nichol et al., 2008; Sasson, Keirns et al., 2010). One important factor related to survivability after OHCA is the presence of witnesses and timely administration of cardiopulmonary resuscitation (CPR). However, not all OHCA patients receive CPR or have a witness at the time of cardiac arrest (McNally et al., 2011). The guidelines of CPR chain on survivability from the American Heart Association stress the importance of timely administration of CPR. However, approximately 80% of OHCA and 55% of Intra-Hospital Cardiac Arrest (IHCA) adult patients still did not regain ROSC (Return of Spontaneous Circulation) after receiving CPR (Manuel, 2013). The age makeup of the OHCA patients varied from young to old. Older patients commonly also have various chronic diseases like cardiovascular disease (CVD), high blood pressure, and diabetes (Lee, 2010). A major concern with a CVD patient is delayed medical attention during the critical moment after the onset of a heart attack. Studies have shown that the survival rate of a cardiac arrest patient is significantly improved if the patient receives basic CPR within 4 min, or advanced CPR within 8 min (Valenzuela, Roe, Cretin, Spaite, & Larsen, 1997).

In Taiwan, the four major types of EMS cases are (1) motor vehicle accidents, (2) acute illness, (3) mental illness, and (4) roadside collapse. Many cases of acute illness and roadside collapse involve acute CVD, which occupies the second position among the 10 major causes of death in Taiwan. On average, one life was lost every 31 min and 50 s due to CVD in 2015, according to Ministry of Health and Welfare, Republic of China. The EMS systems of the governments at different levels have various EMS resources, such as Basic Life Support (BLS) units consisting of an ambulance with only Emergency Medical Technicians (EMT), and Advanced Life Support (ALS) units consisting of an ambulance with EMT-P (Paramedic). Some ambulances may equip with remote vital sign monitor, which can send vital signs to hospital by advanced ICT (Information and Communication Technology). There are also Patrols equipped with portable first-aid devices. They ride motorcycles to fast pass through traffic jams to the site of OHCA cases and then give a first aid before the arrival of EMT. The EMS systems can organize training and education programs of CPR and cardiac arrest (Sasson et al., 2013). They can preplace AED (Automated External Defibrillator) in suitable places, for example convenient stores, which are of a very high density in Taiwan. However, the first-aid resources are not limitless. It heavily challenges the resource allocation and management policy for EMS of a metropolis. The EMS systems have to decide how many first-aid resources are allocated in different districts. It had been proposed to organize CPR education and training programs in high-risk areas by spatial analysis (Nassel et al., 2014).

Ubiquitous computing technologies can enhance EMS very much. For example, the EMS can locate the OHCA event by the help of calling smartphones equipped with GPS sensor. Geography Information System (GIS) can provide much valuable spatial information, such as the location of the most nearby EMT-P team, suitable hospitals, and traffic condition. Spatial analysis and data mining technologies can help the administrators identify the areas of high risks and important factors to the survivability of OHCA. Thus, the administrators can allocate EMS resources to effectively improve the survival rate of OHCA patients.

Although there are geographical variations in OHCA survival rates in different cities, there also exist variations in populations (Sasson, Rogers, Dahl, & Kellermann, 2010). The frequency of bystander CPR also appears to aggregate within cities (Root et al.,

2013). Districts of high risks can be defined as those of a higher prevalence of OHCA and a lower prevalence of the bystander CPR. In this study, we adopted spatial cluster analysis with a finer granularity to identify the districts of high OHCA risks. Furthermore, we use data mining technologies to find important factors to the survival rate of OHCA patients. Consequently, the EMS systems can maximize public health resources to the communities most in need.

There are various spatial analysis methods, e.g., spatial scan statistic (Kulldorff, 1997) and kernel density (Waller and Gotway, 2004). However, there is currently no consensus on how to identify districts of high risks. The main objective of this study is to propose an integrated method to identify districts of high OHCA risks and important factors to the 2-h survivability after OHCA through spatial analysis and data mining technologies. Given OHCA hotspots and information of an OHCA patient's medical history, public health institutions may adopt suitable ICT to increase the probability of received CPR and prioritize the dispatch of emergency aid resources.

2. Methods

2.1. Data acquisition and preprocessing

This study analyzed the OHCA data registered in the Fire Department of the New Taipei City Government from January 1 to December 31, 2011.

Fig. 1 shows the Taipei metropolitan area, the largest metropolis situated in the Taipei Basin in the northern Taiwan Island. It consists of Taipei City, New Taipei City (previously Taipei County), and Keelung City. In general, Taipei City in the flat center of the basin has a higher standard of living. Keelung City is a major harbor city located in the northern part of Taiwan. New Taipei City surrounds Taipei City and separates Keelung City with mountains. The city has a coastline of about 120 km and an area of 2052 km². It contains various terrain features. Except the border areas nearby Taipei City, most areas in New Taipei City are mountains and hills. It has an estimated population of 3.9 million. However, the distribution of the population is not even.

The dataset is the emergency rescue statistics of the emergency service. All identity information was stripped. Hence, informed consent was not needed. There were a total of 2416 OHCA cases registered in 2011. Those with unrecognized addresses were removed at the initial processing stage. The resultant dataset included 2172 OHCA cases. The data were collected during emergency calls and complied with the international Utstein-style criteria. It includes patient demographics (name, age, birth date, and gender), event information (event date and time, location, hospital of emergency service, and speculated cause of emergency) and first aid factors before admission (bystander witness, time of ambulance arrival, time of onsite treatment, time from site to emergency service, total response time, location type, onsite CPR, and the use of AED). Also included are first aid factors after admission (AED initial cardiac rhythm, cardiac rhythm before AED shutdown, intubation, drug administration, and AED status), prognostic outcomes (return of spontaneous circulation (ROSC), 2-h survival after OHCA, cardiac resuscitation before admission) and medical history (past history of CVD, pulmonary diseases, asthma, diabetes, high blood pressure, renal diseases, and cerebrovascular diseases). Based on the aforementioned event descriptions, 28 variables were extracted from the dataset. An additional variable is first-aid capability hospital, which is classified by the regulations based on the emergency medical service capability accreditation system of Ministry of Health and Welfare, Taiwan. The 29 variables were assessed for 2-h survivability after OHCA.

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