

Geographic-Time Distribution of Ambulance Calls in Singapore: Utility of Geographic Information System in Ambulance Deployment (CARE 3)⁺

Marcus EH Ong,¹*MBBS, MPH*, Faith SP Ng,²*M App Stat*, Jerry Overton,³*MPA*, Susan Yap,¹*RN*, Derek Andresen,³*EMT-P*, David KL Yong,¹ Swee Han Lim, *MBBS, FRCS Edin (A&E)*, V Anantharaman,¹*MBBS, FRCS Ed (A&E)*

Abstract

Introduction: Pre-hospital ambulance calls are not random events, but occur in patterns and trends that are related to movement patterns of people, as well as the geographical epidemiology of the population. This study describes the geographic-time epidemiology of ambulance calls in a large urban city and conducts a time demand analysis. This will facilitate a Systems Status Plan for the deployment of ambulances based on the most cost effective deployment strategy. **Materials and Methods:** An observational prospective study looking at the geographic-time epidemiology of all ambulance calls in Singapore. Locations of ambulance calls were spot mapped using Geographic Information Systems (GIS) technology. Ambulance response times were mapped and a demand analysis conducted by postal districts. **Results:** Between 1 January 2006 and 31 May 2006, 31,896 patients were enrolled into the study. Mean age of patients was 51.6 years (S.D. 23.0) with 60.0% male. Race distribution was 62.5% Chinese, 19.4% Malay, 12.9% Indian and 5.2% others. Trauma consisted 31.2% of calls and medical 68.8%. 9.7% of cases were priority 1 (most severe) and 70.1% priority 2 (moderate severity). Mean call receipt to arrival at scene was 8.0 min (S.D. 4.8). Call volumes in the day were almost twice those at night, with the most calls on Mondays. We found a definite geographical distribution pattern with heavier call volumes in the suburban town centres in the Eastern and Southern part of the country. We characterised the top 35 districts with the highest call volumes by time periods, which will form the basis for ambulance deployment plans. **Conclusion:** We found a definite geographical distribution pattern of ambulance calls. This study demonstrates the utility of GIS with despatch demand analysis and has implications for maximising the effectiveness of ambulance deployment.

Ann Acad Med Singapore 2009;38:184-91

Key words: Demand analysis, Despatch, Emergency Medical Services

Introduction

Singapore is a city-state with a land area of 707.1 square kilometres and a population of 4.5 million.¹ The population is multiracial with the major ethnic groups being Chinese, Malay and Indian. There has been an increasing utilisation of emergency ambulance services, with increasing acuity of patients every year. Data from the Singapore Civil Defence Force (SCDF) 2006 annual report² show a constant rise in ambulance calls every year since 1998, rising an average of about 6.5% to 8.0% each year, topping off at 96,006 total calls in 2006. In addition, over the same

period, the proportion of emergency calls of the total has increased from 64.2% to 91.0%.

The “chain of survival” concept,³ states that survival from out-of-hospital cardiac arrest can be improved with early emergency medical services (EMS) response. Furthermore, the survival rate is related to response times. There is currently good evidence that indicates the importance of delivering early defibrillation (<4 min) in out-of-hospital cardiac arrest.⁴⁻⁷ All emergency SCDF ambulances in Singapore carry defibrillators. In addition, there are many other important trauma and medical

¹ Department of Emergency Medicine, Singapore General Hospital, Singapore

² Clinical Trials and Epidemiology Research Unit, Singapore

³ Richmond Ambulance Authority, Richmond, Virginia, USA

For the CARE study group

Address for Correspondence: Dr Marcus Ong Eng Hock, Department of Emergency Medicine, Singapore General Hospital, Outram Road, Singapore 169608. Email: marcus.ong.e.h@sgh.com.sg

⁺ This paper was presented at the 9th Society for Emergency Medicine in Singapore Annual Scientific Meeting in March 2008 and the 17th Singapore General Hospital Annual Scientific Meeting in April 2008.

conditions in which outcomes are dependant on fast response times.

It has been noticed that acute medical events such as cardiac arrests are not random events, but rather have definite time-geographic distribution patterns.⁸⁻¹⁰ This is related to the underlying population demographics and movement patterns. Using Geographic Information Systems (GIS) technology, we are able to depict such time-geographic patterns to aid the planning for ambulance deployment. GIS is multi-layering mapping software that is able to portray multiple geographic-time information in an easy to read, graphical manner.

The question is, what is the location and pattern of ambulance calls in Singapore and how can we design the most cost-effective ambulance deployment strategy? It has been pointed out that it would be prohibitively expensive and logistically difficult for ambulances to respond within 4 minutes for every ambulance call. This is the rationale for call prioritisation and targeting ambulance placement according to a demand analysis. This will allow fast response times for calls that are time-dependent, such as cardiac arrests. This study will be a natural follow-on to the Cardiac Arrest and Resuscitation Epidemiology (CARE) project.¹¹

We aimed to conduct a multi-phase study in Singapore, with this phase describing the geographic epidemiology of ambulance calls in Singapore using GIS technology. This will allow us to prepare a demand analysis and in subsequent phases, to derive the most cost-effective ambulance deployment strategy by time and geography.

Materials And Methods

Study Design

The CARE study is a multi-phase, observational prospective study looking at the geographic location of pre-hospital cardiac arrest and ambulance calls in Singapore. The study period for this phase was between 1 January 2006 and 31 May 2006.

Setting

Singapore's EMS system is run by the SCDF, which operates the national 995 (universal access number) emergency telephone service. '995' is a universal, centralised, enhanced dispatching system, utilising Computer Aided Dispatch, Medical Dispatch protocols, Global Positioning Satellite (GPS) Automatic Vehicle Locating Systems and road traffic monitoring systems.

The SCDF currently operates 34 ambulances based in 14 fire stations and 10 satellite fire posts (Fig. 1). It is primarily a single tier system, able to provide basic life support and defibrillation with automated external defibrillators (AEDs). Private ambulances currently do not attend to emergencies such as cardiac arrest. Emergency ambulance

patients are delivered to 6 major public hospitals in the country that are equipped with modern Emergency Departments (ED).

Since 1996, ambulances in Singapore have been manned by specifically trained paramedics (roughly equivalent to North American EMT-Intermediate), replacing the nurses that previously served as ambulance officers. The paramedics undergo an 18-month training including theory, hospital and ambulance attachments. They are able to provide basic life support (BLS) and defibrillation with AED. They are able to give symptom relief medication such as salbutamol, nitroglycerin, diazepam, aspirin, intravenous adrenaline (epinephrine), dextrose and saline infusions. They also perform laryngeal mask airway insertion in cardiac arrest.

The CARE study group includes representatives from the 6 major public hospitals in Singapore, the Singapore Civil Defence Force, Health Sciences Authority and the Clinical Trials and Epidemiology Research Unit, Singapore. CARE phase I found survival from out-of-hospital cardiac arrest (OHCA) in Singapore to be 2.0%.¹¹ Mean (S.D.) EMS response time was 10.2 (4.3) minutes. Mean (S.D.) time from call to defibrillation was 16.7 (7.2) minutes.

Data Collection

All calls to '995' were included. Exclusion criteria were those calls which did not require an ambulance to be dispatched, or 'false' calls for which no ambulance was dispatched.

Patient characteristics, call circumstances, EMS response times and traffic conditions were recorded in a standard report. Geographic location of ambulance calls (including postal code) and type of location (house, office, public place, shopping mall, school etc) was recorded.

Data were collected from '995' dispatch records, as well as ambulance patient case notes. EMS timings were automatically recorded by the computerised central dispatch system. All watches and timings were synchronised with the central dispatch clock at the beginning of each shift. Institutional Review Board approval was obtained to conduct this study.

Outcome Measures

Outcome measures that were collected included the number of dispatch calls, the geographic location of calls, including the specific address as well as postal code and date-time of the event. Other variables that were collected included the demographic characteristics of patients, incident classification (trauma/medical), EMS response characteristics, severity classification of the call, whether the patient was conveyed and the traffic conditions en route to hospital.

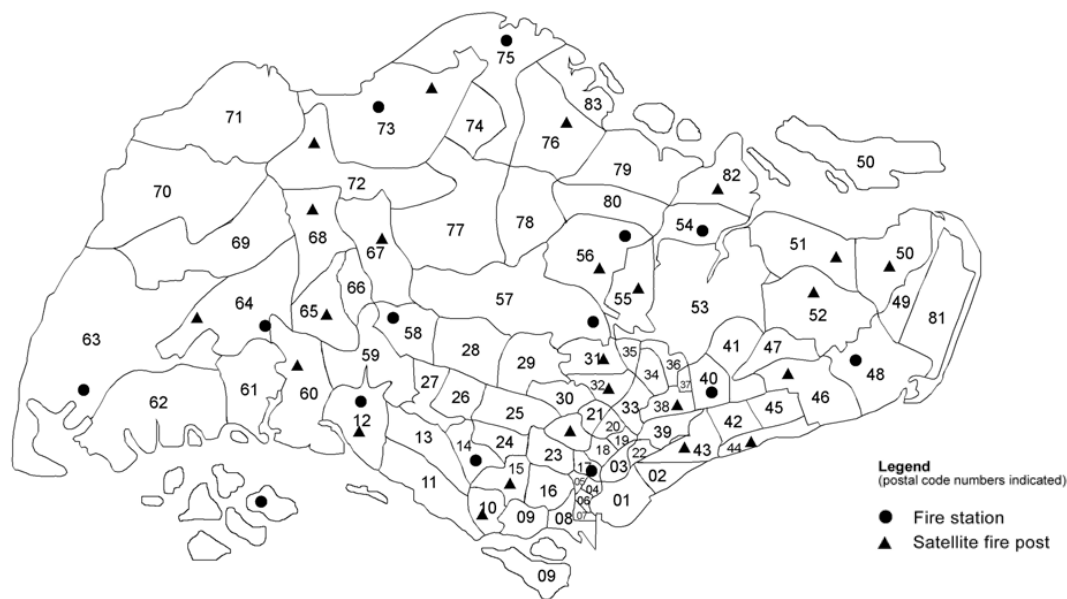


Fig. 1. Geographic distribution of SCDF fire stations and satellite stations, with postal code numbers indicated in each district.



Fig. 2. Geographical distribution of ambulance calls for Mondays.

Primary Data Analysis

Data management was carried out using the Clintrial application software version 4.4. All data analyses were performed using SPSS version 14.0 (SPSS Inc., Chicago, IL), presenting descriptive statistics and frequencies.

Locations of ambulance calls were spot mapped using Geographic Information Systems (GIS) technology (ArcGIS9, ESRI, Redlands, California). This was graphically displayed according to postal codes and correlated with other factors including time of day and day

Table 1. CARE 3 Patients' Characteristics

Characteristics	All patients (n = 31,896)
Mean age (n = 31,843; SD)	51.6 (23.0)
Male (n = 31,892; %)	19,143 (60.0)
Race (n = 31,892; %)	
Chinese	19,945 (62.5)
Malay	6177 (19.4)
Indian	4099 (12.9)
Others	1671 (5.2)
Incident classification (n = 31,895; %)	
Trauma	9937 (31.2)
Medical	21,945 (68.8)
Conveyance (Y) (n = 31,888; %)	31,862 (99.9)
Patient Emergency Status (n = 31,875; %)	
Priority 1	3093 (9.7)
Priority 2	22,331 (70.1)
Priority 3	6372 (20.0)
Priority 4	79 (0.2)
Standby case (Y) (n = 31,883; %)	2706 (8.5)
Traffic condition to hospital (n = 31,737; %)	
Heavy	2985 (9.4)
Moderate	26,409 (83.2)
Light	2343 (7.4)
Hospital (n = 31,878; %)	
Alexander Hospital	1310 (4.1)
Changi General Hospital	6752 (21.2)
KK Women and Children's Hospital (Adult)	359 (1.1)
KK Women and Children's Hospital (Children)	829 (2.6)
Tan Tock Seng Hospital	11,131 (34.9)
National University Hospital	7199 (22.6)
Singapore General Hospital	4294 (13.5)
Institute of Mental Health	4 (0.01)
Call receipt – arrival, min (n = 31,808; SD)	7.97 (4.75)
Scene interval, min (n = 31,617; SD)	15.15 (21.39)
Leave location – hospital, min (n = 31,498; SD)	16.47 (19.98)

of the week. Call occurrence was also compared with the census district population demographics, according to the 2000 census.¹²

Results

Between 1 January 2006 and 31 May 2006, 31,896 patients were enrolled into the study. Table 1 shows the characteristics of patients in the study. Mean age was 51.6

Table 2. Top 35 Postal Code Districts with the Highest Number of Ambulance Calls

Area	2 digit Postal code	N	Estimated Population base (2000 census)
Woodlands/Marsiling	73	1752	186,805
Yishun	76	1641	176,689
Hougang/Upp Serangoon Rd/ Paya Lebar	53	1629	203,402
Ang Mo Kio	56	1613	180,112
Tampines/Simei	52	1433	252,448
Bedok	46	1429	141,523
Jurong West	64	1293	203,838
Toa Payoh	31	1055	121,004
Tiong Bahru/Outram	16	813	148,299
Choa Chu Kang/Teck Whye	68	808	136,105
Sengkang	54	776	60,870
Bukit Batok	65	754	126,200
Clementi/West Coast	12	752	90,864
Bishan/Thomson	57	744	89,746
Bukit Merah/Redhill	15	709	11,639
Jurong East/Teban Gdn	60	693	88,883
Aljunied/Geylang East	38	680	118,565
Bukit Panjang	67	595	96,031
Queenstown	14	559	97,684
Serangoon Gdn/North/Ave	55	555	141,523
Pasir Ris	51	550	116,245
Towner Rd/Whampoa	32	475	31,481
Orchard	23	434	186,805
Sembawang	75	409	90,864
Tk Blangah/Bt Purmei/Mt Faber/ Sentosa	9	401	43,634
Marine Parade/East Coast	44	370	46,306
Beach Rd/Lavender	19	352	88,883
Kallang Bahru/Bendemeer	33	350	92,099
Ubi/Eunos	40	344	43,310
Jln Besar	20	325	43,310
Bedok Reservoir Rd	47	325	19,999
Jurong Town	61	317	203,402
Ghim Moh/Holland	27	309	12,436
South Bridge Rd/Chinatown	5	282	11,047
Bras Basah/Bugis	18	275	203,838

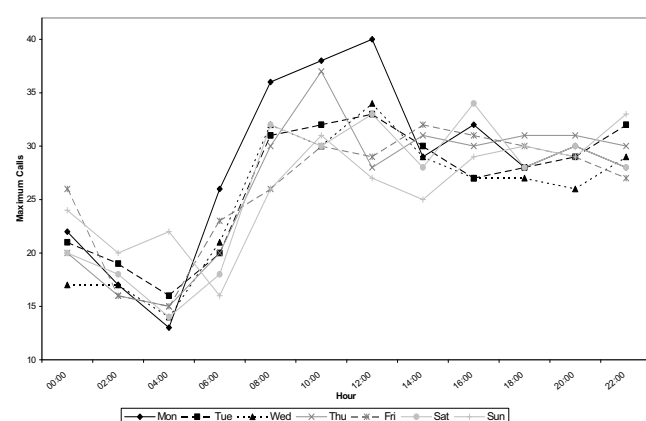


Fig. 3. Distribution of ambulance calls by hour of the day.

years with 60.0% males. 31.2% of calls were trauma cases and conveyance rate was 99.9%. 9.7% were judged by paramedics to be priority 1 (the most severe) and 70.1% priority 2 (moderate severity). Mean EMS response time was 8.0 minutes with an average scene interval of 15.2 minutes.

Table 2 shows the top 35 postal code districts with the highest number of ambulance calls. The estimated population base for each postal code is taken from the Singapore 2000 census.

Figure 2 shows the geographical distribution of ambulance calls for Mondays. Monday was chosen as a sample representative of the daily geographic distribution of calls. Figure 3 shows the distribution of ambulance call by hour of the day for all the days of the week. A general trend can be seen in the calls, with heaviest volumes from 0900h to 1300h, with a second, broader but lower peak occurring from 1800h to 2300h.

Figure 4 shows the number of ambulance calls by day of the week, with Mondays having the highest call volumes. Figure 5 shows top 35 postal code districts with the highest number of ambulance calls by time periods.

Limitations

Limitations of this study include data that is based on '995' calls reported to the national ambulance service. There may have been a number of medical emergencies that were brought to a healthcare facility by private ambulance operators or by their own transport. However our subjective experience is that this number is likely to be small and with more public education, use of the '995' universal access number is increasing.

Another limitation when considering a systems status plan is that currently, there is minimal prioritisation of ambulance calls by the severity of the medical condition. SCDF currently operates a basic criteria-based medical

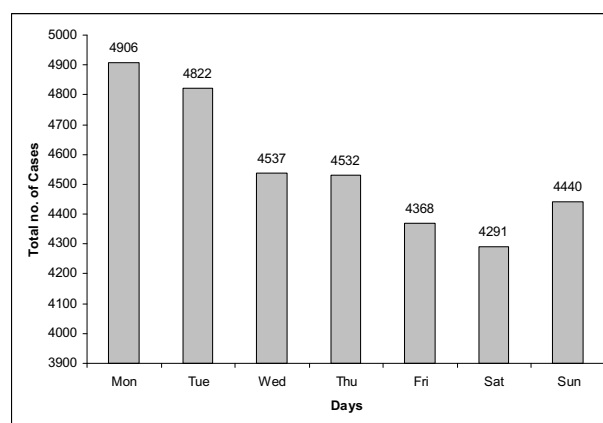


Fig. 4. Number of ambulance calls by day.

dispatching system, with a single tier response. This is an important consideration in ambulance deployment. However SCDF has implemented the use of fast response motorcycle paramedics (FRPs) for certain 'severe' conditions, especially where a defibrillator may be needed. Such FRPs have been shown to successfully reduce response times.¹³ SCDF is now studying the implementation of protocol based medical priority dispatching to further refine ambulance deployment.¹⁴⁻¹⁸ There are also plans to introduce a tiered response system, with different capabilities of treatment on ambulances. More study is needed to integrate any future medical prioritisation system with our GIS analysis.

Discussion

In this study, we found a definite geographical-time distribution pattern of EMS calls. This demonstrates the utility of using GIS in demand analysis and for planning ambulance deployment in an urban setting.

There has been a growing understanding that medical emergencies and ambulance calls are not random events, but occur in patterns and trends that can be observed historically. This is related to how circadian rhythms affect disease processes, movement patterns of people according to the time of day, as well as geographical epidemiology of the population and health seeking behaviours.

For example, it has been observed that sudden cardiac arrests follow a circadian pattern,¹⁹⁻²² with an increasing incidence in the mornings until noon.^{8,23} Weekly patterns have also been noticed, with increased frequency of cardiac events on Mondays.²⁴⁻²⁷ Seasonal variations have also been described.²⁴ Similar patterns have been observed in acute myocardial infarction,²⁸⁻³⁴ stroke^{22,35} and pulmonary embolism.³⁶ Various explanations for this effect that have been proposed include circadian variations in the autonomic nervous system,³⁷ variations in electrical activity,³⁸⁻⁴⁰

vascular changes^{41,42} and hormonal/metabolic fluctuations.⁴³ It is interesting that our ambulance calls also seem to correspond to these circadian rhythms.

In our study, we found that ambulance call occurrence was highest in the suburban town centres of the Eastern and Southern parts of the country (Fig. 2). This roughly corresponds with population densities, with a higher distribution in the Eastern and Southern parts of the country. The communities listed in Table 2 had the highest ambulance call occurrence; however we would need to consider not only the absolute number of calls occurring, but also the population base, as well as the geographic spread of the area involved.

We found that about twice as many ambulance calls occurred during the day (0701h to 1900h) compared to night (1901h to 0700h) (Fig. 3), with the most calls on Mondays (Fig. 4). In addition, the day cases were more clustered in the Southern commercial and business areas, in contrast to at night (Fig. 5). Figure 3 also shows that the general time-of-day pattern of call volumes was stable irrespective of the day of the week. This suggests to us that ambulance manpower should be deployed to match these peaks, rather than the current fixed manpower and shift system being used now.

We characterised the top 35 districts with the highest call

volumes by times periods, which will form the basis for ambulance deployment plans (Fig. 5). Currently, the SCDF ambulances operate out of fixed fire stations and satellite fire posts. However our data suggests that a mobile ambulance deployment pattern would result in shorter response times. This would mean placing ambulances in the districts with the highest anticipated call volumes for that time of the day. Real time monitoring of calls would allow redeployment of available ambulances to cover 'gaps' that occur when calls come in. This may mean that ambulances would not return to their base stations but be redeployed to districts where higher call volumes are anticipated. Other factors that might influence ambulance placement include population demographics, for example, the age of the population. This may account partially for the differing ambulance call rates within communities.

In a Scottish study, Pell et al,⁴⁴ calculated that a reduction in target ambulance response to 90% of calls from 14 minutes to 8 minutes would increase cardiac arrest survival from 6% to 8% and a response of 5 minutes would increase survival by up to 11%. Faster ambulance response times mean earlier initiation of CPR and earlier defibrillation. Survival after pre-hospital cardiac arrest has been shown to be determined mainly by the time from onset of ventricular fibrillation to electrical defibrillation.⁵ The advent of the

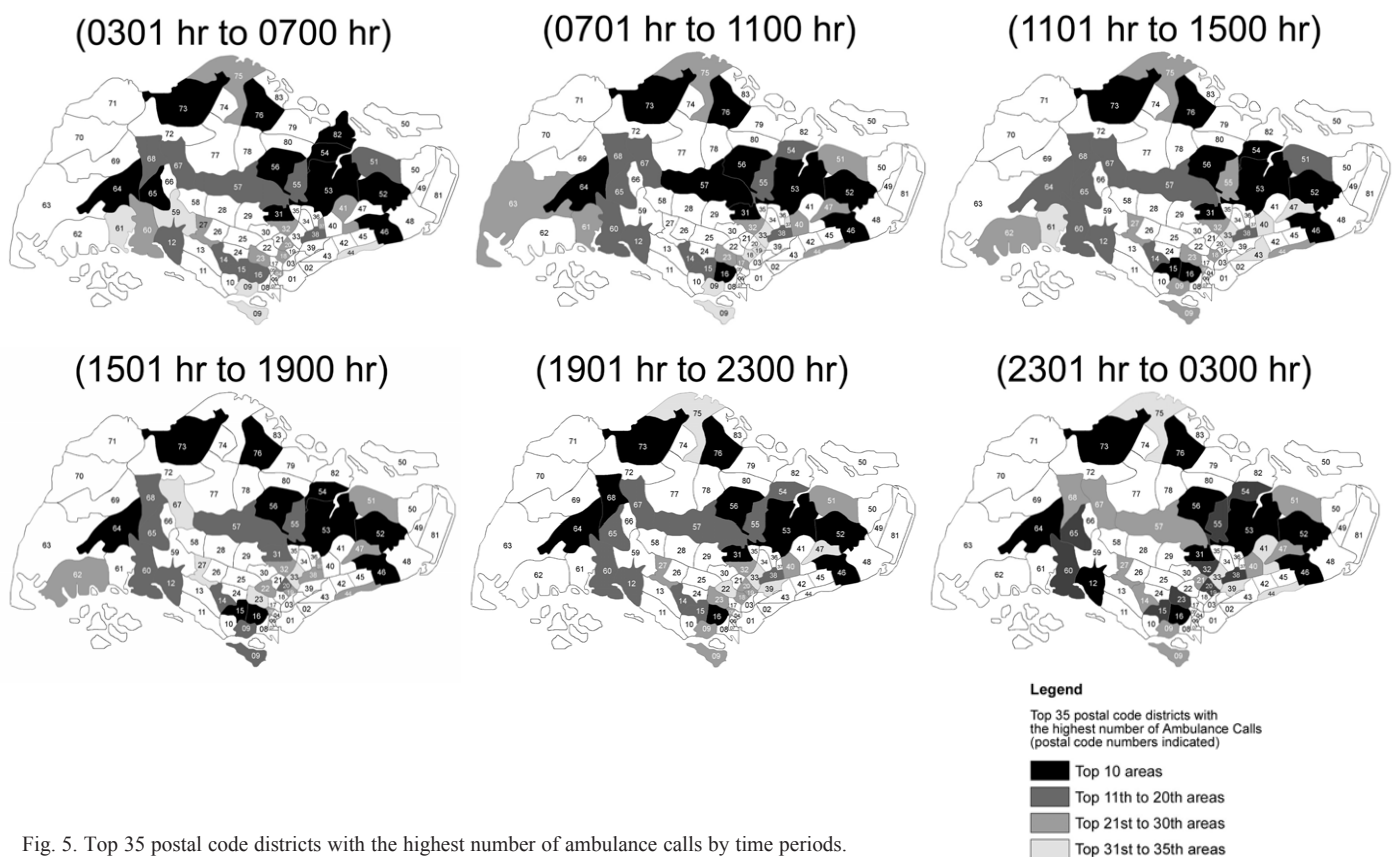


Fig. 5. Top 35 postal code districts with the highest number of ambulance calls by time periods.

AED allows ambulance paramedics to perform defibrillation safely, making pre-hospital defibrillation feasible.^{6,7,45,46} Survival rates of 74% have been reported where defibrillation has been performed within 3 minutes from collapse.⁴ Likewise, early initiation of CPR has been shown to improve survival.⁴⁷

Our results thus have application for ambulance deployment. Systems Status Management (SSM) is a technique for matching the movement of ambulances in anticipation of where they will be needed next by using historical temporal and geographic ambulance response data. SSM is a key tool for high performance ambulance, or EMS systems.⁴⁸ This is then combined with flexible, real time management of the deployment of resources to meet response time performance requirements. Our results show potential for the application of such theories. A specific challenge in our high-rise, urbanised city is the delay in reaching the patient associated with arrests occurring in high-floor buildings⁴⁹ which we have previously described. In communities that have longer ambulance response times, staffing, ambulance shifts, availability and placement can be looked into. For example, SCDF has since adjusted staffing to have more ambulances on the roads during the day, and fewer during the night, according to our demand analysis. We have also re-distributed ambulance deployment from an original 13 base fire stations, to an additional fire station and 10 satellite fire posts, in order to be closer to where predicted calls are occurring.

In this study, we have attempted to elaborate on the relationship between ambulance calls occurrence and population density in Table 2. However the difficulty is that the postal districts used in our EMS data do not exactly correspond to the census districts used to report population data. Thus, it is difficult to accurately determine arrest rates and to match numerators and denominators and the figures given are best estimates. This could be an area for future study.

Other areas for future study would include correlating the population age and social economic status distribution to the occurrence of ambulance calls. This may reveal further patterns that may influence ambulance placement. We also intend to continue with an in-depth demand analysis of possible sites of ambulance placement and their relative cost-benefit ratios. We intend to continue with an in-depth demand analysis and a pilot systems status plan. These results will enable us to derive the most effective ambulance deployment strategy by type and geography of location to reduce response times.

In conclusion, we found a definite geographical distribution pattern of ambulance calls in Singapore. This study demonstrates the utility of GIS and demand analysis for planning ambulance deployment in an urban setting.

Acknowledgements

This study was supported by grants from the National Medical Research Council, Ministry of Health, Singapore (NMRC/0989/2005).

We thank the following CARE study group investigators:

Medical Department, Singapore Civil Defence Force: COL (Dr) Tan Eng Hoe, Masnita Rahmat; Emergency Medicine Department, National University Hospital: Dr Benjamin SH Leong; Accident and Emergency Department, Changi General Hospital: Dr Tan Hock Heng, Dr Steven Lim Hoon Chin, Dr Tiah Ling; Department of Emergency Medicine, Alexandra Hospital: Dr Victor YK Ong; Children's Emergency, KK Women's & Children's Hospital: Dr Tham Lai Peng; Department of Emergency Medicine, Singapore General Hospital: Dr Rabind Antony Charles, Dr Fatimah Abdul Lateef, Nur Shahidah Ahmad; and Clinical Trials and Epidemiology Research Unit: Anushia Panchalingham.

REFERENCES

1. Singapore Department of Statistics: Key annual indicators. <http://www.singstat.gov.sg/stats/keyind.html#popnarea>. 2007. Accessed 26 October 2007.
2. Singapore Civil Defence Force Annual Ambulance Statistics. <http://www.scdf.gov.sg/General/News/statistics.html>. 2006. Accessed 26 October 2007.
3. Cummins RO, Ornato JP, Thies WH, Pepe P. Improving survival from sudden cardiac arrest: the "chain of survival" concept. *Circulation* 1991;83:1832-47.
4. Valenzuela TD, Roe DJ, Nichol G, Clark LL, Spaite DW, Hardman RG. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. *N Engl J Med* 2000;343:1206-9.
5. Valenzuela TD, Roe DJ, Cretin S, Spaite DW, Larsen MP. Estimating effectiveness of cardiac arrest interventions: a logistic regression survival model. *Circulation* 1997;96:3308-13.
6. White RD, Asplin BR, Bugliosi TF, Hankins DG. High discharge survival rate after out-of-hospital ventricular fibrillation with rapid defibrillation by police and paramedics. *Ann Emerg Med* 1996;28:480-5.
7. Eisenberg MS, Copass MK, Hallstrom AP, Blake B, Bergner L, Short FA, et al. Treatment of out-of-hospital cardiac arrests with rapid defibrillation by emergency medical technicians. *N Engl J Med* 1980;302:1379-83.
8. Levine RL, Pepe PE, Fromm RE Jr, Curka PA, Clark PA. Prospective evidence of a circadian rhythm for out-of-hospital cardiac arrests. *JAMA* 1992;267:2935-7.
9. Warden CR, Daya M, Legrady LA. Using geographic information systems to evaluate cardiac arrest survival. *Prehosp Emerg Care* 2007;11:19-24.
10. Lerner EB, Fairbanks RJ, Shah MN. Identification of out-of-hospital cardiac arrest clusters using a geographic information system. *Acad Emerg Med* 2005;12:81-4.
11. Ong EHM, Chan YH, Anantharaman V, Lau ST, Lim SH, Seldrup J. Cardiac Arrest and Resuscitation Epidemiology in Singapore (CARE I study). *Prehosp Emerg Care* 2003;7:427-33.
12. Singapore Department of Statistics: Singapore Census of Population. Available at: <http://www.singstat.gov.sg/pubn/census.html#c2000sr4>. 2000. Accessed 26 October 2007.
13. Ong M, Chan Y, Anantharaman V. Improved response times with motorcycle based Fast Response Paramedics. *SGH Proceedings* 2003;12:114-9.
14. Bailey ED, O'Connor RE, Ross RW. The use of emergency medical dispatch protocols to reduce the number of inappropriate scene responses made by advanced life support personnel. *Prehosp Emerg Care* 2000;4:186-9.
15. Hjalte L, Suserud BO, Herlitz J, Karlberg I. Initial emergency medical

- dispatching and prehospital needs assessment: a prospective study of the Swedish ambulance service. *Eur J Emerg Med* 2007;14:134-41.
16. Kuisma M, Holmstrom P, Repo J, Maatta T, Nousila-Wiik M, Boyd J. Prehospital mortality in an EMS system using medical priority dispatching: a community based cohort study. *Resuscitation* 2004;61:297-302.
 17. Reilly MJ. Accuracy of a priority medical dispatch system in dispatching cardiac emergencies in a suburban community. *Prehosp Disaster Med* 2006;21:77-81.
 18. Stout JL. Priority dispatching vs. call screening. *JEMS* 1984;9:34-9.
 19. Willich SN, Levy D, Rocco MB, Tofler GH, Stone PH, Muller JE. Circadian variation in the incidence of sudden cardiac death in the Framingham Heart Study population. *Am J Cardiol* 1987;60:801-6.
 20. Savopoulos C, Ziakas A, Hatzitolios A, Delivoria C, Kounanis A, Mylonas S, et al. Circadian rhythm in sudden cardiac death: a retrospective study of 2,665 cases. *Angiology* 2006;57:197-204.
 21. Jones-Crawford JL, Parish DC, Smith BE, Dane FC. Resuscitation in the hospital: circadian variation of cardiopulmonary arrest. *Am J Med* 2007;120:158-64.
 22. Hayashi S, Toyoshima H, Tanabe N, Miyanishi K. Daily peaks in the incidence of sudden cardiac death and fatal stroke in Niigata Prefecture. *Jpn Circ J* 1996;60:193-200.
 23. Muller JE, Ludmer PL, Willich SN, Tofler GH, Aylmer G, Klangos I, et al. Circadian variation in the frequency of sudden cardiac death. *Circulation* 1987;75:131-8.
 24. Arntz HR, Willich SN, Schreiber C, Bruggemann T, Stern R, Schultheiss HP. Diurnal, weekly and seasonal variation of sudden death. Population-based analysis of 24,061 consecutive cases. *Eur Heart J* 2000;21:315-20.
 25. Arntz HR, Muller-Nordhorn J, Willich SN. Cold Monday mornings prove dangerous: epidemiology of sudden cardiac death. *Curr Opin Crit Care* 2001;7:139-44.
 26. Gruska M, Gaul GB, Winkler M, Levnaic S, Reiter C, Voracek M, et al. Increased occurrence of out-of-hospital cardiac arrest on Mondays in a community-based study. *Chronobiol Int* 2005;22:107-20.
 27. Willich SN, Lowel H, Lewis M, Hormann A, Arntz HR, Keil U. Weekly variation of acute myocardial infarction. Increased Monday risk in the working population. *Circulation* 1994;90:87-93.
 28. Muller JE, Tofler GH, Willich SN, Stone PH. Circadian variation of cardiovascular disease and sympathetic activity. *J Cardiovasc Pharmacol* 1987;10 Suppl 2:S104-9; discussion S110-1.
 29. Lucente M, Rebuzzi AG, Lanza GA, Tamburi S, Cortellessa MC, Coppola E, et al. Circadian variation of ventricular tachycardia in acute myocardial infarction. *Am J Cardiol* 1988;62:670-4.
 30. Muller JE, Tofler GH, Stone PH. Circadian variation and triggers of onset of acute cardiovascular disease. *Circulation* 1989;79:733-43.
 31. Goldberg RJ, Brady P, Muller JE, Chen ZY, de Groot M, Zonneveld P, et al. Time of onset of symptoms of acute myocardial infarction. *Am J Cardiol* 1990;66:140-4.
 32. Hausmann D, Lichtlen PR, Nikutta P, Wenzlaff P, Daniel WG. Circadian variation of myocardial ischemia in patients with stable coronary artery disease. *Chronobiol Int* 1991;8:385-98.
 33. van der Palen J, Doggen CJ, Beaglehole R. Variation in the time and day of onset of myocardial infarction and sudden death. *N Z Med J* 1995;108:332-4.
 34. Cannon CP, McCabe CH, Stone PH, Schactman M, Thompson B, Theroux P, et al. Circadian variation in the onset of unstable angina and non-Q-wave acute myocardial infarction (the TIMI III Registry and TIMI IIIB). *Am J Cardiol* 1997;79:253-8.
 35. Manfredini R, Boari B, Smolensky MH, Salmi R, la Cecilia O, Maria Malagoni A, et al. Circadian variation in stroke onset: identical temporal pattern in ischemic and hemorrhagic events. *Chronobiol Int* 2005;22:417-53.
 36. Gallerani M, Manfredini R, Portaluppi F, Salmi R, Zamboni P, Cocurullo A, et al. Circadian variation in the occurrence of fatal pulmonary embolism. Differences depending on sex and age. *Jpn Heart J* 1994;35:765-70.
 37. Piepoli MF, Capucci A. Autonomic nervous system in the genesis of arrhythmias in chronic heart failure: implication for risk stratification. *Minerva Cardioangiol* 2007;55:325-33.
 38. Wennerblom B, Lurje L, Karlsson T, Tygesen H, Vahisalo R, Hjalmarson A. Circadian variation of heart rate variability and the rate of autonomic change in the morning hours in healthy subjects and angina patients. *Int J Cardiol* 2001;79:61-9.
 39. Beyerbach DM, Kovacs RJ, Dmitrienko AA, Rebhun DM, Zipes DP. Heart rate-corrected QT interval in men increases during winter months. *Heart Rhythm* 2007;4:277-81.
 40. Oren H, Cosgun A. Weekly variation of the QT dispersion in healthy subjects and in patients with coronary heart disease. *Cardiology* 2007;108:55-61.
 41. Pringle E, Phillips C, Thijs L, Davidson C, Staessen JA, de Leeuw PW, et al. Systolic blood pressure variability as a risk factor for stroke and cardiovascular mortality in the elderly hypertensive population. *J Hypertens* 2003;21:2251-7.
 42. Otto ME, Svatikova A, Barretto RB, Santos S, Hoffmann M, Khandheria B, et al. Early morning attenuation of endothelial function in healthy humans. *Circulation* 2004;109:2507-10.
 43. Li JJ. Circadian variation in myocardial ischemia: the possible mechanisms involving in this phenomenon. *Med Hypotheses* 2003;61:240-3.
 44. Pell JP, Sirel JM, Marsden AK, Ford I, Cobbe SM. Effect of reducing ambulance response times on deaths from out of hospital cardiac arrest: cohort study. *BMJ* 2001;322:1385-8.
 45. Eisenberg MS, Hallstrom AP, Copass MK, Bergner L, Short F, Pierce J. Treatment of ventricular fibrillation. Emergency medical technician defibrillation and paramedic services. *JAMA* 1984;251:1723-6.
 46. Herlitz J, Bang A, Axelsson A, Graves JR, Lindqvist J. Experience with the use of automated external defibrillators in out of hospital cardiac arrest. *Resuscitation* 1998;37:3-7.
 47. Martens PR, Mullie A, Calle P, Van Hoeyweghen R. Influence on outcome after cardiac arrest of time elapsed between call for help and start of bystander basic CPR. The Belgian Cerebral Resuscitation Study Group. *Resuscitation* 1993;25:227-34.
 48. Overton J, Stout J, Kuehl A. System Design, Prehospital Systems and Medical Oversight, National Association of EMS Physicians. 3rd ed. Kendall/Hunt Publishing, 2002:114-31.
 49. Lateef F, Anantharaman V. Delays in the EMS response to and the evacuation of patients in high-rise buildings in Singapore. *Prehosp Emerg Care* 2000;4:327-32.