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Factors affecting the ambulance response times of trauma incidents in Singapore

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A B S T R A C T

Objectives: Time to definitive care is important for trauma outcomes, thus many emergency medical services (EMS) systems in the world adopt response times of ambulances as a key performance indicator. The objective of this study is to examine the underlying risk factors that can affect ambulance response times (ART) for trauma incidents, so as to derive interventional measures that can improve the ART.
Material and methods: This was a retrospective study based on two years of trauma data obtained from the national EMS operations centre of Singapore. Trauma patients served by the national EMS provider over the period from 1 January 2011 till 31 December 2012 were included. ART was categorized into "Short" (<4 min), "Intermediate" (4–8 min) and "Long" (>8 min) response times. A modelling framework which leveraged on both multinomial logistic (MNL) regression models and Bayesian networks was proposed for the identification of main and interaction effects.
Results: Amongst the process-related risk factors, weather, traffic and place of incident were found to be significant. The traffic conditions on the roads were found to have the largest effect—the odds ratio (OR) of "Long" ART in heavy traffic condition was 12.98 (95% CI: 10.66–15.79) times higher than that under light traffic conditions. In addition, the ORs of "Long ART" under "Heavy Rain" condition were significantly higher (OR 1.58, 95% CI: 1.26–1.97) than calls responded under "Fine" weather. After accounting for confounders, the ORs of "Long" ART for trauma incidents at "Home" or "Commercial" locations were also significantly higher than that for "Road" incidents.
Conclusion: Traffic, weather and the place of incident were found to be significant in affecting the ART. The evaluation of factors affecting the ART enables the development of effective interventions for reducing the ART.

1. Introduction

Emergency medical services (EMS) is a critical link in any trauma and emergency care system (Cowley, 1976; Cummins, 1993; I.O.M., 2007). The growing demand for more efficient EMS has sparked off efforts to evaluate and improve the quality of many EMS systems in recent years.

The key objective of many successful EMS systems can be operationally defined by the effective and consistent provision of immediate medical care to seriously ill or injured patients, and the expeditious conveyance of patients to advanced resuscitation and

Abbreviations: EMS, emergency medical services; OR, odds ratio; PACS, patient acuity category scale; ED, emergency department; MNL, multinomial logistic model; ART, ambulance response time; ITT, ideal travel time; LRT, likelihood ratio test; CI, confidence interval; IQR, interquartile range.

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lifesaving care (I.O.M., 2007). Medical conditions of patients who require immediate care imply that delay in treatment could result in the worsening of patients' conditions. This has been shown to be the case particularly for out-of-hospital cardiac arrest cases (Valenzuela et al., 2000) and trauma victims in selected urban settings (Feero et al., 1995).

Trauma has always been acknowledged to be an acute time sensitive condition, and its care outcomes are of key importance in the performance of many healthcare systems in the world. In Singapore, trauma (defined under "External Causes of Morbidity and Mortality" in ICD10 (W.H.O., 1994)) has been the fifth leading cause of death over 2006–2012 (M.O.H., 2014). The acute time-sensitive nature of trauma further highlights its importance in the performance of the Singapore's EMS system.

The 'Golden Hour' of trauma idea recognizes the time-sensitive nature of trauma and suggests that the mortality and morbidity of trauma patients may be affected if definitive care is not given within the first hour of injury (Cowley, 1976; Trunkey, 1983; Lerner and Moscati, 2001). Another similar concept which relates to the time-sensitive nature of trauma is the "trimodal distribution" of trauma deaths (Baker et al., 1980; Trunkey, 1983). These two concepts are considered in the Advanced Trauma Life Support (ATLS) program (A.C.S., 2008) and have led to the design and planning of many EMS systems around the world (Strawder, 2006; Newgard et al., 2010). The International Standards Organization (ISO) has thus adopted EMS response times as a key performance indicator of fire and emergency services, providing a comparable and verifiable measure of EMS performance across diverse cities (I.S.O., 2014). For cities seeking to improve their EMS systems, it is imperative to examine the factors that can impact EMS response times in order to identify effective interventions (Ong et al., 2010; Lam et al., 2013, 2015; Goh et al., 2014).

This study builds on the existing literature which dealt with specifically out-of-hospital cardiac arrests based on primarily geospatial factors (Ong et al., 2009, 2010, 2012) to investigate generic risk factors affecting the ambulance response times (ART) for trauma incidents, so as to derive interventional measures that can potentially improve the ART.

2. Methods

2.1. Study setting

This study is based on the EMS system of Singapore. Singapore is a city-state island with a land area of approximately 714 square kilometers and a resident population of approximately 5.4 million (World Bank, 2013). The population base for each postal district and corresponding distribution of ambulance call volumes have been detailed in an earlier related study on the geospatial–temporal distribution of calls in Singapore (Ong et al., 2009).

Singapore's national EMS system is operated by the Singapore Civil Defence Force (SCDF) who is also the national fire-department with a centralized emergency operations centre (Lam et al., 2013). The highest medically trained personnel within the ambulance team are intermediate Emergency Medical Technicians (EMTs) who have undergone 14–18 months of EMT training (S.C.D.F., 2013). The deployment of intermediate EMTs in the EMS system is similar across many Asian cities (Shin et al., 2012).

Singapore has been known to have the lowest number of ambulances per 100,000 population as compared to other similar Asian cities (Shin et al., 2012; Ong et al., 2013). To provide a context on the healthcare system which the Singapore's EMS system operates in, some results comparing the state of development and healthcare resources (public expenditure in healthcare, hospital and ambulance resources per capita) across various cities derived from earlier studies are summarized in Table 1 (Shin et al., 2012; Ong et al., 2013; Shin et al., 2012; Austin et al., 2014).

Singapore's EMS system relies on the national "995" emergency hotline with round-the-clock operations which responds to medical, fire-related and other civil emergencies. The EMS provider currently operates 50 ambulances capable of providing Basic Life Support (BLS) in a tiered response system using both ambulances and fast response motorcycles. Apart from the 50 BLS equipped ambulances, the EMS provider manages a team of fast response paramedics on motorcycles to initiate first response for specific time-sensitive conditions, such as out-of-hospital cardiac arrest cases (OHCA) and major trauma incidents. Motorcycle-based fast responders can initiate first aid and treatment, but they do not possess the conveyance capabilities of ambulances. Consequently, all motorcycle-based responses will have to be followed up by ambulances irrespective of whether a motorcycle has been dispatched (Goh et al., 2014).

During the study period, the fleet of ambulances was distributed over a network of 18 fire stations and 29 satellite posts island-wide (S.C.D.F., 2014b). Patients were conveyed to one of the seven public hospitals spread out over the island. Out of these seven hospitals, there is one specialized maternity and paediatric hospital. Depending on projected demands, the aggregate number of operational ambulances may differ across different

Table 1
Comparison of healthcare infrastructure and investments across global cities.

City	Singapore	Seoul	Boston	Paris	Chennai	Recife	Bogota
Country	Singapore	Korea	USA	France	India	Brazil	Colombia
Population (million)	5.399[a]	9.895[g]	5.576[c]	11.915[c]	8.784[c]	3.744[c]	8.759[c]
Land area (km^2)	700[a]	605[g]	4,595[c]	2,845[c]	1,189[c]	2,768[c]	1,587[c]
Population Density (persons/km^2)	7,713 [a]	16,356[g]	1,193[c]	4,171[c]	7,388[c]	1,069[c]	4,705[c]
GDP per capita (2013 International$ PPP)[a]	78,763	33,062	53,042	37,532	5,418	15,038	12,424
Income group[a]	High	High	High	High	Lower middle	Upper middle	Upper middle
Estimated RTA fatalities per 100,000 population[b]	5.1	14.1	11.4	6.4	18.9	22.5	15.6
Public Health Expenditure (% of GDP)[a]	1.5	4.2	8.0	9.0	1.2	4.5	5.2
Hospitals per 100,000 population (for cities)	0.13[f]	NA	1.47[c]	0.55[c]	1.05[c]	1.28[c]	0.67[c]
Hospital beds per 1,000 population	2.0[d]	10.3[h]	2.9[d]	6.4[d]	0.7[d]	2.3[d]	1.5[d]
Ambulances per 100,000 population	0.93[e]	1.2[g]	27.80[c]	4.20[c]	1.76[c]	2.03[c]	3.96[c]

[a] Country Data from World Bank (2013) (Accessed 23 May 2015).
[b] Data from World Health Organization—Road Traffic Deaths by Country (2010) (Accessed 23 May 2015).
[c] Data extracted from Austin et al. (2014).
[d] Country Data from World Bank (2011) (Accessed 23 May 2015).
[e] Ambulance statistics from Singapore Civil Defence Force. Population statistics from World Bank (2013) (Accessed 23 May 2015).
[f] http://www.moh.gov.sg/content/moh_web/home/our_healthcare_system/Healthcare_Services/Hospitals.html (Data is for 7 public hospitals including one paediatric/maternity hospital) (Accessed 23 May 2015).
[g] Data extracted from Shin et al. (2012).
[h] Country Data from World Bank (2009) (Accessed 23 May 2015).