ORIGINAL ARTICLE

THE EFFECTIVENESS OF A NAVIGATION SYSTEM FOR AMBULANCE SERVICE IN KUALA LUMPUR, MALAYSIA

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Running head: Navigation system for ambulance

ABSTRACT

The response and transport intervals of an ambulance dispatch are affected by various factors. The present ambulance system relies on the driver's experience, knowledge of local road map and estimations of directions. These may contribute to delays, misdirection and inefficient utilization of resources. The objectives of this study were to assess the effects of GPS navigation device on the response and transport time intervals of an ambulance service operating in urban setting. This was a three-month experimental study involving simulated ambulance dispatch based in a hospital. A total of 50 simulated cycles were constructed. Travel time, arrival time and distance were documented from each cycle. The median actual response time using map and GPS navigation device was 11.82 min and 10.47 min respectively. The median actual transport time using map and GPS navigation device was 11.00 min and 10.74 min respectively. The differences in response time and transport time between map and GPS navigation were not statistically significant (p= 0.215 and p=0.710). The application of GPS reduced the error value between estimated and actual response time by 8.73%. It also reduced the mean error value between estimated and actual transport time by 1.42%. The result shows that the GPS navigation device allowed for more accurate travel time estimation and its application in an urban setting such as Kuala Lumpur has the potential to reduce ambulance response time.

Keywords: *Emergency; GPS navigation; Prehospital care; Response time; Transport time.*

INTRODUCTION

Rapid ambulance response and transport intervals are key performance parameter for pre-hospital Emergency Medical Services (EMS), especially for cases involving severe trauma or cardiac arrest[1]. Response and transport intervals are associated with patients' survival[2]. The importance of EMS response times is closely related to "The Golden Hour" concept[3]. The likelihood for successful defibrillation and survival of out of hospital cardiac arrest reflects the importance of EMS travel times in the chain of survival[4-7]. One cohort study showed an increase of survival rate by two times when ambulance response was reduced by five minutes[5].

There is a need to improve ambulance travel time intervals in developing countries. Accurate communication of information and traffic conditions may influence the response and transport times[7]. Most ambulances are already equipped with two-way radio communication. However, navigation to an incident site requires ambulance drivers to rely on their experience, familiarity with local maps and radio assistance from the base. This may contribute to the delay and errors in directions and prolonging ambulance travel intervals.

Many land transportation vehicles and services are now equipped with Global Positioning Systems (GPS) navigation. It is a satellite-based navigation system that provides tracking and navigation functions based on the triangulation of positioning information. It covers a wider area for positioning on the map compared to other localization method, such as radio frequency triangulation[8].

The purpose of this study is to determine the significance of GPS as a navigation tool for ambulance service operating in urban area.

METHODOLOGY

This was a three-month experimental study involving simulated ambulance dispatch from an emergency department (ED). A total of 50 simulated cycles were constructed for this study. The ambulance was dispatched from the ED to 50 randomly selected locations within 15 km ambulance coverage area based on the previous year record of emergency calls. The study instrument consisted of one ambulance equipped with a GPS navigation tool (Global Positioning System-GARMIN®), a local map, a stopwatch to record times and a questionnaire. The ambulance team consists of a paramedic and a driver. The ambulances used in this study were also equipped with global system for mobile (GSM) communications with a general package radio service (GPRS) tracking system that is used to identify the vehicle's location from ED. It was unable to provide automated driving directions to the drivers. All assistance for directions were obtained via two-way radio communication with ED.

Each simulation cycle consisted of two runs. The ambulance team chose the route for the first run based on their familiarity and guided with a local map. Navigation for the second run to the same address was provided by the Garmin® GPS Navigator. The route provided by the GPS may not be the same as the route chosen by the ambulance team. The interval between the first and second run was less than 30 minutes. All cycles were conducted during working days (Monday to Friday) and working hours (8.00 am to 5.00 pm). The same ambulance team and ambulance were involved in each simulation cycle. Prior to a simulation cycle, brief explanation and information about the study were provided and the ambulance team completed a consent form.

Data was collected following institutional ethical committee approval. Trained data collectors were assigned to monitor the ambulance response and documentation of data. Warning lights without sirens were used for each ambulance run. All speed limits were closely adhered to. Travel time, arrival time and distance travelled were collected from each cycle. The estimated time of arrival (ETA) en route to location and back to ED were obtained from the ambulance team during the first run. The calculated time of arrival (CTA) en route to the location and back to ED were obtained from the GPS used during the second run. Trained data collectors documented the actual time of arrival (ATA) en route to location and back to ED, and all enquiries for directions from the ambulance team. The ambulance drivers and paramedics completed a questionnaire at the end of each simulation cycle.

There were four variables measured in this study. These are the response time, transport time, distance travelled and the ambulance team. Response time is defined as the time interval between ambulance dispatch from ED and arrival to the scene. Transport time is defined as the interval between ambulance departure from the scene and arrival at ED. Travel time is the sum of response and transport times. The ambulance team and the navigation device respectively provide the estimated and calculated travel times. The actual travel time is the time recorded during the ambulance run. There were two distance components, response distance and transport distance. The route used for response may differ from that used for transport to the hospital. The profile of the ambulance team includes age, years of working experience, familiarity of the ambulance coverage area (address, street names and route). Their opinion on the relevance of the navigation device in emergency response were taken into consideration. Data was analysed using Statistical Package for Social Science (SPSS) version 18 and Microsoft Office Excel 2007.

RESULTS

There were 20 male respondents involved in this study. The majority was between 26 to 35 years (60%). There were 13 ambulance drivers and seven paramedics. The majority has one to five years working experiences (55%). Fifteen respondents were familiar with the current ambulance coverage area and nine were familiar with the street names and addresses (Table 1).

Table 1: Distribution of Study Respondent Demographic Characteristic

Demographic Characteristics	Frequency (*f*)	Percent (%)
Age		
<26 years	2	10
26years-35 years	12	60
36 years-45 years	2	10
46 years-55 years	4	20
Gender		
Male	20	100
Female	0	0
Position		
Driver	13	65
Paramedic	7	35
Service Experience		
1 year- 5 years	11	55
6 years-10 years	5	25
11 years- 15 years	3	15
>16 years	1	5

There is no statistical difference of actual travel time between the two navigation methods (Table 2). However, there is a significant difference between the median calculated and actual transport time using GPS navigation device (Table 3).

Table 2: Actual Response and Transport Time using Map and GPS navigation

	Navigation	Time Interval					*p* (Mann-Whitney test)
		Min	Max	Mean	Standard Deviation	Median	
Actual Response Time	Map	3.28	29.52	11.85	5.38	11.82	0.215
	GPS	2.77	20.47	10.52	4.00	10.47	
Actual Transport Time	Map	3.17	20.70	10.73	4.58	11.00	0.710
	GPS	3.07	27.12	11.43	5.55	10.74	

P value <0.05 statistically significant using Mann-Whitney test

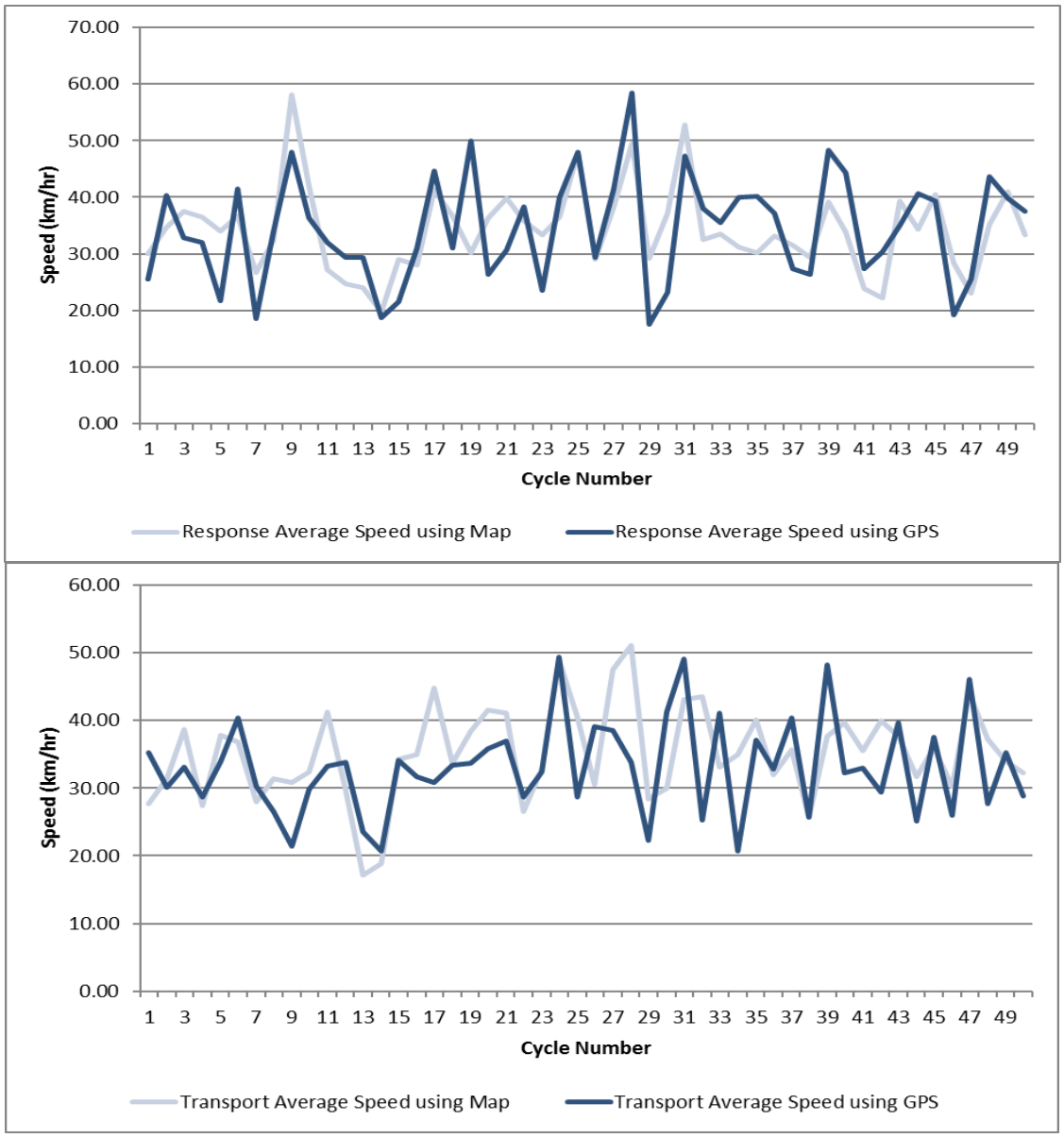
Table 3: ETA, CTA and ATA for Response and Transport Time using Map and GPS navigation

	Navigation	Time Interval (Median)			*p* (Mann-Whitney test)
		ETA	CTA	ATA	
Response Time	Map	10.00	-	11.82	0.233
	GPS	-	8.66	10.47	0.053
Transport Time	Map	10.00	-	11.00	0.602
	GPS	-	8.43	10.74	0.028

Abbreviations: ETA, estimated time of arrival; CTA, calculated time of arrival; ATA, actual time of arrival. P value <0.05 statistically significant using Mann-Whitney test

Mean speed is the distance (km) divided by travel time (hr). The mean speed for response using GPS navigation and map navigation were 34.35 km/hr and 34.22 km/hr respectively (Figure 1). The mean speed for response using GPS navigation was higher by 0.13 km/hr than map navigation. Standard deviation values for the mean speed for response using GPS navigation and map navigation were 9.38 km/hr and 7.57 km/hr respectively. The mean speed for transport using GPS navigation and map navigation were 33.06 km/hr and 35.18 km/hr respectively. The mean speed for transport using GPS navigation was lower by 2.12 km/hr than map navigation. Standard deviation values for the mean speed for response using GPS navigation and map navigation were 7.02 km/hr and 6.90 km/hr respectively.

Figure 1: ***Mean Speed using Map and GPS navigation for each response and transport cycle***



Error values may be interpreted as an accuracy of estimated or calculated travel time compared to actual travel time. Error value formula is as follows in Equation (1) and Equation (2).

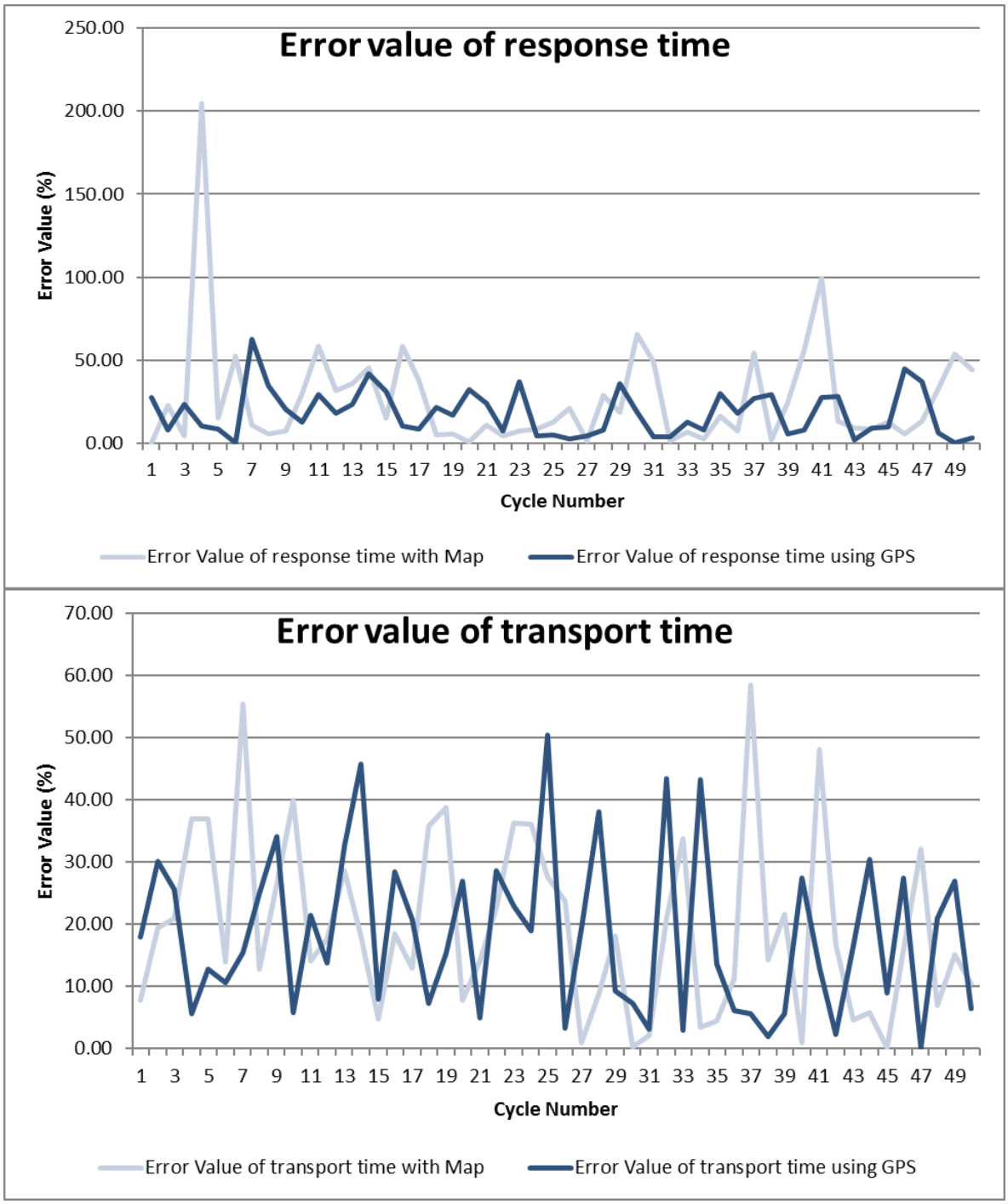
$$(1)\quad \text{Error value using Map} = \frac{\text{abs(ETA-ATA)}}{\text{ATA}} \times 100\%$$

$$(2)\quad \text{Error value using GPS} = \frac{\text{abs(CTA-ATA)}}{\text{ATA}} \times 100\%$$

Map-navigated response recorded a minimum error value of 0.21% and maximum of 204.57% with a mean of 26.81%. GPS-navigated response recorded a minimum error value of 0.29% and maximum of 62.54% with the mean of 18.08%. GPS use decreased the mean error value in response by 8.73% compared to map navigation. Map-navigated transport recorded a minimum error value of 0.11% and a maximum of 58.42% with the mean error of 19.64%.

GPS-navigated transport recorded minimum error value of 0% and a maximum error value of 50.46% with a mean 18.22%. GPS use decreased the mean error value in transport by 1.42% compared to map navigation (Figure 2).

Figure 2: Error values derived from Map and GPS navigation for response and transport

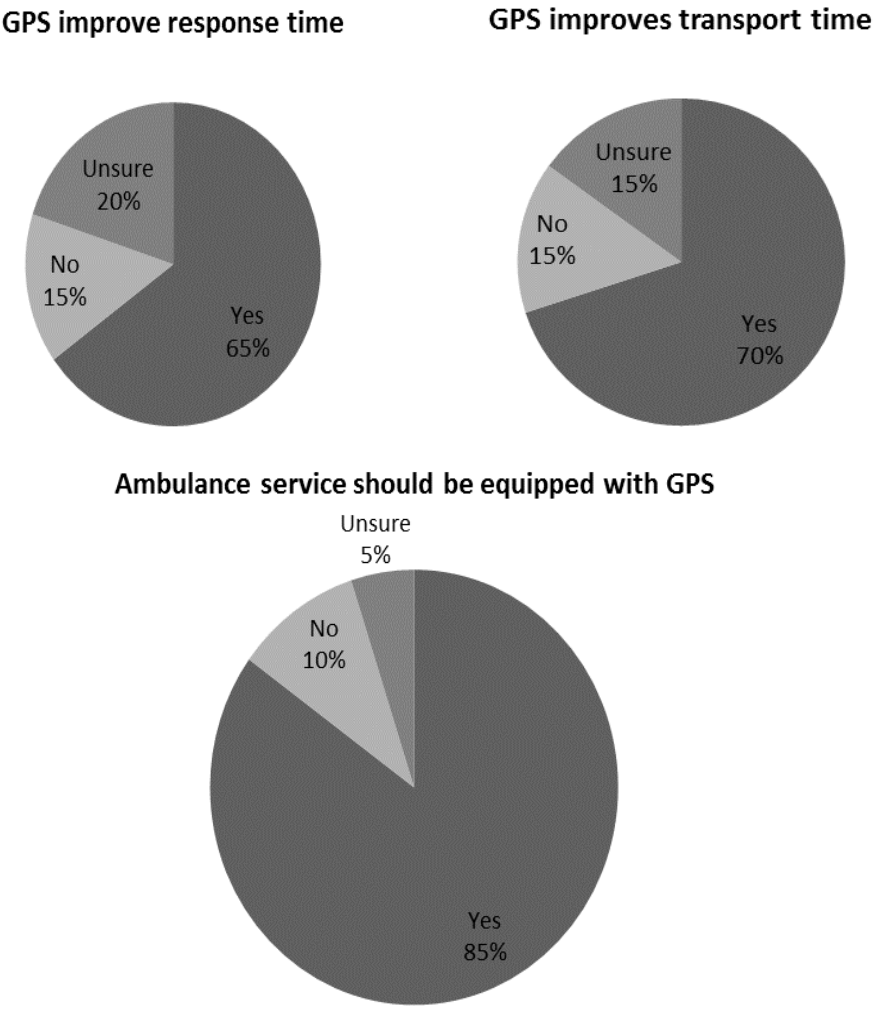


There were 28 radio calls for navigational assistance recorded for map-navigated responses compared to just one for GPS-navigated response. There were zero calls for navigational assistance recorded during transport times.

From the questionnaire, eighteen respondents had past experience of difficulties in locating addresses when responding to emergency calls. Seven respondents were familiar with alternative routes to a location within the ambulance coverage area.

Following the implementation of GPS navigation, 13 respondents agreed that the device improved response time and 14 respondents agreed that it improved transport times. Seventeen respondents found the device easy to operate and agreed that every emergency ambulance should be equipped with a GPS navigating device (Figure 3).

Figure 3: ***Emergency team's opinion on GPS***



DISCUSSION

The provision of quality care and the time required for ambulance response and transport to the hospital are the main parameters that significantly affect patient outcome[5]. The overall transportation time from the onset of the incident depends on four individual parameters[5]. These parameters are notification interval, response interval, on-scene interval, and transport interval. Reducing each one of these intervals will result in faster initiation of the definitive treatment in the hospital.

The application of GPS technology in ambulances has been shown to improve response and transport times in developed countries[9]. It has also been suggested that a portable GPS computer navigator system can enhance the ability of pre-hospital care providers to locate their destinations. Real time traffic broadcasts were not integrated into the GPS navigation system used in this study. The GPS navigation device used assumes that the traffic conditions were clear and the traffic lights were green at all times. A GPS navigation system which allows the driver to reach the same destination using alternative route depending on the estimated traffic volume on the road at that particular time may further improve the response and transport times[10]. A device that can automatically upload the address or coordinates using wireless technology can eliminate the time taken to communicate the location address to the dispatch team. This would reduce the human error of manually writing down and keying the address into a GPS navigation system in the ambulance. Thus, the development and application of an integrated system by combining both tools for tracking and navigation may positively influence the critical aspect of emergency response in an urban setting.

The differences in response time and transport time between map and GPS navigation in this study were not statistically significant. Traffic conditions

in the city may have contributed to our findings. The most probable cause for failure to reduce ambulance transport time is unpredicted traffic congestion[10]. Ambulance drivers were more familiar with a route based on their previous experience. This may provide them with the confidence to drive faster or to select a less congested route to the scene and hospital. GPS used in this study did not significantly increase the mean speed of travel. However, GPS navigation is useful in identifying a location, especially in responding to cases in unfamiliar areas. These findings were reflected in the feedback given by the paramedics and ambulance drivers of this study. GPs navigation may resolve the problems of ambulance drivers who are unfamiliar or inexperienced with alternative routes in urbanized areas.

This study showed that GPS use increased the accuracy of travel time estimation. A retrospective study done on all scene transports in Multnomah County, Oregon showed an estimate of transport time based only on a street network significantly underestimated transport times[11]. The study also noted the combination of GPS data with a web map application and the use of lights and sirens had a significant effect on transport times and may optimize emergency department resource use. Accurate arrival time estimation is important, because it provide reassurance to the caller and patient at the location. It also provides the opportunity for optimal preparation to receive the patient in ED. Underestimation of transport time may contribute to delay and inadequacy of ED staff to receive patient[11]. On the other hand, overestimation of transport time can lead to wastage and prevent ED staff to provide care to other patient. Inefficient utilization of human resource is also caused by excessive radio communication between ambulance driver and dispatch operator during the ambulance response. This prevents the dispatch operator from attending to other calls or performing other tasks. This inefficiency may be improved by the use of GPS navigation.

Limitations

The location chosen for this study may not represent all urbanized area. The utilisation of the same medical team to compare both navigational methods may not demonstrate unambiguously the effectiveness of GPS.

CONCLUSIONS

The application of ambulance navigation system in an urban setting such as Kuala Lumpur is as effective as using conventional maps and it has the potential to reduce response time. The GPS navigation device allowed for more accurate travel time estimation and was preferred by the ambulance team.

ACKNOWLEDGEMENT

The authors would like to thank Prof Colin Robertson, University of Edinburgh; Prof Shamsul Azhar Shah, Community Health Department, UKMMC; Dr Zuraidah Che Man and Dr Husyairi Harunarashid, Center for Research in Emergency Medicine (CREM) for their support and assistance, The authors declares no conflict of interest. This study was funded by UKM Research University Grant [UKM-GUP-2011-326].

REFERENCES

1. Myers JB, Slovis CM, Eckstein M, et al. Evidence-based performance measures for emergency medical services systems: a model for expanded EMS benchmarking. *Prehosp Emerg Care* 2008; **12**(2):141-151.

2. Blackwell TH & Kaufman JS. Response time effectiveness: comparison of response time and survival in an urban emergency medical services system. *Acad Emerg Med* 2002; **9**(4):288-295.

3. Mullie A, Van Hoeyweghen R & Quets A. Influence of pre-CPR conditions on EMS response times in circulatory arrest. The Cerebral Resuscitation Study Group. *Resuscitation* 1989:S45-51.

4. Feero S, Hedges J, Simmons E, et al. Does out-of-hospital EMS time affect trauma survival? *Am J Emerg Med* 1995; **13**(2): 133-135.

5. Cummins RO, Ornato JP, Thies WH, et al. Improving survival from sudden cardiac arrest: the "chain of survival" concept. A statement for health professionals from the Advanced Cardiac Life Support Subcommittee and the Emergency Cardiac Care Committee, American Heart Association. *Circulation* 1991; **83**(5):1832-1847.

6. Pell JP, Sirel JM, Marsden AK, et al. Effect of reducing ambulance response times on deaths from out of hospital cardiac arrest: cohort study. *BMJ* 2001; **322**(7299):1385-1388.

7. Anisah A, Chew KS, Mohd Shaharuddin Shah CH, et al. Patients' perception of the ambulance services at Hospital Universiti Sains Malaysia. *Singapore Med J* 2008; **49**(8):631-635.

8. Mintsis G, Basbas S, Papaioannou P, et al. Applications of GPS technology in the land transportation system. *European Journal of Operational Research* 2004; **152**(2):399-409.

9. Ota FS, Muramatsu RS, Yoshida BH et al. GPS computer navigators to shorten EMS response and transport times. *Am J Emerg Med* 2001; **19**(3):204-205.

10. Van der Pols H, Mencl F, De Vos R. The impact of an emergency motorcycle response vehicle on prehospital care in an urban area. *Eur J Emerg Med* 2011; **18**(6):328-333.

11. Ross JF, Mark L, Jonathan J, et al. Predicting ambulance time of arrival to the emergency department using global positioning system and google maps. *Prehospital Emergency Care* 2013; **17**(4):458-465.