Original article

An analysis of Emergency Medical Services demand: Time of day, day of the week, and location in the city

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ABSTRACT

Objective: Effective planning of Emergency Medical Services (EMS), which is highly dependent on the analysis of past data trends, is important in reducing response time. Thus, we aimed to analyze demand for these services based on time and location trends to inform planning for an effective EMS.
Materials and methods: Data for this retrospective study were obtained from the Izmir EMS 112 system. All calls reaching these services during first six months of 2013 were descriptively analyzed, based on time and location trends as a heat-map form.
Results: The analyses showed that demand for EMS varied within different time periods of day, and according to day of the week. For the night period, demand was higher at the weekend compared to weekdays, whereas for daytime hours, demand was higher during the week. For weekdays, a statistically significant relation was observed between the call distribution of morning and evening periods. It was also observed that the percentage of demand changed according to location. Among 30 locations, the five most frequent destinations for ambulances, which are also correlated with high population densities, accounted for 55.66% of the total.
Conclusion: The results of this study shed valuable light on the areas of call center planning and optimal ambulance locations of Izmir, which can also be served as an archetype for other cities.

1. Introduction

Almost all cities in developing or developed countries have Emergency Medical Services (EMS), which consists of pre-hospital medical care and transport to a medical facility such as a hospital.[1] An EMS is defined as consisting of the sequence of events from the dispatcher's notification of a medical emergency, to the transfer of patients to hospital.[2] There has been an increase in demand for such services throughout the world.[3,4] In the United States, almost all EMS demand is made by calls to an emergency number, 911; the corresponding number is 112 in Turkey and some European countries.

The primary role of ambulance services is to provide rapid access to those in need. In Turkey, this process flow is as follows: An emergency call is made to 112, a member of the call center staff responds and determines whether the call is an emergency or not, based on information given, which is assessed according to the dispatch protocols. When a call center staff member is uncertain about the status, the call is directed to the appointed doctors. If it is considered an emergency, the call center member checks availability, and directs the nearest ambulance to the emergency event location. While the exact definition of EMS time intervals is a point of a debate in the literature, the interval from dispatch to ambulance arrival has generally been defined as the response interval.[5—7] Thus, one of the main goals of ambulance services is to minimize the response interval or time.[8] Many studies have analyzed the

problem of how to best deploy or locate the ambulances to minimize response time and cost.[9–11] The solution depends on the number of emergency calls reaching the 112 center at a specific time interval, from a specific location, thus it is important to retain and analyze past data. This paper aims to produce an analysis of 112 calls, based on time and location characteristics, as a basis for the effective planning of EMS in further studies.

2. Material and methods

In this retrospective study, data was taken from the EMS 112 services of the third most populous city of Turkey, Izmir. The city's large geographical scale, dense population and the extensive network of surrounding small towns create a need for the large number of ambulance and health personnel (around 3300 ambulances are divided between the 81 towns in the area, of which 90 are reserved for the city itself). The demand for 112 services in Izmir during the first six months of 2013 was evaluated. The main variables used to describe the data are: time, location, and the status of the calls. From the operations planning and management perspective, status differentiates between emergencies, which require ambulances, and non-emergencies, which do not. Although, both types of the call are important in planning and managing the call centers of 112 ambulance services, just the calls which require ambulances, those we define as emergency calls, are important in planning and managing the ambulances. Differentiation of emergency and non-emergency calls are made by dispatcher physician, according to pre-determined protocols. Thus, in the data that we obtained, we already had an attribute of data regarding whether the ambulance is directed to the call or not.

In analyzing the time variable of the data, weeks were differentiated into days, and days were divided into three 8-h intervals, namely, p_1 as 00:00−08:00, p_2 as 08:00−16:00, and p_3 as 16:00−00:00, where p_1, p_2, and p_3 respectively represent the night, daytime, and evening periods. To analyze location, Izmir was divided into 30 areas based on local district boundaries, numbered according to alphabetical order of the district names.

Population of all these 30 districts or locations of Izmir were obtained from Turkish Statistical Institute data from 2013 statitiscs.[12]

The results were statistically analyzed using Statistical Package for Social Sciences -SPSS- 22.00 (IBM, IL,USA) to calculate significant differences, where p < 0.01, illustrating the 99% confidence level, was considered statistically significant.

3. Results

In the first six months of 2013, a total of 123,239 real calls reached the 112 system. 85,853 or 69.66% were emergency calls, which required ambulances. The remaining 37,386, or 30.34%, were non-emergency calls.

We first represent the result based on call time. In this part, both emergency and non-emergency calls were considered, since both require the attention and consume the time of the call center staff. The distribution of call volume for each day of the week for periods p_1, p_2, and p_3 is given in Table 1, where average number of calls are defined based on the 99% confidence interval, and the variations are defined based on the standard deviation. In Table 1, it is observed that average call volume was lower in p_1 compared to p_2 and p3 for each day of the week. On weekdays (Monday to Friday), the average call volumes were approximately equal during the day in p_2 and p_3. In p_2, call volumes were higher during week-days compared to weekends (Saturday and Sunday), whereas the opposite pattern was seen in p_3. When the average call volumes were compared with the standard deviations, considerable fluctuation between the

different periods in each day were observed.

In order to analyze the statistical comparison between the average call volumes in each period of days of the week, we build up three hypotheses, such as:

H_0: $\mu_{p1} = \mu_{p2}$ for each day of the week, H_1: $\mu_{p1} \neq \mu_{p2}$ for each day of the week

H_0: $\mu_{p1} = \mu_{p3}$ for each day of the week, H_1: $\mu_{p1} \neq \mu_{p3}$ for each day of the week

H_0: $\mu_{p2} = \mu_{p3}$ for each day of the week, H_1: $\mu_{p2} \neq \mu_{p3}$ for each day of the week

We test these hypotheses by using two independent sample t-test based on 99% confidence interval, where $p < 0.01$ is considered as statistically significant. We summarize the p-values of these tests for each day of the week in Table 2.

Based on the p-values of Table 2, we additionally observed that average call volume of p_1 significantly differed from p_2 and p_3 for each day of the week, statistically significant difference was observed between p_2 and p_3 at the weekend, whereas no significant difference between p_2 and p_3 was seen in weekdays.

We then summarize the results based on call location. Ambulances are involved only in case of emergency thus non-emergency calls were excluded from this analysis. In Table 3, the districts or locations are represented by the given numbers or ID, and this table shows the population of each location based on 2013 statistics, percentage of the population for each location, number of ambulances currently located in each district, and the number and percentages of the emergency calls originating from each district.

According to Table 3 values, a significant correlation was observed between the population of each location, and the number or percentage of calls arriving from these locations (r = 0.924; p = 0.000). Similarly, a significant correlation was observed between number of currently deployed ambulances and number of calls arriving from locations (r = 0.885; p = 0.001). The five locations with the highest volume of emergency calls, as shown by the darker areas in Fig. 1, were Konak, Karabaglar, Buca, Bornova and Karsiyaka, locations numbered 21, 15, 8, 7, and 17 respectively, where the populations of these locations are also the highest as represented in Table 3. These percentages show that the more than half the emergency calls (55.66%) originated from these five locations where the total percentage of population of these five location is also more than half of the total population (50.73%).

According to distribution of number of calls given in Table 1, we concluded that weekdays have a similar pattern, and Saturday and Sunday also have a similar pattern which differentiates from weekdays' pattern. Thus, in order to observe the distribution of calls based on the locations at different time intervals, Monday and Saturday were selected to represent weekdays and the weekend respectively. Figs. 2 and 3 represent the average number of calls from each location in periods p_1, p_2 and p_3 for Mondays and Saturdays respectively.

These two Figures also showed that, in each of the three periods, the majority of calls were from the mentioned five locations: Konak, Karabağlar, Buca, Bornova, and Karsiyaka, although, within this group of five, the location generating the most calls varies between time periods. For example, in p_2 for Monday, there were more calls from Bornova than Buca, whereas in p_3, this situation was reversed. Similarly, higher numbers of calls originated from Bornova compared to Karşıyaka in p_1 on Saturdays, while the reverse was seen in p_2.

4. Discussion

In world −wide literature, it is well mentioned that the call

Table 1
Distribution of number of emergency calls according to period of time.

Days/Periods	00:00−08:00 (p_1)		08:00−16:00 (p_2)		16:00−00:00 (p_3)	
	μ	σ	μ	σ	μ	σ
Monday	139.13 (125,59;152,67)	23.03	333.35 (313,38;353,32)	33.97	305.87 (291,01;320,72)	31.27
Tuesday	134.08 (110,64;157,53)	40.91	312.58 (293,20;331,96)	33.82	301.08 (282,96;319,20)	31.62
Wednesday	121.75 (112,31;131,19)	14.47	325.71 (301,49;349,93)	42.27	300.96 (283,45;318,46)	40.55
Thursday	120.96 (110,17;131,74)	18.82	322.46 (306,88;338,03)	27.18	302.79 (285,95;319,63)	29.39
Friday	121.67 (112,47;130,86)	16.04	335.17 (321,15;349,18)	24.45	323.13 (301,47;344,78)	27.79
Saturday	135.57 (124,87;146,26)	18.19	255.61 (239,86;271,35)	26.79	315.04 (291,74;338,35)	29.66
Sunday	159.83 (141,57;178,08)	31.05	241.00 (228,11;253,89)	21.92	316.04 (291,84;340,24)	31.17

Note: In defining average number of calls, μ, 99% confidence interval is used.

Table 2
Statistical comparison between time periods of day.

Days	00:00−08:00 (p_1)/08:00−16:00 (p_2)		00:00−08:00 (p_1)/16:00−00:00 (p_3)		08:00−16:00 (p_2)/16:00−00:00 (p_3)	
	t-value	p-value	t-value	p-value	t-value	pvalue
Monday	−22.69 (−217.42,-171.01)	0.000	−23.39 (−185.96,-147.52)	0.000	5.11 (3.60,51.36)	0.013
Tuesday	−16.47 (−207.70,-149.30)	0.000	−15.82 (−195.40,-138.60)	0.000	1.22 (−13.92,36.92)	0.230
Wednesday	−22.03 (−229.48,-178.44)	0.000	−25.30 (−198.50,-159.91)	0.000	2.33 (−4.00,53.50)	0.025
Thursday	−29.86 (−219.75,-183.25)	0.000	−25.53 (−201.12,-162.54)	0.000	2.41 (−2.31,41.64)	0.020
Friday	−36.76 (−229.67,-197.33)	0.000	−24.04 (−224.45,-178.46)	0.000	1.31 (−12.84,36.92)	0.198
Saturday	−17.78 (−138.35,-101.73)	0.000	−19.73 (−204.50,-154.46)	0.000	−5.96 (−86.49,-32.38)	0.000
Sunday	−10.24 (−102.64,-59.71)	0.000	−14.53 (−185.30,-127.10)	0.000	−7.71 (−101.63,-48.46)	0.001

Note: 99% confidence interval for differences are used.

Table 3
Locations with, population, number of deployed ambulances, and number (%) of demand.

ID of the location	Name of the location	Population of the location	Percentage of the population	Number of ambulance	Number of calls	Percentage of calls (%)
1	Aliağa	80,948	1.99	2	3065	3.57
2	Balçova	77,624	1.91	1	1920	2.24
3	Bayındır	40,690	1.00	1	774	0.90
4	Bayraklı	310,656	7.65	2	4143	4.83
5	Bergama	101,217	2.49	3	1838	2.14
6	Beydağ	12,555	0.31	1	310	0.36
7	Bornova	426,490	10.50	5	7636	8.89
8	Buca	454,112	11.18	5	8494	9.89
9	Çeşme	35,965	0.89	4	1100	1.28
10	Çiğli	173,667	4.28	2	3049	3.55
11	Dikili	36,124	0.89	2	990	1.15
12	Foça	32,534	0.80	2	713	0.83
13	Gaziemir	129,534	3.19	2	2233	2.60
14	Güzelbahçe	27,389	0.67	1	626	0.73
15	Karabağlar	471,676	11.62	6	10,617	12.37
16	Karaburun	9,092	0.22	2	413	0.48
17	Karşıyaka	321,870	7.93	5	7177	8.36
18	Kemalpaşa	97,499	2.40	3	2195	2.56
19	Kinik	28,000	0.69	1	457	0.53
20	Kiraz	44,017	1.08	1	652	0.76
21	Konak	385,843	9.50	13	13,864	16.15
22	Menderes	77,706	1.91	2	1452	1.69
23	Menemen	142,836	3.52	4	2253	2.62
24	Narlıdere	63,743	1.57	1	885	1.03
25	Ödemis	129,295	3.18	3	1972	2.30
26	Seferihisar	33,588	0.83	2	1089	1.27
27	Selçuk	34,979	0.86	2	901	1.05
28	Tire	80,381	1.98	1	1029	1.20
29	Torbalı	144,293	3.55	4	2749	3.20
30	Urla	56,571	1.39	2	1257	1.46

Note: The remaining 5 ambulances are mobile.

volumes of EMS fluctuate according to day of the week, period within the day, and locations.[13−16] These fluctuations were considered as very important from the operations management perspective. Hence, the researchers focused on the classification of demand based on the time and location properties while planning and managing EMS.

To do best of our knowledge, this is such a first study carried out in EMS of Turkey, aiming to focus on these services from an operations management viewpoint. In the literature, the usage of EMS and ambulances in Turkey has been examined on the basis of age, gender, reason for calls, the preclinical diagnosis of crews, and the intervention outcomes of ambulance crew.[17−21] The major findings
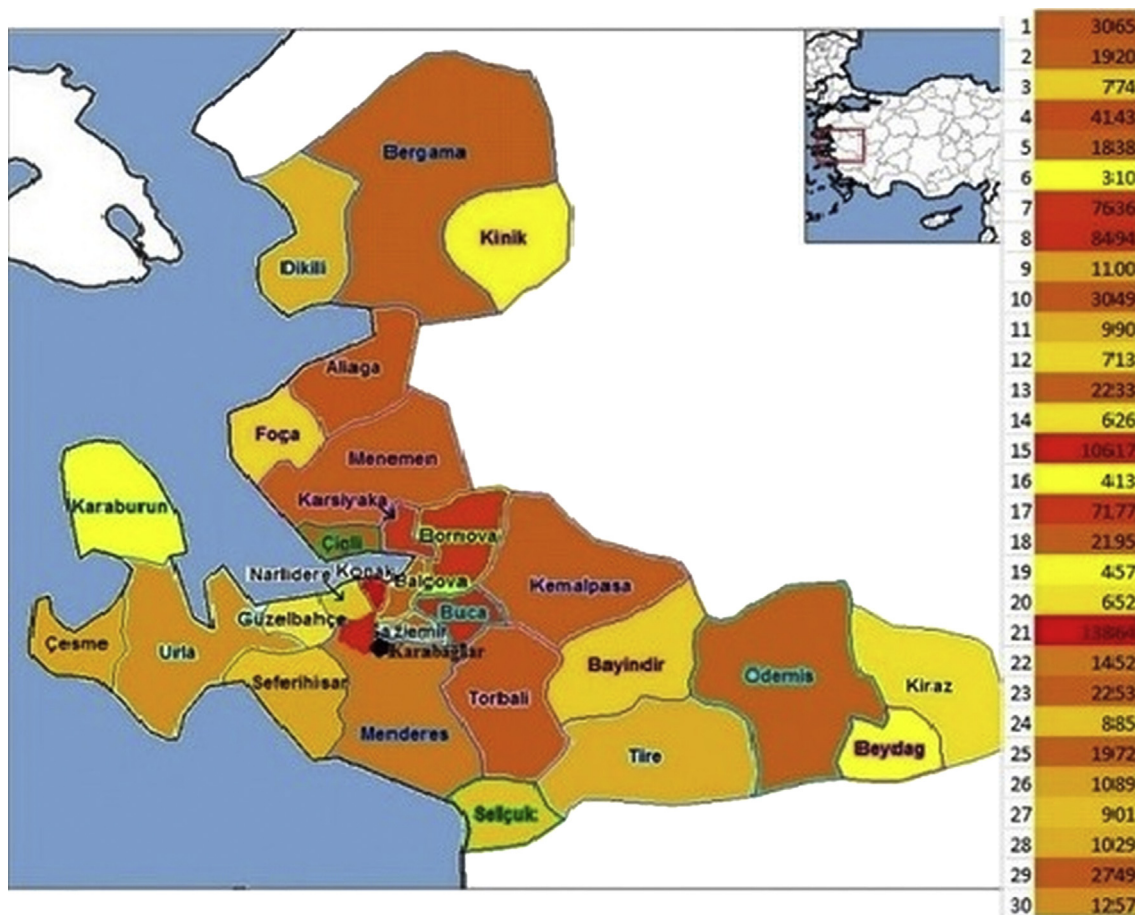
Fig. 1. Emergency call distribution based on location as a heat-map form.

intervals/locations	Aliağa	Balçova	Bayındır	Bayraklı	Bergama	Beydağ	Bornova	Buca	Çeşme	Çiğli
00:00–08:00	5	1	1	5	1	0	11	12	1	4
08:00–16:00	4	4	2	12	5	2	24	21	3	8
16:00–00:00	8	5	2	10	5	1	17	23	2	8

intervals/locations	Dikili	Foça	Gaziemir	Güzelbahçe	Karabağlar	Karaburun	Karşıyaka	Kemlapaşa	Kınık	Kiraz
00:00–08:00	1	1	2	1	14	2	10	2	1	1
08:00–16:00	2	2	7	2	30	1	20	6	1	3
16:00–00:00	3	2	6	1	28	1	18	6	1	2

intervals/locations	Konak	Menderes	Menemen	Narlıdere	Ödemiş	Seferihisar	Selçuk	Tire	Torbalı	Urla
00:00–08:00	18	1	2	2	2	2	2	2	2	3
08:00–16:00	43	4	7	3	7	2	3	3	8	4
16:00–00:00	32	3	5	2	5	2	2	3	7	3

Fig. 2. Emergency call distribution based on periods and location as a heat-map form (Mondays).

of these studies can be summarized as follows: First, the rate of ambulance use in Turkey, even in İzmir, one of the most populous cities, is lower compared to developed countries.[17] Secondly, an analysis of calls to the Kayseri 112 Emergency services shows that only 37.50% of calls were classified as genuine and necessary.[18] Another finding was that trauma, cardiovascular diseases (medical conditions) and traffic accidents were the most frequent reasons for calls.[17–21] Finally, very low levels of awareness that the ambulance emergency call number was also used for the Turkish coast guard service, and males, and the young and educated were found to make greater use of the emergency call number compared to other demographic groups.[22] Despite the value of these findings, more research, from an operations planning and management perspective, is needed in this area to increase the effectiveness in planning EMS systems and decrease the response time of the ambulances, and thus improve public health services.[23]

In this study, data were taken from one of the most populous districts of Izmir. Although, it seems that the study is limited in its

intervals/locations	Aliağa	Balçova	Bayındır	Bayraklı	Bergama	Beydağ	Bornova	Buca	Çeşme	Çiğli
00:00-08:00	1	2	1	4	2	1	8	9	1	3
08:00-16:00	5	4	1	8	5	5	5	18	3	7
16:00-00:00	6	5	2	12	4	1	21	24	3	8
intervals/locations	Dikili	Foça	Gaziemir	Güzelbahçe	Karabağlar	Karaburun	Karşıyaka	Kemlapaşa	Kınık	Kiraz
00:00-08:00	1	1	3	1	12	1	8	2	1	1
08:00-16:00	2	2	5	1	24	1	16	5	1	1
16:00-00:00	2	2	7	2	25	1	17	6	2	2
intervals/locations	Konak	Menderes	Menemen	Narlıdere	Ödemiş	Seferihisar	Selçuk	Tire	Torbalı	Urla
00:00-08:00	16	1	3	1	2	2	1	1	3	1
08:00-16:00	29	4	5	2	4	3	2	2	5	2
16:00-00:00	38	3	6	2	5	3	3	2	7	3

Fig. 3. Emergency call distribution based on periods and location as a heat-map form (Saturdays).

design, and the potential for generalization is restricted, its contribution to effective planning of EMS for Izmir will have implications for other Turkish cities in the process of developing their health services.

The current work takes an innovative approach to the evaluation of EMS of Turkey, by analyzing the time, location, and the status of the emergency calls. In line with findings of other studies,[13–16] we showed that demand for ambulances fluctuates based on time and location factors which should be considered in the design and planning stages of EMS. It is important that the number of personnel (of call center and others within the system) and ambulances should be flexible, rather than fixed to allow for these fluctuations in EMS demand. Thus, we hardly suggest EMS planners and managers to use dynamic models, instead of using static models. For example, according to Tables 1 and 2 values, we concluded that call volume in p_1, 00:00—08:00, differs from the call volume in p_2, 08:00—16:00, and p_3, 16:00—00:00 in all days of the week, where the average call volumes are the lowest in p_1. Taking this result into the account, EMS manager can change the capacity levels in call center in different periods, where he sets higher capacity (number of personnel) in p_2 and p_3, compared to p_1. In order to follow this suggestion, it is obvious that 24-h shift of personnel will not be feasible. It will be better to arrange the plan based on three 8-h shifts, and in a day personnel can be scheduled at most 16 h, which covers the period between 08:00—00:00, and clearly number of personnel in p_1, between 00:00—08:00, will be decreased. Similar approach also follows based on the comparison between days. Assume we just consider the planning of p_2 during the week. Table 1 values showed that average call volume in p_2 during weekdays is higher than it is in Saturday and Sunday. Then, it is more efficient for the EMS planner to set a lower capacity in p_2 periods, morning hours, in Saturday or Sunday compared to same period in weekdays.

Turning our attention to results related with location classification, based on the correlation value between number of currently deployed ambulances and demand for these systems, we observed that EMSs seems to be successful in accounting for shifting trends in location of calls. The reason under this is the relation between the population of the location, and the number of calls arriving from each location. This means, as a main decision parameter, currently EMS planners take the population of locations into account while planning the number of ambulances in each location. Thus, since the population of Karabağlar is the highest they arrange 6 of the ambulances between the total of 90 to this location. The populations of Buca, Bornova, and Karşıyaka follow the population of Karabağlar, hence 5 ambulances are located in each of these

districts. In this setting, the location of Konak leads the important observation. Although the population of Konak is lower than the populations of Karabağlar, Buca, and Bornova, 13 of the ambulances are located in Konak (Table 3). The reason under this arrangement is related with the geographic position of Konak. When we check the map of Izmir given in Fig. 1, we clearly see that Konak locates at the city center, and is close to all these mentioned locations. Thus, the planners considered this property into account, and decided that the ambulances in Konak can arrive the emergency situations in Karabağlar, Buca, and Bornova in a (relatively) shorter time periods, when it is required. These approaches all worked well while planning the ambulance locations, since a statistically significant correlation exists between the population of the location and the number of emergency calls arriving from each location. However, while planning the number of ambulances in each location, a greater range of information should be considered, such as the trends according to time of day, and day of week. Similarly, instead of using static plans, more dynamic plans should be considered. For example, when we analyze Fig. 2, we observed that in the location of Konak, on average 18 emergency calls arrived in p1, where the average number of emergency calls were 43 and 32 during p_2 and p_3 respectively. Based on this data, it is very clear that fixing the number of ambulances in all of the three 8-h period is not efficient. The number of deployed ambulances in p_1 can be decreased compared to p_2 and p_3. Besides, for the rush hours of especially the locations that accounts for more than half of the total emergency calls, number of ambulances can be increased by using the 5 mobile ambulances, or shifting some ambulances from the other and closest locations, i.e. in the rush hour of Karşıyaka, an ambulance which locates in Çiğli can be shifted to Karşıyaka.

To sum up, we can conclude that classifying the EMS demand based on time, location, and call status potentially allows for more efficient planning in EMS systems, which leads the reduced response time for EMS calls. Such an approach can contribute to the effective planning of the call centers, and ambulance locations.

As a final discussion point, we want to denote that the mechanism of emergency situation can be another important analysis for future researches. As it is given in our research, the status of call is very important in planning and managing EMS, i.e. only the emergency calls are considered in ambulance planning. However, in this research we just made the differentiation between the emergency and non-emergency calls based on the attribute (whether ambulance is directed or not) of the obtained data. Thus, for future researches, which will most probably require a prospective design, such an analysis can take interest of EMS researchers.

5. Conclusions

Since EMS are crucially important in saving lives, their planning and management is one of the key tasks for service providers, including state authorities. To plan these systems efficiently, a series of questions can be used to generate information that can contribute to reducing response time. The current retrospective work aimed to analyze the EMS system calls using the first series of questions, based on time and location distributions or trends. These analyses have led to valuable insight, which has the potential to contribute to the shaping of future series of questions in the planning EMS call center departments, and the deployment of ambulances. One other contribution of this study is the provision of EMS data for Turkey for comparison with other countries in further research efforts.

Conflict of interest

No conflict of interest was declared by the authors.

Ethical approval

Ethics committee approval was received from the ethics committee of İzmir KatipÇelebi University Atatürk Research and Training Hospital Chief Physician Office Local Ethics Committee (15.02.2014).

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