Original Article

Characteristics and subgroups of frequent emergency department users in an academic hospital in Japan

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Aim: Frequent emergency department (ED) users increase the burden on EDs. However, little is known about the characteristics and subgroups of frequent ED users in Japan.

Methods: We retrospectively analyzed data on patients who had visited the ED of an academic hospital in Japan between 2014 and 2015. We identified adult frequent ED users (four or more ED visits within 365 days prior to one's last visit) and sampled adult non-frequent ED users. We compared these groups to delineate the characteristics of frequent ED users and examined the association between frequent ED use and hospitalization rates. Additionally, to identify latent subgroups of frequent ED users, we undertook a cluster analysis.

Results: We identified 259 frequent ED users and 297 non-frequent ED users from 9,546 patients who had visited the ED in 2015. Frequent ED users accounted for 8.2% of all ED visits. Frequent ED users tended to be older, have comorbidities, and be receiving public assistance compared to non-frequent ED users. There was a significant association between frequent ED use and higher hospitalization rates, which was partially attributable to (older) age and comorbidities. In the cluster analysis, we identified four subgroups of frequent ED users: (i) older patients with malignant tumors and the highest hospitalization rates, (ii) patients with mental illnesses and the lowest hospitalization rates, (iii) patients who were at risk of cardiovascular diseases, (iv) others.

Conclusions: Frequent ED users tended to be older and have comorbidities. Four latent subgroups of frequent ED users were identified.

Key words: Cluster analysis, emergency department, frequent user, frequent visits, Japan

INTRODUCTION

An increase in the number of emergency department (ED) visits results in ED overcrowding. Common problems caused by ED overcrowding include delayed initial management, an increase in the burden placed on hospital staff, and higher ED-related health-care costs.[1–3] Surveillance data regarding current ED visits can offer valuable insights that can be used to promote appropriate resource allocation and provision of advanced emergency care within the stressful environment of an ED.

Studies have found that frequent ED use is a major contributor to ED crowding.[2,3] A systematic review reported that approximately 5–8% of frequent ED users account for 21–28% of ED visits.[4] Frequent ED users are more likely to be transported by ambulance, covered by public insurance, and physically and/or mentally ill. They also tend to live in poverty and are hospitalized more frequently than non-frequent ED users.[4–6] It is well known that characteristics of ED users could vary across different health-care systems and cultural contexts;[4,7] however, studies on frequent ED users have primarily been undertaken in the USA, and published works on frequent ED users in aging societies and countries with a universal health-care system (e.g., Japan)

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are limited.[8] In addition, although the public assistance system has been adopted to exempt impoverished citizens from paying their medical bills,[9] little is known about the ED visits by patients who receive such assistance. Given that the ED burden continues to increase in Japan,[10] there is a pressing need to delineate the characteristics of current frequent ED users and develop multifaceted strategies to reduce the ED burden.

To address these knowledge gaps in published reports, we aimed to compare frequent and non-frequent ED users of one of the largest academic hospitals in Japan and delineate the characteristic features of frequent ED users based on the resultant findings. Additionally, we examined whether frequent ED use is associated with ED disposition. We also aimed to identify latent subgroups of frequent ED users using cluster analysis.

METHODS

Study design and population

THIS RETROSPECTIVE OBSERVATIONAL study was carried out at The University of Tokyo in Japan. The University of Tokyo Hospital is one of the largest academic hospitals in Japan, and annual visits to its ED have been estimated at approximately 15,000. Data regarding ED patients were retrieved from the ED patient database and electronic health records. Chart reviews were undertaken by a medical student who was completely blinded to the actual clinical course of each patient. Electronic health records were reviewed using a structured checklist created by emergency physicians. The institutional review board of the University of Tokyo approved this study.

Study participants

We analyzed the data of all adult patients (age ≥18 years) who had visited the ED between 1 January 2014 and 31 December 2015.

Measurements

To examine the characteristics of frequent ED users, we collected the following information: age, sex, date of visit to the ED, insurance status, mode of arrival (i.e., ambulance versus walk-in), selected comorbidities (diabetes mellitus [DM], hypertension, atrial fibrillation [AF], asthma, chronic obstructive pulmonary disease [COPD], malignant tumors, epilepsy, and mental illness),[11,12] and ED disposition (in-ED death, hospitalization, transfer to another hospital, discharge from the ED). Every physician and resident in the ED was instructed to enter details regarding all comorbidities into the electronic health records system, irrespective of the patient's chief complaint or symptom.

Definition of frequent and non-frequent ED users

In accordance with the definitions used in past studies, we defined frequent ED users as patients with four or more ED visits within 1 year prior to their last visit in 2015 (e.g., if a patient's last visit was on 5 May 2015, we counted his or her number of ED visits between 6 May 2014 and 5 May 2015).[4,6,12] We aimed to delineate the characteristics of frequent ED users by comparing them to non-frequent ED users. Therefore, it was necessary to develop a definition of the latter group. However, it was impractical to undertake chart reviews for all ED visits. Therefore, we extracted data on non-frequent ED users (i.e., those who were not frequent ED users and visited the ED on the 15th of each month in 2015). These subjects were considered as a quasi-random sample of the total population of non-frequent ED users.

Statistical analysis

Comparisons of frequent and non-frequent ED users

First, we computed summary statistics to examine the characteristics of the participants and compare the characteristics of frequent and non-frequent ED users.

Second, to examine whether there is an association between frequent ED use and ED disposition, we developed univariate and multivariate logistic regression models with hospitalization as a binary outcome. In the multivariate logistic regression model, patient demographics (i.e., age and sex), a marker for socioeconomic status (i.e., public assistance), and comorbidities were entered as predictors.[4,12] We did not enter in-ED death as an outcome because the number of cases was small.

Cluster analysis

To identify latent subgroups of frequent ED users, we used partitioning around medoids, which is a machine learning-based clustering approach. The following variables were used for clustering: age, sex, socioeconomic status (i.e., public assistance), and selected comorbidities (i.e., DM, hypertension, AF, asthma, COPD, malignant tumors, epilepsy, and mental illness). We used Gower's distance measure to calculate the distances between variables. The optimal number of clusters was determined using the consensus clustering method, which provides quantitative and visual stability

evidence for estimating the number of unsupervised classes in a dataset.[13] Specifically, we examined the separation of the consensus matrix heatmaps and used the elbow method, cumulative distribution function, and a combination of phenotype sizes. We also visually evaluated the clusters using the t-distributed stochastic neighbor embedding (t-sne) method. Specifically, t-sne is a dimensionality reduction technique that is well suited for the visualization of high-dimensional datasets.[14]

The results of the two-tailed tests with $P < 0.05$ were considered to be statistically significant. All analyses were undertaken using R version 3.6.1 (R Foundation, Vienna, Austria).

RESULTS

Characteristics of frequent ED users and their visits

A TOTAL OF 9,546 adult ED patients accounted for 11,614 adult ED visits in 2015. Furthermore, 259 frequent ED users accounted for 955 ED visits (2.7% of ED patients accounted for 8.2% of adult ED visits). With regard to non-frequent ED users, we identified 297 ED users who had visited the ED on the 15th of each month in 2015. These 297 non-frequent ED users accounted for 346 ED visits (3.1% of ED patients accounted for 3.0% of adult ED visits).

Frequent ED users were significantly older than non-frequent ED users (median age, 64 years versus 47 years, respectively; $P < 0.001$) and had more comorbidities (DM, hypertension, AF, COPD, malignant tumors, and mental illness; $P < 0.05$; Table 1). Frequent ED users were more likely to have been receiving public assistance (i.e., exemption from paying medical bills) than non-frequent ED users (8.9% versus 4.7%, respectively). Although frequent ED users were more likely to use ambulances more frequently (1.2 times versus 0.56 times per patient, respectively, during the 1-year study period; $P < 0.001$), an ED-visit level analysis revealed that frequent ED visits significantly tended not to be by ambulances compared to non-frequent ED visits (33.6% versus 48.3%, respectively; $P < 0.001$; Table 2).

Table 1. Characteristics of the analytic cohorts of frequent emergency department (ED) users (four or more visits in 1 year) and non-frequent ED users

	Frequent ED users *n* = 259	Non-frequent ED users *n* = 297	*P*-value
Age, median (IQR)	64 (41–76)	47 (32–67)	<0.001
Male sex	127 (49.0)	145 (48.8)	0.990
Number of ED visits in 2015, mean (SD)	6.2 (3.4)	1.2 (0.5)	<0.001
Number of ambulance uses in 2015, mean (SD)	1.2 (2.2)	0.56 (0.58)	<0.001
Insurance status[†]			
Health insurance for employees	109 (42.1)	124 (41.8)	<0.001
National health insurance	41 (15.8)	84 (28.3)	
Medical care system for elderly in the latter stage of life (age ≥75 years)	86 (33.2)	44 (14.8)	
Public assistance	23 (8.9)	14 (4.7)	
Others	0 (0.0)	31 (10.2)	
Selected comorbidities			
Diabetes mellitus	48 (18.5)	28 (9.4)	0.003
Hypertension	69 (26.6)	52 (17.5)	0.010
Atrial fibrillation	23 (8.9)	9 (3.0)	0.006
Asthma	13 (5.0)	13 (4.4)	0.880
COPD	9 (3.5)	2 (0.7)	0.030
Malignant tumors	56 (21.6)	31 (10.4)	<0.001
Epilepsy	9 (3.5)	6 (2.0)	0.430
Mental illnesses	49 (18.9)	32 (10.8)	0.010

Values represent *n* (%), unless otherwise indicated.
COPD, chronic obstructive pulmonary disease; IQR, interquartile range; SD, standard deviation.
[†]Proportions of patients' medical expenses that were covered by "Health insurance for employees," "National health insurance," "Medical care system for elderly in the latter stage of life," and "Public assistance" were 30%, 30%, 10%, and 0%, respectively.

Table 2. Characteristics of emergency department (ED) visits of the analytic cohorts of frequent users (four or more visits in 1 year) and non-frequent ED users

	Frequent ED users' visits $n = 955$	Non-frequent ED users' visits $n = 346$	*P*-value
Ambulance use	321 (33.6)	167 (48.3)	<0.001
Disposition			
In-ED death	3 (0.3)	3 (0.9)	0.001
Hospitalization	250 (26.2)	66 (19.1)	
Transferred to another hospital	7 (0.7)	10 (2.9)	
Discharged from the ED	695 (72.8)	267 (77.2)	

Values represent *n* (%).

Association between frequent ED use and ED disposition

Frequent ED use was significantly associated with higher hospitalization rates when compared to non-frequent ED use (26.2% versus 19.1%, respectively; unadjusted odds ratio, 1.50; 95% confidence interval, 1.12–2.05; $P < 0.05$; Table 3). This association was attributable to age (i.e., being older) and comorbidities (e.g., DM, AF, asthma, and malignant tumors).

Cluster analysis

Based on the results of the consensus clustering, we decided that a four-class model (A, B, C, and D) was an optimal fit. Indeed, using the consensus matrix plots, elbow method, and cumulative distribution function curve, we found that the four-class model was optimal (Figs. S1–S3). However, the cluster-consensus plot varied across different numbers of clusters (Fig. S4), and the t-sne plot revealed that some patients could be situated on the borderlines between clusters (Fig. S5).

Characteristics of the frequent ED users who belonged to each cluster are presented in Tables 4 and 5. In short, patients who belonged to cluster A were older, had poor health and malignant tumors, and had been receiving public assistance. Hospitalization rates were the highest (40.2%) among patients who belonged to this cluster. All patients who belonged to cluster B had mental illnesses. They were more likely to have used ambulances to visit the ED. Hospitalization rates (16.4%) were the lowest among the patients who belonged to this cluster. The patients who belonged to cluster C were older and at risk for cardiovascular diseases

Table 3. Unadjusted and adjusted odds ratios for the association between hospitalization rates and the frequency of emergency department (ED) use in 2015

	Unadjusted model OR (95% CI)	*P*-value	Adjusted model OR (95% CI)	*P*-value
Frequent ED users (versus non-frequent ED users)†	1.50 (1.12–2.05)	0.010	1.30 (0.95–1.80)	0.110
Covariates				
Age	–		1.01 (1.00–1.02)	0.002
Male sex	–		1.16 (0.88–1.52)	0.290
Insurance status				
Public assistance‡	–		1.21 (0.74–1.96)	0.430
Selected comorbidities				
Diabetes mellitus	–		1.48 (1.02–2.14)	0.040
Hypertension	–		0.61 (0.43–0.85)	0.005
Atrial fibrillation	–		1.76 (1.09–2.82)	0.020
Asthma	–		1.92 (1.08–3.33)	0.020
COPD	–		1.58 (0.75–3.27)	0.220
Malignant tumors	–		1.65 (1.19–2.27)	0.002
Epilepsy	–		0.79 (0.28–1.96)	0.430
Mental illnesses	–		0.56 (0.38–0.82)	0.004

–, no data; CI, confidence interval; COPD, chronic obstructive pulmonary disease; OR, odds ratio.
†Frequent ED users were defined as patients with four or more ED visits within 1 year prior to their last visit.
‡The proportion of medical expenses that were paid by patients with "Public assistance" was 0%.

Table 4. Characteristics of frequent emergency department (ED) users (four or more visits in 1 year) and their subgroups

	Overall *n* = 259	Cluster A *n* = 59	Cluster B *n* = 41	Cluster C *n* = 68	Cluster D *n* = 91	*P*-value
Age, median (IQR)	64 (41–76)	72 (65–80)	57 (42–70)	73(57–80)	40 (33–64)	<0.001
Male sex	127 (49.0)	30 (50.8)	18 (43.9)	36 (52.9)	43 (47.3)	0.797
Number of ED visits in 2015, mean (SD)	6.2 (3.4)	6.0 (2.3)	6.4 (5.2)	6.5 (3.3)	5.9 (3.2)	0.646
Number of ambulance uses in 2015, mean (SD)	1.2 (2.2)	1.3 (1.8)	2.3 (3.7)	1.4 (2.0)	0.64 (1.2)	0.001
Insurance status						
Public assistance[†]	23 (8.9)	12 (20.3)	1 (2.4)	8 (11.8)	2 (2.2)	<0.001
Selected comorbidities						
Diabetes mellitus	48 (18.5)	4 (6.8)	2 (4.9)	42 (61.8)	0 (0.0)	<0.001
Hypertension	69 (26.6)	9 (15.3)	4 (9.8)	56 (82.4)	0 (0.0)	<0.001
Atrial fibrillation	23 (8.9)	8 (13.6)	3 (7.3)	10 (14.7)	2 (2.2)	0.012
Asthma	13 (5.0)	3 (5.1)	0 (0.0)	5 (7.4)	1 (1.1)	0.085
COPD	9 (3.5)	5 (8.5)	2 (4.9)	2 (2.9)	4 (4.4)	0.580
Malignant tumors	56 (21.6)	45 (76.3)	2 (4.9)	9 (13.2)	0 (0.0)	<0.001
Epilepsy	9 (3.5)	4 (6.8)	4 (9.8)	1 (1.5)	0 (0.0)	0.004
Mental illnesses	49 (18.9)	5 (8.5)	41 (100.0)	3 (4.4)	0 (0.0)	<0.001

Values represent *n* (%), unless otherwise indicated.
COPD, chronic obstructive pulmonary disease; IQR, interquartile range; SD, standard deviation.
[†]The proportion of medical expenses that were paid by patients with "Public assistance" was 0%.

Table 5. Characteristics of the visits of frequent emergency department (ED) users (four or more visits in 1 year) and their subgroups

	Overall *n* = 955	Cluster A *n* = 194	Cluster B *n* = 159	Cluster C *n* = 260	Cluster D *n* = 342	*P*-value
Ambulance use	321 (33.6)	74 (38.1)	93 (58.5)	96 (36.9)	58 (17.0)	<0.001
Disposition						
In-ED death	3 (0.3)	1 (0.5)	1 (0.6)	1 (0.4)	0 (0.0)	<0.001
Hospitalization	250 (26.2)	78 (40.2)	26 (16.4)	69 (26.5)	77 (22.5)	
Transferred to another hospital	7 (0.7)	3 (1.5)	0 (0.0)	4 (1.5)	0 (0.0)	
Discharged from the ED	695 (72.8)	112 (57.7)	132 (83.0)	186 (71.5)	265 (77.5)	

Values represent *n* (%), unless otherwise indicated.

(i.e., they had DM, hypertension, and AF). Patients who belonged to cluster D were younger and had fewer comorbidities. They were also less likely to have used an ambulance to visit the ED (17.0%).

DISCUSSION

IN THIS RETROSPECTIVE study undertaken in the largest academic hospital in Japan, frequent ED users (2.7% of all ED users) accounted for 8.2% of all ED visits in 2015. Frequent ED users tended to be older and have more comorbidities, and they were more likely to have been receiving public assistance (exemption from paying medical bills) than non-frequent ED users. Frequent ED use was significantly associated with higher hospitalization rates when compared with non-frequent ED use. This association was attributable to (older) age and comorbidities (e.g., DM, AF, asthma, and malignant tumors). Notably, the reception of public assistance was not associated with hospitalization rates. Additionally, using cluster analysis, frequent ED users were categorized into four clinically meaningful clusters: (i) older patients with malignant tumors and the highest hospitalization rates, (ii) patients with mental illnesses and the lowest

hospitalization rates, (iii) older patients who were at risk of cardiovascular diseases (i.e., they had DM, hypertension, and AF), (iv) younger patients who had fewer comorbidities and were less likely to have used ambulances.

In this study, the proportion of ED visits that was attributable to frequent ED users was approximately 8%. This figure is lower than those reported in other countries (21–28%),[4] but similar results were found in another study that was undertaken in a community hospital in Japan (6.8%).[7] This discrepancy might be attributable to differences in clinical settings, health-care systems (e.g., universal health coverage versus no universal health coverage), and cultural backgrounds (e.g., the role of family practitioners). These differences in frequent ED use underscore the importance of researching ED patients in different health-care settings.

As mentioned, frequent ED use was associated with higher hospitalization rates. The results of the cluster analysis also supported this association. Indeed, patients with malignant tumors (i.e., cluster A) were attributable to the association between frequent ED use and high hospitalization rates. On the contrary, the lowest hospitalization rates emerged for patients with mental illnesses (i.e., patients who belonged to cluster B), and this finding is also clinically intuitive. A previous study in a community hospital in Japan reported that frequent ED use was associated with lower hospitalization rates.[8] These discrepant findings could be due to differences in hospital settings. For example, academic hospitals (e.g., The University of Tokyo Hospital) could provide care to patients with severe, complicated comorbidities (e.g., malignant tumors and cardiovascular diseases), whereas community hospitals could provide care to patients with a wide variety of ailments ranging from common colds to mild injuries.

It is well known that frequent ED users are a heterogeneous group, but the subgroups that constitute this group are yet to be adequately examined.[4] The four latent subgroups of frequent ED users that were identified through cluster analysis should be the key to allow directed policy design for ED overcrowding. For example, given their lower hospitalization rates, patients with mental illnesses (i.e., patients who belonged to cluster B) could be an intervenable group in academic hospitals. However, it is difficult to identify the commonalities that underlie frequent ED users with mental illnesses because of the multiplicity and complexity of their characteristics.[15] In addition, the relationship between receiving public assistance with a higher hospitalization rate suggests that social factors (e.g., family environment, occupational factor, and income) might contribute to the frequent ED visits and their hospitalization. In this regard, future studies should account for social factors and develop effective strategies to reduce the ED burden among each intervenable group.

Limitations

Our study has several limitations. First, this retrospective study was carried out in a single academic hospital, and the sample size was relatively small. Therefore, selection bias could have influenced the results, and the findings might have limited generalizability. Second, the control group was not a completely random sample, whereas the characteristics of the patients who visited the ED might not have varied across different days of the month. Finally, as we did not review detailed information regarding each patient's visit (i.e., triage level, chief complaint, and final diagnosis), the severity of each patient's sickness could not be evaluated accurately. Therefore, to verify our findings in the setting of a single academic hospital and delineate more detailed characteristics of frequent ED users from a nationwide perspective, further various multicenter, community-based studies are needed.

CONCLUSIONS

IN THIS RETROSPECTIVE study undertaken in one of the largest academic hospitals in Japan, we found that frequent ED users were older and more likely to have comorbidities. Hospitalization rates were also higher among this group than among non-frequent ED users. Furthermore, frequent ED users were classified into four clusters. These findings underscore the heterogeneity of frequent ED users. Further research is needed to enhance the generalizability of our findings. The present findings regarding the characteristics and latent subgroups of frequent ED users can be used to develop multifaceted strategies that can reduce ED overcrowding and improve emergency care.

DISCLOSURE

Approval of the research protocol: The protocol of this retrospective study was approved by the institutional review board of The University of Tokyo.
Informed consent: N/A.
Registry and the registration no. of the study/trial: N/A.
Animal studies: N/A.
Conflict of interest: Dr. Sonoo reports the AI Hospital Research grant from the Japan Cabinet Office and personal fees as CEO of TXP Medical Inc., outside the submitted work. Dr. Iwai reports grants from Toyota and Dwango advanced artificial intelligence scholarship and grants from External Fund Research Assistant, Softbank, during the

conduct of the study. The other authors have no conflict of interest.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Figure S1. Consensus matrix heatmaps for different numbers of clusters
Figure S2. Elbow method
Figure S3. Consensus cumulative distribution function plot
Figure S4. Cluster-consensus plot
Figure S5. The t-distributed stochastic neighbor embedding plot