Development and Validation of a Risk Score to Predict the Frequent use of Emergency House Calls among Older People who Receive Regular Home Visits

Yu Sun

University of Tsukuba

Masao Iwagami (✉ iwagami-ky@umin.ac.jp)

University of Tsukuba

Nobuo Sakata

University of Tsukuba

Tomoko Ito

University of Tsukuba

Ryota Inokuchi

University of Tsukuba

Kazuaki Uda

University of Tsukuba

Shota Hamada

University of Tsukuba

Miho Ishimaru

University of Tsukuba

Jun Komiyama

University of Tsukuba

Naoaki Kuroda

University of Tsukuba

Satoru Yoshie

University of Tokyo

Tatsuro Ishizaki

Tokyo Metropolitan Institute of Gerontology

Katsuya Iijima

University of Tokyo

Nanako Tamiya

University of Tsukuba

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Abstract

Background: Demand for home care services is increasing in Japan, and a 24-hour on-call system could be a burden for primary care physicians. Identifying high-risk patients who need frequent emergency house calls could help physicians prepare and allocate medical resources. The aim of the present study was to develop a risk score to predict the frequent use of emergency house calls in patients who receive regular home visits.

Methods: We conducted a retrospective cohort study with linked medical and long-term care claims data from two Japanese cities. Participants were ≥ 65 years of age and had newly started regular home visits between July 2014 and March 2018 in Tsukuba city and between July 2012 and March 2017 in Kashiwa city. A total of 4,888 eligible patients were randomly divided into a derivation cohort ($n=3,259$) and a validation cohort ($n=1,629$). The primary outcome was the frequent use of emergency house calls, defined as the use once per month or more on average during each observation period. We considered pre-specified variables, such as age, gender, medical procedure performed in home health care, long-term care need level, and medical diagnosis at the start of the regular home visit. We used the least absolute shrinkage and selection operator (Lasso) method to select predictor variables.

Results: The frequent use of emergency house calls was observed in 13.0% participants (424/3,259) in the derivation cohort and 12.9% participants (210/1,629) in the validation cohort. The risk score included three variables with the following point assignments: home oxygen therapy (4 points); care need level 4-5 (2 point); cancer (5 point). The area under the curve (AUC) in the derivation cohort was 0.708, whereas the AUC of a model that included all pre-specified variables was 0.729. The AUC in the derivation cohort was 0.708, showing moderate discrimination.

Conclusions: This easy-to-use risk score would be useful for assessing high-risk patients and would allow the burden on primary care physicians to be reduced through measures such as clustering high-risk patients in well-equipped medical facilities.

Introduction

In recent years, the organization of primary health care after office hours has changed in many countries. There are new models for after-hours care, such as large-scale general practice cooperatives, primary care centers integrated into hospital emergency departments, or telephone triage and consultation services [1]. These changes are partly due to primary care physicians' reluctance to commit to being on-call 24-hour a day and 7 days a week because of the workload burden, increasing patient demand for after-hours care, and regional shortages of primary care physicians [2, 3].

In Japan, where the population is aging the fastest in the world [4], the demand for home care services has also increased due to the aging population and the government-sponsored shift of care from the hospital to the community [5]. However, previous research has shown that more than 70% of physicians in home care support clinics (HCSCs) feel burdened by the 24-hour on-call coverage mandated for HCSCs

[6]. To enhance home medical care, it is essential to identify a high-risk population who frequently use emergency house calls and take measures to reduce physical and psychological burdens for primary care physicians.

Studies have shown that the common reasons for emergency house calls are fever, end-of-life care, dyspnea, and cough among patients who receive regular home visits in Japan [7, 8]. However, these studies focused on the chief complaint and did not consider factors of the patient's condition such as comorbidities or medical procedures performed in the home care setting. In addition, they were single- or few-center studies, which limits their generalizability. To take measures to relieve the burden on primary care physicians, it is necessary to assess the risk of patients who frequently use emergency house calls. However, to date, no study has developed risk prediction models for the frequent use of emergency house calls.

Using claims data from two Japanese cities, we developed and validated a risk score that includes comorbidities and medical interventions in home health care to predict the frequent use of emergency house calls among older people who receive regular home visits.

Methods

Data source

We obtained linked data on medical and long-term care insurance claims from the municipal governments of two cities (Tsukuba city, Ibaraki Prefecture, and Kashiwa city, Chiba Prefecture) in Japan. The populations of Tsukuba city and Kashiwa city in 2015 were approximately 224,000 and 410,000, respectively, with about 43,000 (19.2%) and 97,000 (23.7%) people ≥ 65 years. For this research, the data were available from April 2014 to March 2019 in Tsukuba city and from April 2012 to March 2018 in Kashiwa city. As both cities are suburbs in the Tokyo metropolitan area and there are no major differences in the characteristics of the two cities, we combined their data to increase the generalizability of study findings.

Medical claims data included data from individuals with National Health Insurance for the self-employed and retirees under 75 years and Late-stage medical care system for the elderly for individual prefectures, while data from individuals with other health insurance credentials (e.g., insurance for corporate employees) were not included [9]. Medical insurance claims records included covered diagnoses, medical procedure information, and prescription information on a monthly basis. The recorded diagnoses were based on the original Japanese disease codes linked to the International Classification of Diseases 10th Revision (ICD-10) codes [10].

Under the statutory long-term care insurance system, older people who need living assistance can receive care services based on the seven levels of the certificate of need for long-term care: Support 1 (lowest disability) to 2 and Care 1 to 5 (highest disability) [11]. All Japanese citizens who are ≥ 65 and individuals 40–64 years whose need of care is derived from aging-related diseases, such as stroke, cancer, and

rheumatoid arthritis, are eligible for benefits. Long-term care need level is a nationally standardized certification that is assessed based on a person's physical and cognitive functioning [12]. Long-term care insurance claims data contains information on the care need levels and services used for all residents receiving long-term care services.

The linkage between medical and long-term claims data was made in each municipal government using personally identifiable information. In the data we received, anonymized ID numbers were assigned to individuals in both medical and long-term care insurance claim datasets.

Study design and population

We conducted a retrospective cohort study. Individuals who had newly started availing regular home visits between July 2014 and March 2018 in Tsukuba city and between July 2012 and March 2017 in Kashiwa city were included ($n = 5,895$). Individuals who did not receive regular home visits between April and June 2014 in Tsukuba city and between April and June 2012 in Kashiwa city were considered newly enrolled. First, we excluded people whose medical and long-term care claims data could not be linked ($n = 534$). Next, we excluded people who were <65 years when they started regular home visits ($n = 242$). The age of 65 years was chosen as the lower limit because (i) all people ≥ 65 years are eligible for long-term care insurance benefits, (ii) the vast majority (over 95%) of regular home visits are conducted for this age group [13]. We then excluded those who had a certificate of support level 1 or 2 ($n = 231$), because home visits are generally performed for patients who are disabled and cannot go to a clinic or hospital. Thus, a final sample of 4,888 individuals was evaluated (Figure 1).

Outcome variable

The primary outcome of the present study was the frequent use of emergency house calls during the period of regular home visits. The frequent use of home emergency calls was defined as the use on average once per month or more during each observation period. We followed patients to one year after the start of the regular home visit or until the month following the end of the regular home visit if it was completed within one year. During the period, the total number of emergency house calls was determined using medical insurance records. We calculated the average number of emergency house calls per month by dividing the total number of emergency house calls by the number of months each person received regular home visits (1–13 months).

Predictor variable

For each patient, we pre-defined variables potentially associated with the frequent use of emergency house calls, including age (categorized as 65–74, 75–84, 85–94, or ≥ 95 years); gender; medical procedures performed in home health care including self-injection, central venous nutrition, enteral nutrition, home oxygen therapy [7], use of ventilator/tracheostomy performed, and urinary self-catheterization; long-term care need levels [7] classified as care need level 1–3, and care need level 4–5; medical diagnosis at the start of the regular home visit, including cerebrovascular diseases, cardiac diseases, lower respiratory tract diseases, joint diseases, dementia, Parkinson's disease, diabetes, visual

of hearing impairment, fractures, and cancer. Medical interventions performed in the month in which the regular home visit began were identified from medical insurance claims records. In contrast, the care need levels were determined at the time of the most recent use of long-term care insurance service within three months of the start of the regular home visit. We identified medical diagnoses from medical insurance claims data during the three months before the start of the regular home visit. Medical diagnoses were categorized based on ICD-10 codes related to diseases associated with the initiation of long-term care in the Comprehensive Survey of Living Conditions in Japan [14] (Supplementary Appendix 1). The “suspected” diagnosis codes were excluded from the datasets.

Statistical analysis

Two-thirds of the study participants (n=3,259) were randomly assigned to a derivation cohort to develop risk prediction models using computer-generated random numbers. The remaining third (n=1,629) was reserved as an internal validation cohort. Among the patients assigned to the derivation cohort, we compared those with frequent use of emergency house calls and the others by using chi-square tests or Fisher's exact test when the expected frequency was less than 5. Then we performed multivariable logistic regression analysis with all pre-specified variables included. To create the most efficient and easy-to-use risk score in actual clinical practice, we used Lasso logistic regression to select predictor variables. Lasso is an extended standard regression model, developed as a parsimonious prediction model by selecting important predictors [15]. The model resulting from Lasso is known to have better predictive model selection performance and predictor identification than classical regression methods [16]. We extracted the variables through Lasso logistic regression to build the predictive model by 5-fold cross-validation with the largest lambda at which the mean-squared error (MSE) was within one standard error of the minimal MSE [17]. Using the variables selected with Lasso, we derived a scoring system by multiplying each beta coefficient by four and rounding to the nearest integer [18]. The integer values of all applicable variables were then summed to determine a total score for each patient. The Receiver Operating Characteristic (ROC) curve for the risk score was drawn, and the area under the curve (AUC) was compared with the model in which all previously specified variables were included. To test the performance of our risk scores, we assessed discrimination by measuring the AUC from the validation cohort. Calibration was assessed graphically by plotting the average predicted probabilities against the observed probabilities corresponding to the quintiles of predicted probabilities.

All analyses were conducted using STATA version 15 (Stata Corp., Texas, USA). Statistical significance was set at $P < 0.05$.

Results

We included 3259 people in the derivation cohort and 1629 in the validation cohort. Clinical characteristics are summarized in Table 1.

Table 1
Characteristics of patients in the derivation cohort and the validation cohort.

	Entire cohort	Derivation cohort	Validation cohort
	N = 4,888	N = 3,259	N = 1,629
	n (%)	n (%)	n (%)
Mean age, years (SD)	84.1 (7.4)	84.0 (7.5)	84.3 (7.3)
Age category (years)			
65–74	505 (10.3)	353 (10.8)	152 (9.3)
75–84	1895 (38.8)	1260 (38.7)	635 (39.0)
85–94	2131 (43.6)	1402 (43.0)	729 (44.8)
≥ 95	357 (7.3)	244 (7.5)	113 (6.9)
Gender: male	1972 (40.3)	1317 (40.4)	655 (40.2)
Medical procedure at home			
Self-injection	99 (2.0)	73 (2.2)	26 (1.6)
Central venous nutrition	64 (1.3)	45 (1.4)	19 (1.2)
Enteral nutrition	14 (0.3)	12 (0.4)	2 (0.1)
Home oxygen therapy	292 (6.0)	199 (6.1)	93 (5.7)
Use of ventilator/ tracheostomy performed	30 (0.6)	24 (0.7)	6 (0.4)
Urinary self- catheterization	18 (0.4)	13 (0.4)	5 (0.3)
Long-term care need levels			
Care-need levels 1–3	3019 (61.8)	2007 (61.6)	1012 (62.1)
Care-need levels 4–5	1869 (38.2)	1252 (38.4)	617 (37.9)
Medical diagnosis at the start of the regular home visit			

Abbreviations: SD = Standard Deviation, IQR = Inter Quartile Range.

*Emergency house calls once per month or more on average during each observation period.

	Entire cohort	Derivation cohort	Validation cohort
	N = 4,888	N = 3,259	N = 1,629
	n (%)	n (%)	n (%)
Cerebrovascular diseases	1953 (40.0)	1277 (39.2)	676 (41.5)
Cardiac disease	2783 (56.9)	1863 (57.2)	920 (56.5)
Lower respiratory tract disease	2240 (45.8)	1478 (45.4)	762 (46.8)
Joint diseases	2978 (60.9)	1938 (59.5)	1040 (63.8)
Dementia	2111 (43.2)	1421 (43.6)	690 (42.4)
Parkinson's disease	335 (6.9)	233 (7.2)	102 (6.3)
Diabetes	1615 (33.0)	1081 (33.2)	534 (32.8)
Vision or Hearing impairment	342 (7.0)	221 (6.8)	121 (7.4)
Fractures	892 (18.3)	580 (17.8)	312 (19.2)
Cancer	1404 (28.7)	939 (28.8)	465 (28.6)
Month of receiving regular home visits: median (IQR)	7 (2–12)	7 (2–12)	7 (2–12)
The frequent use of emergency home visits*	634 (13.0)	424 (13.0)	210 (12.9)
Abbreviations: SD = Standard Deviation, IQR = Inter Quartile Range.			
*Emergency house calls once per month or more on average during each observation period.			

The mean age was 84.1 (standard deviation 7.4) years for the entire sample, and 40.3% of participants were male. There were no clear differences in patient characteristics between the two cohorts. In the first year after the start of the regular home visit or by the month after the end of the regular home visit, 13.0% (424/3,259) and 12.9% (210/1,629) of the derivation cohort and the validation cohort, respectively, used emergency house calls once a month or more on average. The distributions of the average number of emergency house calls per month are shown in Supplementary Appendix 2. The derivation and validation cohorts showed right-skewed distributions, with 0 accounting for approximately 50%.

The characteristics associated with the frequent use of emergency house calls in the univariable analysis (chi-squared tests or Fisher’s exact test) and multivariable analysis are shown in Table 2.

Table 2
Univariate and multivariable analysis in the derivation cohort.

Univariable analysis				Multivariable logistic regression		Lasso logistic regression	Point score
	Non-frequent use of emergency house calls (n=2,835)	Frequent use of emergency house calls* (n=424)	P value	OR (95%CI)	P value	β coefficient	
	n (%)	n (%)					
Age category (years)							
65–74	289 (10.2)	64 (15.1)	0.002	Reference	-	-	-
75–84	1090 (38.5)	170 (40.1)		0.88 (0.63–1.25)	0.483	-	-
85–94	1249 (44.1)	153 (36.1)		0.85 (0.60–1.22)	0.390	-	-
≥ 95	207 (7.3)	37 (8.7)		1.41 (0.86–2.30)	0.169	-	-
Gender: male (vs. female)	1107 (39.1)	210 (49.5)	< 0.001	1.23 (0.98–1.54)	0.079	-	-
Medical procedure at home						-	-
Self-injection	67 (2.4)	6 (1.4)	0.218	0.64 (0.27–1.54)	0.322	-	-
Central venous nutrition	31 (1.1)	14 (3.3)	<0.001	1.66 (0.84–3.26)	0.141	-	-
Enteral nutrition	9 (0.3)	3 (0.7)	0.198	1.48 (0.38–5.79)	0.572	-	-

Abbreviations: OR = odds ratio, CI = confidence interval.

* Emergency house calls once per month or more on average during each observation period.

	Univariable analysis			Multivariable logistic regression		Lasso logistic regression	Point score
Home oxygen therapy	133 (4.7)	66 (15.6)	< 0.001	2.55 (1.80–3.62)	<0.001	1.06	4
Use of ventilator/ tracheostomy performed	23 (0.8)	1 (0.2)	0.161	0.18 (0.02–1.36)	0.096	-	-
Urinary self-catheterization	10 (0.4)	3 (0.7)	0.234	2.66 (0.68–10.37)	0.158	-	-
Long-term care need levels						-	-
Care need levels 4–5 (vs. 1–3)	1033 (36.4)	219 (51.7)	<0.001	1.84 (1.48–2.29)	<0.001	0.64	3
Medical diagnosis at the start of the regular home visit							
Cerebrovascular diseases	1142 (40.3)	135 (31.8)	0.001	0.78 (0.62–0.98)	0.037	-	-
Cardiac disease	1623 (57.3)	240 (56.6)	0.802	0.92 (0.73–1.16)	0.467	-	-
Lower respiratory tract disease	1237 (43.6)	241 (56.8)	<0.001	1.29 (1.03–1.62)	0.027	-	-
Joint diseases	1679 (59.2)	259 (61.1)	0.467	0.91 (0.73–1.15)	0.440	-	-
Dementia	1281 (45.2)	140 (33.0)	<0.001	0.92 (0.72–1.16)	0.474	-	-
Parkinson's disease	207 (7.3)	26 (6.1)	0.383	1.10 (0.70–1.72)	0.676	-	-

Abbreviations: OR = odds ratio, CI = confidence interval.

* Emergency house calls once per month or more on average during each observation period.

	Univariable analysis			Multivariable logistic regression		Lasso logistic regression	Point score
Diabetes	928 (32.7)	153 (36.1)	0.172	1.08 (0.85–1.36)	0.525	-	-
Vision or Hearing impairment	203 (7.2)	18 (4.3)	0.026	0.58 (0.35–0.96)	0.035	-	-
Fractures	514 (18.1)	66 (15.6)	0.198	1.01 (0.75–1.36)	0.940	-	-
Cancer	707 (24.9)	232 (54.7)	< 0.001	3.10 (2.46–3.91)	<0.001	1.21	5
Abbreviations: OR = odds ratio, CI = confidence interval.							
* Emergency house calls once per month or more on average during each observation period.							

In the univariable analysis, patient in the group that made frequent use of emergency house calls tended to be 65–84 and ≥ 95 years, male, more likely to be receiving central venous nutrition, home oxygen therapy, and had a higher care need level. Regarding patients' diseases, lower respiratory diseases and cancer were more frequent in the group that frequently used emergency house calls, whereas cerebrovascular diseases, dementia, and visual or hearing impairment were less frequent. In multivariable logistic regression analysis, home oxygen therapy, care need level 4–5 (compared with care need level 1–3), lower respiratory disease, and cancer showed positive associations with the frequent use of emergency house calls, whereas vision and hearing impairment showed negative associations.

Of the 19 pre-specified predictors included in the Lasso logistic model, three were found to be significant predictors of the frequent use of emergency house calls: home oxygen therapy, care need level 4–5, and cancer. The result of the beta coefficient and the created score is summarized in Table 2. The distribution of the total score in the derivation cohort and the validation cohort is shown in Supplementary Appendix 3. The ROC curve and the AUC for the risk score are shown in Figure 2. Compared with the model with all variables pre-specified (AUC; 0.729), the predictive ability of the 3-factor risk score (AUC; 0.708) was only slightly lower.

The AUC in the validation cohort was 0.708, indicating a moderate discriminatory ability. The calculation of the score and the estimated probability of frequent use of emergency house calls are shown in Figure 3. Figure 4 shows the calibration of the prediction model. The plotted points are relatively close to the 45° line, demonstrating good calibration over the whole range of the predictions.

Discussion

Using claims data from two Japanese cities, we developed and internally validated a multivariable risk prediction model and scoring system to predict the frequent use of emergency house calls. This risk score showed modest discrimination, good calibration, and satisfactory internal validity. It provides a useful and easily applicable tool for identifying high-risk patients who may require frequent emergency house calls in the community. The home health care team should promote understanding of the patient's disease and prepare for anticipated events for these patients and their families.

Our findings regarding the association between cancer patients and the frequent use of emergency house calls are consistent with a previous study reporting that cancer patients are almost seven times more likely to become frequent attenders at primary care after-hours services compared with non-cancer patients [19]. According to a previous study, cancer in the digestive or respiratory system was the most frequent reason for cancer patients' use of primary care after-hours services [20]. Another previous study showed that the most common complaints in patients with advanced cancer in the emergency department were pain, shortness of breath, and vomiting, which could also be the reason for emergency house calls [21]. In addition, as "death" is one of the major reasons for emergency house calls in Japan [7, 8], calls due to end-of-life care may be included in cancer patients.

We found that the frequent use of emergency house calls was more likely to occur in patients with high-care need levels. This finding may be explained as follows: Higher level of care needed is associated with fever events, and fever is a significant reason for emergency house calls [7]. A previous study in Japan found that fever was more likely in patients with care need levels ≥ 3 than ≤ 2 , and the conditions most likely to cause fever were pneumonia/bronchitis, skin and soft tissue infections, and urinary tract infections [22]. The authors explained that this was due to an increased risk of aspiration because of decreased strength to cough and increased susceptibility to infections caused by decreased muscle strength and poor nutritional status.

Home oxygen use was associated with the frequent use of emergency house calls. This is consistent with a study in Japan in which dyspnea was a common chief complaint and there was an association between emergency house calls for dyspnea and home oxygen use [7]. Another study has shown that chronic obstructive pulmonary disease (COPD) is more prevalent among those requiring frequent primary care after-hours services and that complications and exacerbations of chronic diseases are the reasons for this help-seeking behavior [19].

This risk score would be useful to allocate medical resources and maintain a home healthcare system in the community. In Japan, a revision of the medical fee schedule introduced HCSCs with home care support functions available 24-hour a day until the patient dies, which enabled 24-hour home visit care at the patient's request in 2006 [23]. In 2012, enhanced HCSCs, which required the appointment of three or more full-time doctors, were institutionalized. Although the number of HCSCs facilities is increasing, enhanced HCSC accounts for only a small percentage of the total HCSC (approximately 24% in 2018) [6]. Moreover, many general clinics do not meet HCSC requirements while providing home visits [6]. Most of these clinics are in solo practice and have difficulties providing three or more full-time doctors [24].

Therefore, our tool would be helpful to identify high-risk patients who may require the frequent use of emergency house calls and reduce the burden on primary care physicians, especially for solo practitioners, by associating high-risk patients to well-staffed medical institutions, such as enhanced HCSCs.

Our tool is based on information readily available in a primary care setting. Therefore, this score can indicate the risk at the start of the regular home visits to allow targeting a timely approach for high-risk patients. Furthermore, because this score contains only three factors, it is easy to remember and can be quickly calculated in clinical practice.

To the best of our knowledge, this is the first study to develop a risk prediction model for the frequent use of emergency house calls among older people who receive regular home visits. However, this study has several limitations. First, we did not externally validate the proposed model; further validation in different populations is warranted. Second, we did not examine some potential predictors that are known risk-factors, such as the urethral catheter placement [7], because information on these factors was not available. Third, some clinical information generally obtained in clinical settings (such as symptoms, laboratory data, and imaging findings) was unavailable in the database. Fourth, although the instances in which patients and their families perceive the need to request emergency house calls may be influenced by appropriate symptom management, enhanced home health care, palliative care with team coordination, and family caregiver education and support, we were unable to consider these factors. These factors should be included to improve risk score performance in future studies.

Conclusions

This easy-to-use risk scoring allows physicians to prospectively identify patients at high risk for emergency house calls and would help in reducing the physical and psychological burden on primary care physicians by taking measures such as clustering high-risk patients in well-equipped medical facilities, ultimately helping to preserve home health care in the community.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the University of Tsukuba (approval numbers: 1445-6 and 1666).

Consent for publication

Consent of individual participants was waived because of the anonymous nature of the data.

Availability of data and materials

The datasets supporting the conclusions of this article are available from the corresponding author on reasonable request.

Competing interests

The authors have no conflicts of interest.

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Authors' contributions

Study concept and design: Yu Sun, Masao Iwagami, Miho Ishimaru, Kazuaki Uda. Acquisition of data: Naoaki Kuroda, Satoru Yoshie, Tatsuro Ishizaki, Katsuya Iijima. Maintenance of data: Jun Komiyama, Miho Ishimaru. Statistical analysis and interpretation of data: Yu Sun, Masao Iwagami, Kazuaki Uda. Preparation of manuscript: all authors contributed to the drafting and critical revision of the manuscript. All authors have approved the final manuscript.

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Figures

Figure 1

<p>Flow chart of study participant selection.</p>

Figure 2

Receiver operating characteristic (ROC) curves and area under the curve (AUC) for the risk score in the derivation cohorts.

Calculation of the risk score		Estimated risk of the frequent use of emergency house calls	
Home oxygen therapy		Total score	Estimated risk (%)
Care need level	3		
1-3	0	0	5.9
4-5	4	3	11.3
Cancer	5	4	14.0
		5	17.2
		7	25.1
		8	29.9
		9	35.2
		12	52.7

Figure 3

Calculation of scores and the corresponding estimated probabilities of the frequent use of emergency house calls.

Figure 4

Calibration plot for predicting the frequent use of emergency house calls. The solid curve is the Loess-estimated calibration curve.

Supplementary Files

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- [SupprementaryAppendix2ver7.pdf](#)
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