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Analysis of the factors influencing ambulance response time in Liwan District, Guangzhou

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Abstract: To probe into the distribution of and factors influencing the ambulance response time of Liwan District People's Hospital of Guangzhou, to provide references for scientific deployment of emergency medical resources. A multinomial logistic model was established to analyze the factors influencing ambulance response time through acquisition of statistic distribution rules of emergency time and ambulance response time and the work records of pre-hospital care of Liwan District People's Hospital of Guangzhou from May of 2015 to April of 2016.Of the patients receiving emergency care, male patients represented a higher proportion, and patients under the age of 20 represented a lower proportion; emergency respiratory events occurred less often between March and April and more often between May and July. Peak hours for emergency calls were from 9:00AM to 11:00AM. Multinomial logistic model analyses showed that patients' age and time and month of the out-call had a dramatic impact upon the ambulance response time ($p < 0.05$), that the ambulance response time was longer as patient's age increased, that it took longer for ambulances to respond in the morning rush hours (8:00AM~11:00AM) than in other time periods, and that the ambulance response times were longest during October and November. Ambulance response time is influenced by factors like time of day and month of the year when the out-call happens. With respect to the factors influencing response time and its distribution and variation during the day and year, decisions can be made to rationally distribute emergency medical resources and shorten ambulance response time.

Keywords: pre-hospital care; ambulance response time; multinomial logistic regression

I. INTRODUCTION

Pre-hospital care is one of the key segments of emergency medical service [1]. As shown in Figure 1, pre-hospital care services include the entire process from the incoming emergency call to transporting the patient to the hospital by ambulance; ambulance response time (ART) is defined as the time interval from ambulance dispatch to arrival at the emergency site.

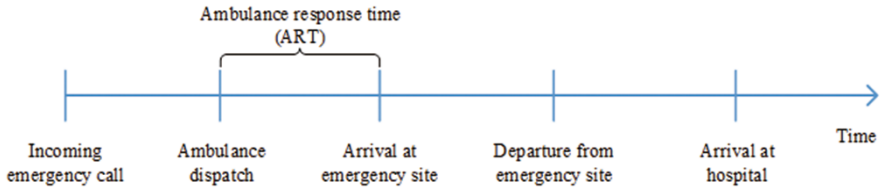

Figure 1. Response Processes of Pre-hospital Care

The performance indicators of some intermediate processes are usually used to evaluate the effectiveness and efficiency of pre-hospital care services, of which ART is one of the most intuitive and important indicators for evaluation [2]. Different areas have different natural and social conditions and different economic and cultural development levels. For these reasons, ART and the factors influencing it differ to some extent.

This article uses pre-hospital care data collected from Liwan District People's Hospital of Guangzhou, between May of 2015 and April of 2016 to conduct a statistical analysis of basic conditions of pre-hospital care and objective factors that influence ART. Results shows that the influence of patient age and time and month of the out-call on ART is significantly correlated, thus providing reference for scientifically and effectively allocating limited emergency medical resources.

1.1 Current Domestic and International Situations

Outside China, Zhang et al. proposed that rational allocation of ambulance quantities in different areas can help reduce average ART [3]; Lam et al. analyzed emergency data in Singapore and discovered that weather, road traffic conditions, accident location, and so on can dramatically affect ART [2]. Through quantile regression analysis, Do et al. indicated that the number of emergency calls an hour prior to an incident will have a quantile impact on ART with a higher quantile indicating a more significant effect [4].

Domestically, Liu et al. analyzed the features of pre-hospital care time distribution of the Emergency Aid Center in Zigong, Sichuan Province. The results indicated that the weekly distribution of the number of the pre-hospital care events did not have an obvious peak period. Pre-hospital care was distributed more in the winter. Differences in the time distribution of pre-hospital care due to different diseases were not statistically significant [5]. Zhang analyzed the distribution of pre-hospital care at People's Hospital in Shaoxing, Zhejiang, with statistical results concluding that diseases requiring pre-hospital care mainly concentrated on digestive system diseases, respiratory system diseases, and injury caused by car accidents and occurred mostly in the overnight hours and the morning and evening rush hours [6].

II. STUDY PARTICIPANTS AND METHODS

2.1 Study Data

Data were obtained from pre-hospital care work records throughout the year (from May of 2015 to April of 2016) of the Liwan District People's Hospital of Guangzhou. Of a total of 2250 records, 1834 were included after filtering canceled calls, invalid calls, and data with missing fields.

2.2 Influencing Factors

The influencing factors researched in this article included patient and environmental characteristics. Patient characteristics included sex, age, and departments dispatched; environmental characteristics included the time, month, and day when the emergency call occurred. These characteristics were extracted from the dataset to analyze whether they affected ART.

ART was categorized into four groups for analysis: less than 4 min, 4 min~8 min, 8 min~12 min, and over 12 min. Sex included male and female. Age was divided into five groups: under 20, 20~40, 40~60, 60~80, and above 80. Departments dispatched included Internal Medicine, Surgery, Gynecology, and Pediatrics. Time of ambulance deployment was divided into four groups according to the extent of the urban road traffic congestion in Guangzhou: 8:00~11:00 (morning rush hour), 11:00~17:00 (midday period), 17:00~20:00 (evening rush hour), 20:00~8:00 (late night period). The morning and evening rush hours and the midday period were combined as day period. Months were divided into four groups depending on the climate characteristics of Guangzhou: December~February of the following year (winter), March~May (spring), June~September (summer), and October~November (autumn). Summer consists of four months because Guangzhou is located near the Tropic of Cancer.

2.3 Statistical Analysis

In this paper, SPSS 22.0 and Microsoft Excel 2010 were utilized for data processing and statistical analysis with two components:

(1) Conventional statistics were utilized to analyze distribution of emergency events and ART.

(2) The multinomial logistic model (MNL) was used to analyze the factors that influence ART. By screening factors with noticeable effects on ART using the chi-square test, an MNL was established to analyze the extent to which different factors affect ART. Within the model, ART less than 4 min was considered a model reference category.

III. RESULTS, DISCUSSION, AND CONCLUSIONS

3.1 Analysis of Emergency Event Characteristics

Patient information from the emergency treatment record is summarized in Table 1. Of the patients receiving emergency treatment, the proportion of male patients was about 10 percentage points higher than that of female patients. After excluding the under-20 age group, which had a lower proportion of patients, patients were evenly distributed between the remaining age groups with the 60~80 age group having the highest proportion (27.7%), showing that patients receiving pre-hospital care were mostly elderly people. The majority of emergency patients were referred to the Internal Medicine department (66.4%) followed by Surgery (26.3%) with fewer patients referred to Gynecology and Pediatrics.

Table 1 Information of Patients Receiving Emergency Treatment

Characteristic	**Total Number of Patients (n = 1834)**
Gender	**Number (percentage)**
Male	1015(55.3%)
Female	819(44.7%)
Age	**Number (percentage)**
<20	90(4.9%)
20~40	438(23.9%)
40~60	449(24.5%)
60~80	509(27.7%)
>80	348(19.0%)
Department	**Number (percentage)**
Internal Medicine	1218(66.4%)
Surgery	483(26.3%)
Gynecology	99(5.4%)
Pediatrics	34(1.9%)

The characteristics of the monthly and hourly distribution of the number of emergency events are shown in Figures 2 and 3. As shown in the monthly distribution figure, emergency events occurred more frequently in May and July (total 31.8%) and less frequently in March and April (5.0% and 6.1%, respectively) and were evenly distributed among the remaining months (around 8%). As indicated in the hourly distribution figure, the period of 0:00~7:00 had a low frequency for emergency events (about 2%). Noticeable peaks appeared during the periods of 9:00~10:00 and 10:00~11:00 (6.8% and 6.4%, respectively). The proportions in the remaining periods were evenly distributed (around 4.5%).

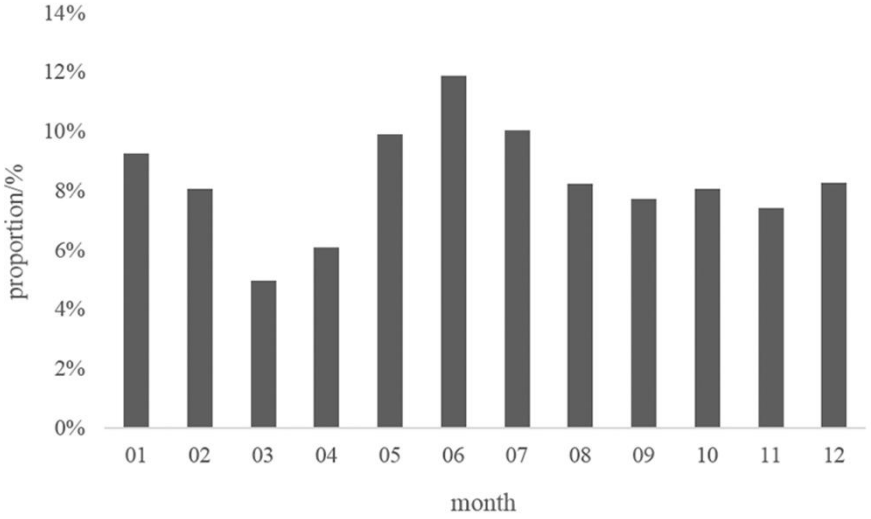

Figure 2 Monthly Distribution of Emergency Events

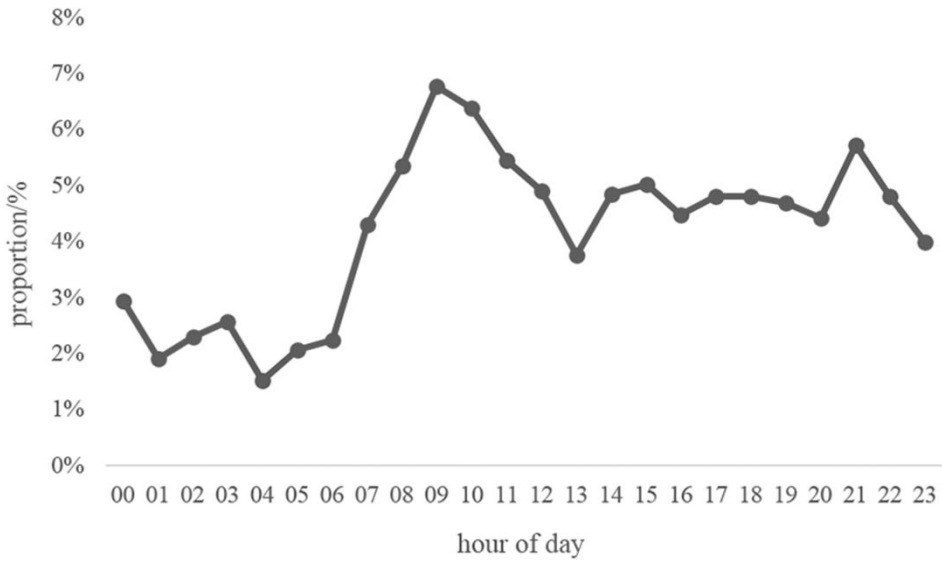

Figure 3 Hourly Distribution of Emergency Events

3.2 ART

ART is generally used to measure the response speed of pre-hospital care service with 8 min as the international standard [7]. The classification of emergency treatment and current ART status quo in some countries and regions are shown in Table 2.

Table 2 Classification of Emergency Treatment Grade and ART Status Quo

Region	Classification of Emergency Treatment	ART Status Quo
Singapore[a]	PACS (Patient Acuity Category Scale)1–4 Sequentially classified into 4 grades according the seriousness of the patients' symptom. PAC1 refers to life-threatening conditions.	ART Median Time: 7 min, 5 sec ART90 Quantile Time: 12 min, 41 sec
Wales[b]	Classified into Red, Yellow, and Green according the patients' symptoms. Red refers to life-threatening conditions.	ART Median time in Red Emergency: 4 min, 38 sec ART Average Time in Red Emergency: 5 min, 12 sec
United Kingdom South East Coast Ambulance Service[c]	Classified as Grade red1 and Grade red2. Red1 refers to life-threatening conditions.	Grade red1 ART: 71.6% below 8 min Grade red2 ART: 67.3% below 8 min
Scotland[d]	Classified as Grade A and Grade B Grade A indicates conditions that are life threatening	Average ART Time in Grade A: 7 min, 24 sec
Liwan District People's Hospital of Guangzhou	No classification for emergency treatment	Average ART Time: 8 min, 37 sec ART: 54.9% less than 8 min

[a]Data from references[3]
[b]Data from Welsh governmental statistics website http://gov.wales/statistics-and-research/ambulance-services
[c]Data from United Kingdom South East Coast Ambulance Service website http://www.secamb.nhs.uk/about_us/our_performance/response_time_targets.aspx
[d]Data from Scottish Ambulance Service Annual Report 2015/2016 http://www.scottishambulance.com/TheService/annualreport.aspx

As shown in Table 2, relatively developed regions abroad had emergency treatment levels that were classified. By classifying emergency treatment patients into different grades, emergency medical resources are appropriately triaged to critical patients, ensuring that ART for these patients is as short as possible, thus raising the patients' survival rate.

Comparing ART of each region vertically reveals that developed regions concentrate more on ART for critical patients, which is usually deemed as the index for statistical evaluation. Overall, the average ART of Liwan District People's Hospital of Guangzhou is higher than those of developed regions abroad. The rescue rate with ART below 8 min is relatively low, which still needs some improvement.

The correlation of ART with patient characteristics and other factors is shown in Table 3. As shown in Table 3, ART is distributed mostly in 4~8 min (43.07%) followed by 8~12 min (30.75%). To investigate specific factors affecting ART and their extent, the chi-square test was used, and the following conclusions were drawn: out-call period, patients' age, and month were significantly correlated with ART; thus, these factors were chosen for study and to establish the MNL. Specific results for the model parameters are shown in Table 4.

Table 3 Distribution of ART

	Proportion of ART/%			
	Below 4 min	4~8 min	8~12 min	Above 12 min
Gender				
Male	7.47	24.37	16.25	7.25
Female	4.36	18.70	14.50	7.09
Age				
Under 20	0.87	2.24	1.47	0.33
20~40	3.71	10.36	6.87	2.94
40~60	3.27	10.85	7.09	3.27
60~80	2.73	12.10	8.12	4.80
Above 80	1.25	7.52	7.20	3.00
Department				
Internal Medicine	7.20	28.63	20.83	9.76
Surgery	3.98	11.01	7.63	3.71
Gynecology	0.33	2.78	1.47	0.82
Pediatrics	0.33	0.65	0.82	0.05
Time of Out-call				
8:00~11:00	1.53	7.25	6.38	3.33
11:00~17:00	2.67	11.45	10.30	4.03
17:00~20:00	1.64	6.22	3.98	2.45
20:00~8:00	6.00	18.16	10.09	4.52

Month				
December ~ February of following year	3.54	11.72	7.31	3.05
March ~ May	3.00	9.11	5.78	3.11
June ~	4.20	14.61	12.76	6.32
October ~ November	1.09	7.63	4.91	1.85
Total	11.83	43.07	30.75	14.35

Table 4 MNL Regression Analysis (Model for Reference: ART < 4 min)

Factor	ART: 4–8 min				ART: 8–12 min				ART: >12 min				Likelihood Ratio Test
	OR Value	95% Confidence Interval		P -value	OR Value	95% Confidence Interval		P-value	OR Value	95% Confidence Interval		P-value	
		Lower Limit	Upper Limit			Lower Limit	Upper Limit			Lower Limit	Upper Limit		
Age													
Under 20	0.432	0.207	0.898	0.025	0.319	0.148	0.690	0.004	0.167	0.058	0.484	0.001	
20~40	0.477	0.281	0.811	0.006	0.352	0.204	0.606	0.000	0.365	0.197	0.675	0.001	
40~60	0.553	0.325	0.941	0.029	0.387	0.225	0.667	0.001	0.435	0.236	0.800	0.007	0.001
60~80	0.736	0.429	1.264	0.267	0.520	0.300	0.902	0.020	0.752	0.412	1.373	0.353	
Above 80	1	-	-	-	1	-	-	-	1	-	-	-	
Time of Out-call													
8:00~11:00	1.438	0.901	2.295	0.128	2.186	1.349	3.544	0.002	2.462	1.436	4.222	0.001	
11:00~17:00	1.290	0.878	1.896	0.195	2.049	1.373	3.060	0.000	1.736	1.087	2.773	0.021	0.000
17:00~20:00	1.205	0.759	1.914	0.429	1.334	0.814	2.187	0.253	1.797	1.035	3.121	0.037	
20:00~8:00	1	-	-	-	1	-	-	-	1	-	-	-	
Month													
December～ February of following year	0.442	0.255	0.764	0.003	0.418	0.235	0.744	0.003	0.458	0.235	0.892	0.022	
March～May	0.421	0.240	0.739	0.003	0.415	0.230	0.749	0.004	0.578	0.295	1.134	0.111	0.001
June～ September	0.485	0.284	0.828	0.008	0.652	0.375	1.136	0.131	0.843	0.449	1.581	0.594	
October～ November	1	-	-	-	1	-	-	-	1	-	-	-	

The results of MNL regression analysis show that the likelihood ratio test statistic of patient age and time and month of the out-call in the final model was less than 0.05. Therefore, the null hypothesis is rejected, and the influence of three factors of patient age and time and month of the out-call on ART is significantly correlated. The p-value in the table represents the significance level in a Wald test. When the p-value is less than 0.05, the corresponding factor contributes significantly to this model. For example, when ART is between 4 and 8 min, the p-value of the three segments of the out-call time were all above 0.05, showing that the out-call time between 4 and 8 min plays no significant role in contributing to the model. The OR value indicates the odds ratio. From the table, it can be seen that, for the probability of ART being over 12 min, the period of 8:00~11:00 is roughly 2.46 times more than that of the period of 20:00~8:00 (OR = 2.462, 95% CI 1.436~4.222), and the period from December to February of the following year is 0.46 times higher than that in the period from October to November (OR = 0.458, 95% CI 0.235–0.892).

Even though ambulances enjoy priority in traffic, ART is still influenced by overall traffic conditions. Figures 4 and 5 show the curves of monthly and hourly variations, respectively, of the urban road traffic congestion index of the downtown Guangzhou area, with data from the Guangzhou Transportation Commission.

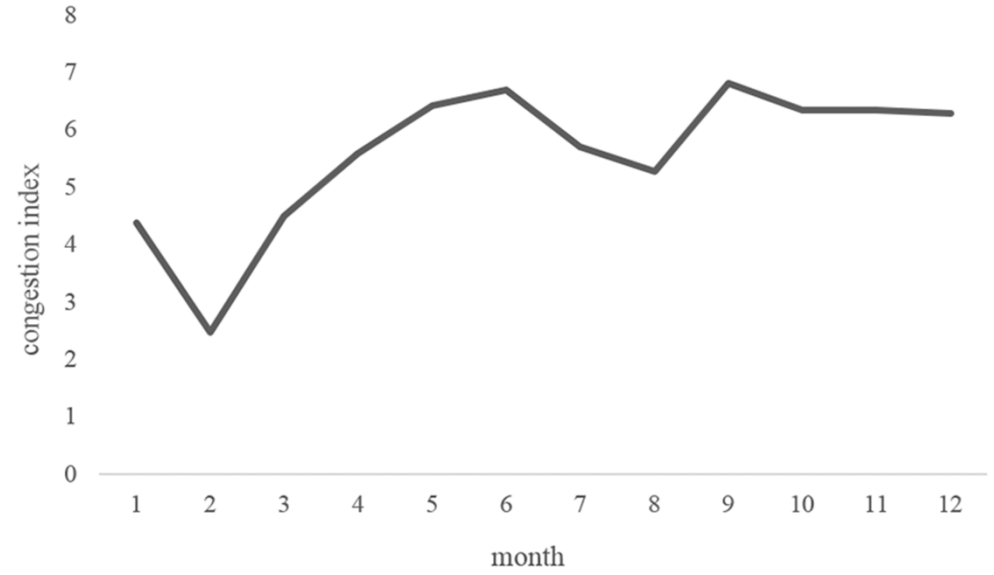

Figure 4 Monthly Variations of Urban Road Traffic Congestion Index in Guangzhou

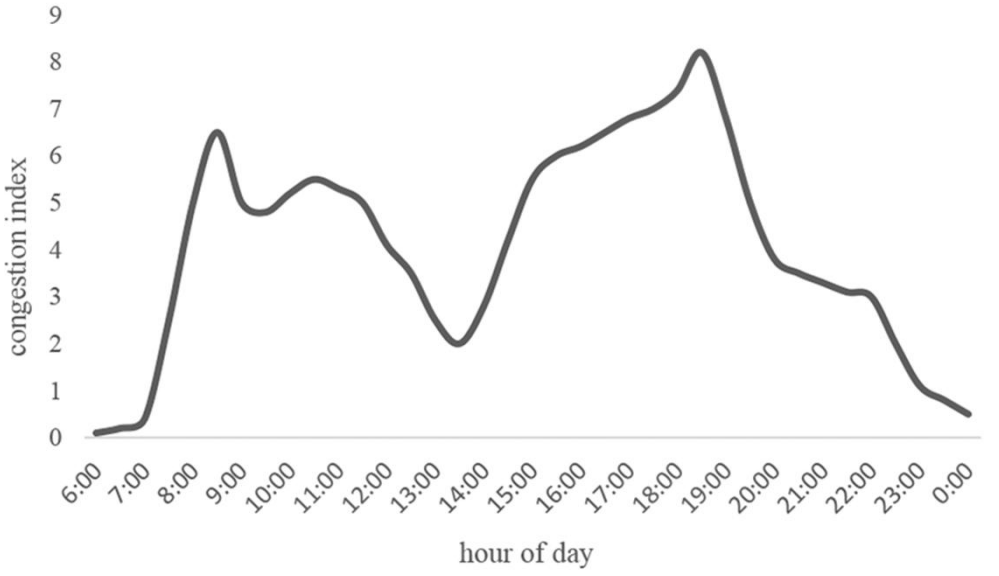

Figure 5 Hourly Variations of Index of Urban Road Traffic Congestion in Guangzhou

As shown in Figure 4, the urban road traffic congestion index in Guangzhou between December and February of the following year are the lowest for the whole year, whereas the level of congestion between October and November tends to be higher. As shown in the results of the MNL analysis, ART between December and February of the following year was relatively low, whereas ART in October and November was longer than in other months.

As Figure 5 indicates, the hourly variations of urban road traffic congestion index in Guangzhou showed two obvious peaks, namely during the morning rush hours (8:00~11:00) and evening rush hours (17:00~20:00). As previously mentioned, the road congestion index during the morning and evening rush hours are comparatively high, lower during the midday period in between, and lowest during the late-night period (20:00~8:00). Combined with the results of the MNL analysis, ART is the longest during the morning and evening rush hours and generally shorter during the late-night period because traffic is sparser.

The results from the MNL analysis also show that patient age is significantly related to ART. Generally speaking, patient age does not impact ART; hence, cross analyses were performed between the patients' age and out-call time. The results shown in Table 5.

Table 5 Distribution of Relation of Patients' Age and Time of Out-call

		Time of Out-call				Total
		8:00~11:00	11:00~17:00	17:00~20:00	20:00~8:00	
Age	Under 20	13.3%	24.4%	20.0%	42.2%	100%
	20~40	13.2%	21.9%	12.3%	52.5%	100%
	40~60	19.8%	26.5%	12.5%	41.2%	100%
	60~80	19.1%	34.4%	14.9%	31.6%	100%
	Above 80	23.9%	31.6%	16.7%	27.9%	100%

As shown in Table 5, the patients' out-call time in the age group of under 20 and 20–40 concentrates on the late-night period (20:00~8:00), 42.2% and 52.5% respectively; the older the patients are, the lower the frequency is for out-call during the late-night period. The out-call time of these patients mostly concentrated on the morning rush hour and the midday period. This distribution explains why patient age is seemingly related to ART; for elderly patients, the out-call time focuses on daytime period with longer ART due to heavy road congestion whereas, for younger patients, the out-call time concentrates on the late-night period with shorter ART due to sparse traffic.

After aggregate analysis, it can be concluded that the ART of Liwan District People's Hospital of Guangzhou is influenced by road traffic congestion. MNL regression analysis showed that ART is influenced by patient age and time and month of the out-call, and, overall, the older the patients are, the longer the ART will be. ART during the morning rush hours (8:00~11:00) is the longest. ART is less affected during the evening rush hours (19:00~22:00) than during the morning rush hours. ART is shorter during December to February of the following year, whereas it is at its highest level of the whole year during October and November.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Study Conclusions

In this article, statistical analyses of whole-year ambulance dispatch data of Liwan District People's Hospital of Guangzhou were performed. The patients' age and time and month of the out-call were input into a multi-variable model to reveal how ART interacted with these factors to provide reference for scientific allocation of emergency medical resources.

Statistical results from the data show that, for emergency patients, male patients represent a higher proportion than female patients, the proportion of patients in the under-20 age group was smaller and was evenly distributed in the remaining age groups, and the majority of patients were referred to the Surgery department followed by Internal Medicine with fewer referrals to Gynecology and Pediatrics. From the monthly distribution of the number of pre-hospital care events, the fewest emergency medical events occur in March and April, whereas peaks appear in May and July with more emergency medical events. From the hourly distribution of the number of the pre-hospital care events, we conclude that the proportion of emergency medical events occurring in 00:00~7:00 is lower while emergency medical events concentrate around 9:00~11:00.

The results of MNL analysis demonstrate that out-call time, patient age, and month are significantly related with ART. Compared with other time periods, longer ART is more likely during morning rush hours (8:00~11:00). Although they enjoy the highest priority on the road, ambulances are still influenced by road traffic conditions. Younger patients need emergency care mostly during the late-night period (20:00~8:00)

whereas elderly patients need emergency care mostly during the daytime period. In addition, because the road traffic is more congested during the daytime period than during the late-night period, ART for elderly patients is more likely to be longer. When the urban road congestion index in Guangzhou is at its highest level for the whole year during October and November, there is more likelihood for longer ART than in other months.

4.2 Suggestions

ART is an issue concerning whether patients can receive timely assistance from medical professionals. Given the information of month and hour of the out-call, the age of the patient, and so on, we can enhance the allocation of emergency medical resources on a well-targeted basis and provide appropriate triage to elderly patients, emergency cases of illness in autumn, and cases that need out-call during morning rush hours in allocating limited emergency medical resources. The preparation time of doctors, nurses, and ambulance drivers should be shortened to reduce ART in the cases that need emergency assistance, thus elevating response speed of emergency rescue services.

In consideration of the pre-hospital care status quo of the of Liwan District People's Hospital of Guangzhou, possible methods that can be adopted to reduce ART include the following:

(1) Use of emergency motorcycles (The primary purpose of emergency motorcycles is to arrive at an emergency site in a timely manner and to provide Basic Life Support (BLS) [8] before arrival of the ambulance. At present, Singapore has adopted emergency motorcycles and achieved satisfactory results.);

(2) Linking with smart traffic management system to regulate and control traffic signals along the route of the ambulance based upon the location information sent by the GPS on the ambulance, ensuring the ambulance's quick passage through intersections [9]; and

(3) Classification of patients that need emergency care (During an emergency call, select critical patients that are in urgent need of services from medical professionals. This will elevate the triage level of services, shorten ART for the patients, and improve the patients' survival rate.).

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