Predictive Model for Emergency Hospital Admission and 6-Month Readmission

Sílvia López-Aguilà, MPH; Joan Carles Contel, MPH; Josep Farré, CIS; José Luis Campuzano, MSTAT; and Luis Rajmil, PhD

Objectives: To study risk factors for and likelihood of unplanned hospital admission and readmission in persons aged ≥65 years in Catalonia, Spain.

Study Design: Retrospective cohort study.

Methods: We used data from clinical records of the primary care centers, pharmacy database, and hospital discharge records for persons aged ≥65 years registered in primary care centers of referral hospitals in the Baix Llobregat healthcare area. Unplanned hospital admission was defined as any unscheduled hospitalization in 2008; unplanned readmission was defined as any unscheduled admission occurring within 6 months after discharge date of index admission. Logistic regression analysis was used to identify predictors of unplanned hospital admission and readmission.

Results: The population included 28,430 individuals. Among them, 2103 (7%) experienced an unplanned admission and 365 (1.3%) an unplanned readmission. The readmission rate for the admitted population was 18.7%. The strongest predictive factor of unplanned admission was ≥2 admissions in the previous 2 years (odds ratio [OR] 24.9, 95% confidence interval [CI] 16.0-38.7 for 2007; OR 15.6, 95% CI 8.6-28.0 for 2006). Factors associated with unplanned readmission were aged ≥80 years (OR 4.6, 95% CI 3.1-7.1) and ≥2 admissions during the previous year (OR 20.4, 95% CI 14.1-29.5). The area under the receiver operating characteristics curve was 0.78 for unplanned admission and 0.85 for unplanned readmission in the development sample and 0.76 and 0.81, respectively, in the validation sample.

Conclusions: Aged persons and those who used more hospital services in previous years had a higher probability of hospital admission and readmission.

(Am J Manag Care. 2011;17(9):e348-e357)

For author information and disclosures, see end of text.

Persons of advanced age have a greater number of chronic diseases and more comorbidity than the remaining population. This population has a considerable economic impact on the healthcare system, particularly when there is a lack of coordination between primary care and hospital services. Patients with chronic diseases and high comorbidity may not always receive optimum care because sometimes they have not been identified as persons at risk or with special needs. Some studies have estimated that the population with greater needs represents around 10% of the total, but consumes about 70% of available healthcare resources.[1] Unplanned hospital admissions and readmissions are included among the indicators of this higher healthcare expenditure. Short periods of time between admission and readmission (eg, 30 days) are used as indicators of quality of hospital care. Longer periods are useful as indicators of the population at risk and to asses the impact on the health system.[2]

Managed care models have been developed to promote integration and coordination of the healthcare system, and to provide patients with different interventions according to their level of need.[3,4] These models have been implemented by various organizations.[5,6] One of these models stratifies the population's healthcare needs into 4 levels and provides patients with different interventions according to their level of need, while the other model focuses on the high-risk population and offers specific resources, particularly nursing case management, to achieve a more proactive approach in the care of high-risk patients. The aim of this strategy is to improve the patient's clinical outcome and quality of life, while reducing the use of more costly services such as unplanned hospital admission. These models have also been applied in the National Health Service in England. Managed care models are based on identification of patients at risk of emergency hospitalization or high consumption of resources, or of requiring high-cost care in the future.

A systematic review published in 1991 identified 44 studies related to predictive models of hospital admission or readmission.[7] Forty-six studies published between 1991 and 2010 that developed predictive models to identify persons at risk were retrieved; most of them cohort studies (n = 30). Eight standardized instruments[8-16] designed to recognize the population at higher

In this article
Take-Away Points / e349
Published as a Web exclusive
www.ajmc.com

risk and to develop interventions to reduce unplanned admissions have been published.

The healthcare system in Catalonia is a public system, financed by taxes, with universal healthcare coverage and free entry for all citizens. It is oriented toward primary care, which is the first contact and level of access users have with the healthcare system (cure, care, prevention, and health promotion), and it is mainly provided in primary care centers.[17-19] The hospitalization rate in Catalonia was 306.3/1000 for the population over age 64 years in 2009.[20] A comparable figure of admission rate in acute, short-stay hospitals was 350.8/1000 for the United States in 2006.[21]

Take-Away Points

Predictive models of people at high risk for hospital admission and readmission were developed using primary care, pharmacy, and hospital care databases.

- Aged people with respiratory and/or cardiac comorbidities and with greater use of hospital care services in previous years had a higher probability of hospital admission and readmission.
- Application of this predictive model to identify people at risk may have a considerable impact on the care of patients with high comorbidity, making for a more proactive healthcare system and at the same time reducing the cost of avoidable hospitalizations.

With the currently available information about the Spanish healthcare system, it would be appropriate to incorporate tools to help identify subpopulations at risk of high consumption of resources.

The aims of this study were to analyze the risk factors for and the likelihood of unplanned hospital admission and readmission in the population over age 64 years who were registered with a primary care center in 1 of the geographical healthcare areas of Catalonia. This tool could potentially provide useful information to establish interventions focused on preventing future unplanned admissions and readmissions.

METHODS

Design and Study Population

This is a retrospective cohort study including all persons more than 64 years of age who were registered in the primary care area of Baix Llobregat Litoral within the health region of Costa de Ponent in Catalonia (Spain). The health services provided in this area include 7 primary care teams and 2 public referral hospitals, Viladecans Hospital, a first-level center, and Bellvitge Hospital, a third-level center for more complex cases. The primary care centers and hospitals provide almost all healthcare services in this area.

Data Source and Study Variables

The data were obtained from the e-CAP, the computerized information system used in primary care; the pharmacy database, which records dispensation of drugs; and the hospital discharge data from Viladecans and Bellvitge. Data used to build the predictive models came from the period encompassing 2006, 2007, and 2008. Data from 2006 and 2007 were used as background information on healthcare service use in both the primary care and hospital settings. To validate the model, data from the period including 2007, 2008, and 2009, were used, with data from 2007 and 2008 being the background information.

The dependent variables were unplanned hospital admission between January 1, 2008, and December 31, 2008, and unplanned readmission within 6 months after discharge day of the index admission.

The exclusion criteria for index admissions were elective or planned admission, readmissions during the same study period, admission of patients who resided outside the area, and hospital discharges without recording the admission or discharge date or the type of admission. In readmissions, the exclusion criteria were persons dead at discharge of index admission and individuals transferred from one hospital to another hospital in the same readmission.

The sociodemographic factors analyzed were age (categorized into 65-69, 70-74, 75-79, and ≥80 years), sex, place of residence, morbidity, and diagnoses recorded in the e-CAP, based on the *International Classification of Diseases, 10th Revision, Clinical Modification* into large groups, from which the more specific, common diagnoses according to the literature were chosen. These included insulin-dependent diabetes (E10), non–insulin-dependent diabetes (E11), heart failure (I50), ischemic heart disease (I20-I50), bronchitis (J40, J41, and J42), emphysema (J43), chronic obstructive pulmonary disease (COPD) (J44), asthma (J45), bronchiectasis (J47), Alzheimer's disease (G30), and femoral neck fracture (S72), plus the total number of concurrent diagnoses (≤4 vs ≥5). In addition, the following factors were analyzed: consumption of primary care resources in the previous 2 years, consultations by telephone contact (0 vs ≥1), general medical visits (≤5 vs ≥6), nursing visits (≤2 vs ≥3), social worker visits (0 vs ≥1), visits to any service (≤5 vs ≥6), drugs dispensed (≤3 vs ≥4), and use of hospital resources in the previous 2 years, including previous unplanned admissions (≤1 vs ≥2) and cumulative days of stay (≤8 vs ≥9). Categorization of these variables was carried out in keeping with data in the literature and according to their skewed distribution in the population studied.

An analysis of the internal validity, quality, and consistency of the information obtained was carried out following a previously designed protocol.

Table 1. Sociodemographic Characteristics of the Population Aged ≥65 Years Who Were Registered With Primary Care Centers and Patients Who Had Unplanned Admissions in 2008

Characteristic	No. (%)		
	Total	Unplanned Admissions	Planned and Unplanned Admissions
Total	28,430	2103	3632
Sex			
Male	12,129 (42.7)	1015 (48.3)	1706 (47.0)
Female	16,301 (57.3)	1088 (51.7)	1926 (53.0)
Age, y			
65-69	7484 (26.3)	264 (12.6)	702 (19.3)
70-74	6670 (23.5)	393 (18.7)	830 (22.9)
75-79	5649 (19.9)	437 (20.8)	811 (22.3)
≥80	8627 (30.3)	1009 (48.0)	1289 (35.5)
Municipality[a]			
Castelldefels	10,107 (35.7)	646 (32.5)	969 (27.5)
Gavá	8038 (28.4)	584 (29.3)	1082 (30.7)
Viladecans	10,173 (35.9)	761 (38.2)	1469 (41.7)

[a]Municipality was missing for 0.39%.

This study was performed in accordance with national and international guidelines (ethics code, Declaration of Helsinki) and with legal regulations on the confidentiality of personal data (Law 15/1999 of December 13 on the protection of personal data).

Statistical Analysis

Logistic regression was used to identify factors predictive of unplanned hospital admission in a 12-month period and readmission within 6 months. The model building process consisted of 3 steps: selecting the variables, building the model, and validating the model. Unplanned hospital admission and readmission models were adjusted for sex and age. Model fitting was realized with an iterative process, selecting in each step the candidate variable to add to the model, using a statistical significance level of <.01. To choose the best model, the likelihood ratio test was used to compare the models in each iteration.

Validation of the model was performed by testing calibration, discrimination, and colinearity, and analyzing the residuals and influence values.[22] SPSS version 18 (SPSS Inc, Chicago, Illinois) and STATA version 11 (StataCorp, College Station, Texas) for Windows were used for the statistical analyses.

RESULTS

A total of 28,430 persons over 64 years of age (57.6% women) were registered in a primary care center in the study area. Among them, 30.3% were 80 years or older, 35.7% were registered in Castelldefels, and 35.9% were registered in Viladecans, Spain.

The sociodemographic characteristics of the entire study population, patients who had any hospital admission (planned or unplanned), and patients who had only an unplanned hospital admission in 2008, are presented in Table 1. Among the total population, 7.4% (n = 2103) had an unplanned admission; 51.7% of this group were women and 48% were 80 years or older (Table 1). The most prevalent diagnoses related to unplanned admissions compared with the total population were COPD, heart failure, ischemic heart disease, non–insulin-dependent diabetes, and having 5 or more concurrent diagnoses (Table 2). Compared with the total population, hospitalized patients in this group consumed an increased amount of healthcare resources, and this increase was higher in 2007 than in 2006.

Among the total population, 1.3% (n = 365) had an unplanned readmission within 180 days from the index admission (53.7% men, 53.7% 80 years or older), and 4.1% had any readmission (unplanned or planned; Table 3). In the admitted population the rate of readmission was 18.7% (365/1952) at 6 months and 13.6% (265/1952) at 30 days. Compared with the total population, readmitted patients had a higher prevalence of almost all the variables analyzed. Emergency admission in the 2 years prior to readmission was also higher in the readmitted population (Table 4).

The predictive factors for unplanned hospital admission were sex (male), age (the older the patient, the higher the

Table 2. Percentage of Individuals With the Diagnoses Studied, Dispensed Medication, and Health Services Use[a]

Characteristic	No. (%)		
	Total (n = 28,430)	Unplanned Admissions (n = 2103)	Planned and Unplanned Admissions (n = 3632)
Morbidity			
Insulin-dependent diabetes	121 (0.4)	20 (1.0)	32 (0.9)
Non–insulin-dependent diabetes	5570 (19.6)	591 (28.1)	970 (26.7)
Ischemic heart disease	2346 (8.3)	374 (17.8)	550 (15.1)
Heart failure	1048 (3.7)	288 (13.7)	336 (9.3)
Unspecified bronchitis (acute or chronic)	66 (0.2)	8 (0.4)	10 (0.3)
Mucopurulent and simple chronic bronchitis	161 (0.6)	21 (1.0)	28 (0.8)
Unspecified chronic bronchitis	443 (1.6)	71 (3.4)	109 (3.0)
Emphysema	127 (0.5)	32 (1.5)	39 (1.1)
Chronic obstructive pulmonary disease	1822 (6.4)	361 (17.2)	506 (13.9)
Asthma	1024 (3.6)	112 (5.3)	199 (5.5)
Bronchiectasis	269 (1.0)	51 (2.4)	71 (2.0)
Alzheimer's disease	379 (1.3)	46 (2.2)	56 (1.5)
Femur fracture	17 (0.1)	3 (0.1)	5 (0.1)
Concurrent diagnoses (≥5)	429 (1.5)	171 (8.1)	200 (5.5)
Use of health services			
Number of drugs prescribed (≥4)	5085 (17.9)	840 (39.9)	1199 (33.0)
Use of services per year (2006)			
Consultation by telephone (≥1)	804 (2.8)	101 (4.8)	175 (4.8)
Social worker visits (≥1)	826 (2.9)	132 (6.3)	171 (4.7)
Emergency visits (≥1)	1250 (4.4)	146 (6.9)	260 (7.2)
Nurse visits (≥3)	14,688 (51.7)	1426 (67.8)	2586 (71.2)
General medical visits (≥6)	11,746 (41.3)	1205 (57.3)	2205 (60.7)
Total of visits (≥6)	16,142 (56.8)	1508 (71.7)	2780 (76.5)
Emergency admissions (≥2)	133 (0.5)	114 (5.4)	133 (3.7)
Planned admissions (≥2)	114 (0.4)	63 (3.0)	114 (3.1)
Days of cumulative stay (≥9)	157 (0.6)	117 (5.6)	157 (4.3)
Use of services per year (2007)			
Consultation by telephone (≥1)	1993 (7.0)	223 (10.6)	412 (11.3)
Social worker visits (≥1)	1083 (3.8)	181 (8.6)	240 (6.6)
Emergency visits (≥1)	20,607 (72.5)	1698 (80.7)	3179 (87.5)
Nurse visits (≥3)	633 (2.2)	179 (8.5)	207 (5.7)
General medical visits (≥6)	12,404 (43.6)	1296 (61.6)	2402 (66.1)
Total of visits (≥6)	16,434 (57.8)	1571 (74.7)	2910 (80.1)
Emergency admissions (≥2)	233 (0.8)	202 (9.6)	233 (6.4)
Planned admissions (≥2)	135 (0.5)	67 (3.2)	135 (3.7)
Days of cumulative stay (≥9)	206 (0.7)	156 (7.4)	206 (5.7)

[a]Total population aged ≥65 years who were registered with primary care centers and patients who had unplanned admissions in 2008.

Table 3. Sociodemographic Characteristics of the Population Aged ≥65 Years Who Were Registered With Primary Care Centers and Patients Who Were Readmitted in 2008

Characteristic	No. (%)		
	Total (n = 28,279)	Unplanned Readmissions (n = 365)	Planned and Unplanned Readmissions (n = 1163)
Sex			
Male	12,050 (42.6)	196 (53.7)	618 (53.1)
Female	16,229 (57.4)	169 (46.3)	545 (46.9)
Age, y			
65-69	7477 (26.4)	28 (7.7)	205 (17.6)
70-74	6648 (23.5)	70 (19.2)	232 (19.9)
75-79	5627 (19.9)	71 (19.5)	258 (22.2)
≥80	8527 (30.2)	196 (53.7)	468 (40.2)
Municipality[a]			
Castelldefels	10,063 (35.7)	123 (35.7)	335 (29.9)
Gavá	8007 (28.4)	98 (28.4)	330 (29.4)
Viladecans	10,121 (35.9)	124 (35.9)	457 (40.7)

[a]Municipality was missing for 0.31%.

risk), COPD, heart failure, 5 or more concurrent diagnoses, dispensation of 4 or more medications, and the use of hospital resources in the 2 years prior to admission (emergency admissions, planned admissions, and cumulative days of hospital stay). Associated factors for unplanned readmission were sex (male), age (the older the patient, the higher the risk), insulin-dependent diabetes, ischemic heart disease, heart failure, the number of dispensed drugs, and emergency admissions and days of hospital stay accumulated in the previous year. The most powerful predictive factor for both admission and readmission was unplanned admissions in the previous year (odds ratio [OR] 24.9, 95% confidence interval [CI] 16.0-38.7 and OR 20.4, 95% CI 14.1-29.5, respectively; **Table 5**).

The area under the receiver operating characteristic (ROC) curve of hospital admission was 0.78 in the study sample and 0.76 in the validation sample (**Figure**). The variance influence factors were 1.03 to 1.24 and the Hosmer-Lemeshow *P* value was .50. For readmission, ROC curves were 0.85 in the study sample and 0.81 in the validation sample (Figure). The variance influence factors were 1.00 to 1.14, and the Hosmer-Lemeshow *P* value was .12.

DISCUSSION

In this study, predictive models for unplanned hospital admission and readmission were developed in a health area of Catalonia using retrospective data from the primary care, pharmacy, and hospital databases. Hospitalization in previous years was the most powerful risk factor for unplanned hospitalization and rehospitalization. These predictive models enable identification of persons at higher risk and establishment of proactive interventions with greater intensity in the high-risk categories, so that more effective allocation of resources to meet population needs can be achieved.

The fact that the Spanish healthcare system is oriented toward primary care, with easy and universal access to care, could be associated with low rates of hospitalizations, both the total rates and specifically the rates for ambulatory care–sensitive conditions.[17] Nevertheless, factors related to the use of primary care did not achieve statistical significance in our predictive models. As almost all the elderly population had consulted regularly with primary care in previous years (mean number of visits to a primary care center per year in the study sample was 10.8 in 2008), these variables lost their ability to discriminate between those who were admitted and those who were not admitted to the hospital. Moreover, in spite of the high mean number of visits to a primary care center in the Spanish elderly population compared with the number of visits in other countries, the present study did not include assessment of the "quality" or effectiveness of those visits.

No differences were found in the probability of admission or readmission related to the place of residence, despite the existing variability in clinical practice in Spain.[23] This may be because the area analyzed was relatively small, including only 2 hospitals and 7 primary care teams.

Table 4. Percentage of Individuals With the Diagnoses Studied, Medication Use, and Health Services Use[a]

Characteristic	No. (%)		
	Total (n = 28,279)	Unplanned Readmissions (n = 365)	Planned and Unplanned Readmissions (n = 1163)
Morbidity			
Insulin-dependent diabetes	120 (0.4)	6 (1.6)	14 (1.2)
Non–insulin-dependent diabetes	5538 (19.6)	108 (29.6)	334 (28.4)
Ischemic heart disease	2327 (8.2)	80 (21.9)	245 (20.8)
Heart failure	1027 (3.6)	90 (24.7)	178 (15.1)
Unspecified bronchitis (acute or chronic)	66 (0.2)	1 (0.3)	3 (0.3)
Mucopurulent and simple chronic bronchitis	160 (0.6)	6 (1.6)	13 (1.1)
Unspecified chronic bronchitis	440 (1.6)	15 (4.1)	46 (3.9)
Emphysema	127 (0.4)	13 (3.6)	25 (2.1)
Chronic obstructive pulmonary disease	1808 (6.4)	97 (26.6)	234 (19.9)
Asthma	1023 (3.6)	23 (6.3)	73 (6.2)
Bronchiectasis	267 (0.9)	16 (4.4)	37 (3.1)
Alzheimer's disease	377 (1.3)	8 (2.2)	21 (1.8)
Femur fracture	17 (0.1)	0 (0.0)	1 (0.1)
Concurrent diagnoses (≥5)	415 (1.5)	45 (12.3)	108 (9.2)
Use of health services			
Number of drugs prescribed (≥4)	5062 (17.9)	175 (48.0)	487 (41.4)
Use of services per year (2006)			
Consultation by telephone (≥1)	795 (2.8)	26 (7.1)	61 (5.2)
Social worker visits (≥1)	819 (2.9)	21 (5.8)	64 (5.4)
Emergency visits (≥1)	1240 (4.4)	40 (11.0)	110 (9.4)
Nurse visits (≥3)	14,595 (51.6)	265 (72.6)	870 (74)
General medical visits (≥6)	11,672 (41.3)	239 (65.5)	756 (64.3)
Total of visits (≥6)	16,049 (56.8)	281 (77.0)	923 (78.5)
Emergency admissions (≥2)	128 (0.5)	39 (10.7)	67 (5.7)
Planned admissions (≥2)	111 (0.4)	17 (4.7)	48 (4.1)
Days of cumulative stay (≥9)	149 (0.5)	34 (9.3)	70 (6.0)
Use of services per year (2007)			
Consultation by telephone (≥1)	1982 (7.0)	54 (14.8)	150 (12.8)
Social worker visits (≥1)	1065 (3.8)	46 (12.6)	101 (8.6)
Emergency visits (≥1)	20,511 (72.5)	295 (80.8)	1003 (85.3)
Nurse visits (≥3)	602 (2.1)	42 (11.5)	90 (7.7)
General medical visits (≥6)	12,328 (43.6)	241 (66.0)	805 (68.5)
Total of visits (≥6)	16,338 (57.8)	281 (77.0)	947 (80.5)
Emergency admissions (≥2)	219 (0.8)	89 (24.4)	143 (12.2)
Planned admissions (≥2)	134 (0.5)	17 (4.7)	61 (5.2)
Days of cumulative stay (≥9)	194 (0.7)	47 (12.9)	98 (8.3)

[a]Total population aged ≥65 years who were registered with primary care centers and patients who were readmitted in 2008.

Table 5. Predictive Models of Unplanned Hospital Admission and Readmission

Characteristic	OR (95% CI)	
	Admission	Readmission
Sex		
Female	1	1
Male	1.26 (1.14-1.40)	1.52 (1.20-1.95)
Age, y		
65-69	1	1
70-74	1.53 (1.28-1.82)	2.37 (1.50-3.75)
75-79	1.85 (1.56-2.20)	2.51 (1.59-3.99)
≥80	3.13 (2.69-3.64)	4.64 (3.05-7.06)
Insulin-dependent diabetes		
No	—	1
Yes	—	4.15 (1.60-10.76)
Chronic obstructive pulmonary disease		
No	1	1
Yes	1.87 (1.59-2.19)	2.18 (1.62-2.94)
Ischemic heart disease		
No	1	—
Yes	1.40 (1.20-1.62)	—
Heart failure		
No	1	1
Yes	2.12 (1.77-2.55)	3.92 (2.93-5.25)
Number of concurrent diagnoses		
≤4	1	—
≥5	2.33 (1.80-3.04)	—
Number of drugs prescribed		
≤3	1	1
≥4	2.89 (2.60-3.21)	3.09 (2.46-3.88)
Emergency admissions 2007		
≤1	1	1
≥2	24.89 (16.00-38.72)	20.40 (14.10-29.51)
Planned admissions 2007		
≤1	1	—
≥2	4.23 (2.66 -6.74)	—
Days of cumulative stay 2007		
≤8	1	1
≥9	14.39 (9.80-21.14)	3.44 (2.12-5.56)
Emergency admissions 2006		
≤1	1	—
≥2	15.58 (8.66-28.02)	—
Planned admissions 2006		
≤1	1	—
≥2	5.85 (3.58-9.56)	—
Days of cumulative stay 2006		
≤8	1	—
≥9	9.54 (6.03-15.09)	—

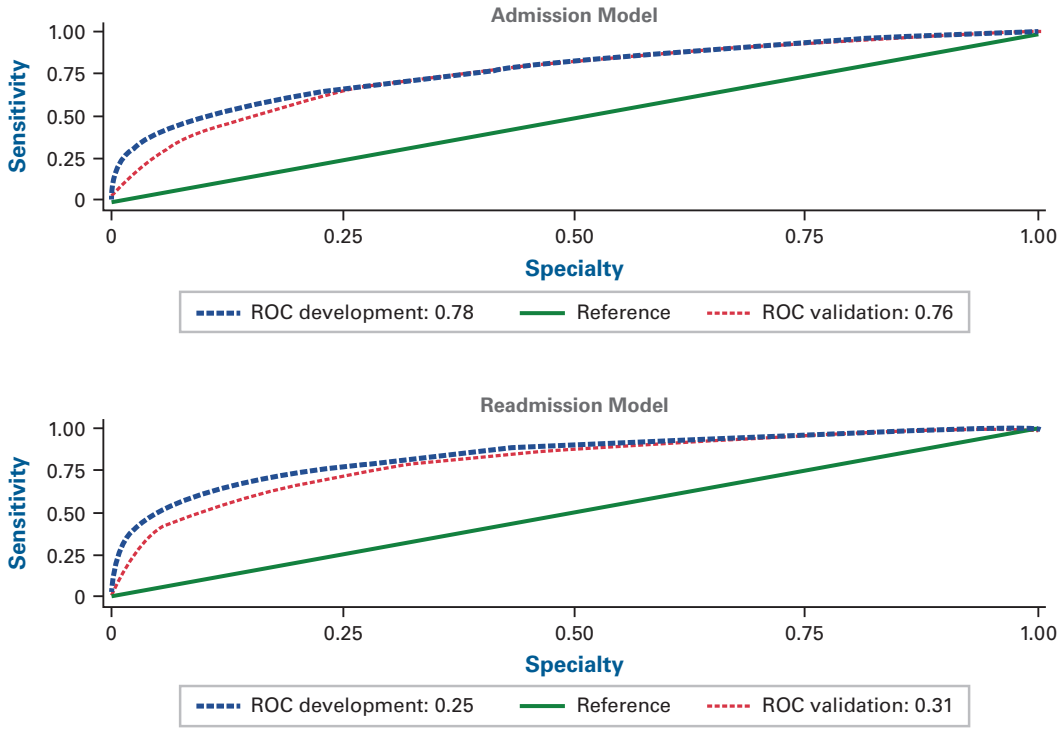
CI indicates confidence interval; OR, odds ratio.

The rates of unplanned readmission for the admitted population in our study were 18.7% at 6 months and 13.6% at 30 days, both lower than the 20.0% generally found in the United States at 30 days.[10]

Previous studies in Spain have analyzed admission and/or readmission for specific diseases or specialties. In Catalonia (Baix Empordà) the relationship between population morbidity and healthcare costs was examined.[24] In Valencia, relationships between comorbidity and hospital stay, mortality, and readmission were analyzed using the Charlson index.[25] The results from the current study cannot be compared with the results of these studies because we examined the risk of unplanned hospitalization using various databases, not using only hospital data. In addition, the study from Baix Empordà analyzed primary care and hospital cost together as a dependent variable.

Similar studies have been carried out in the United Kingdom (Scottish Patients at Risk of Readmission and Admission[11,12] and the combined predictive model Patients at Risk of Re-hospitalisation[13,26]) and in the United States (Probability of Repeated Admission[8,9] and the Triage Risk Stratification Tool.[10,27]) The latter included other variables such as morbidity groups based on cost (Adjusted Clinical Groups[28]). These and other published cohort studies obtained ROC curves between 0.64 and 0.83. On the other hand, a recent published study obtained acceptable predic-

Figure. Receiver Operating Characteristics of the Development and Validation Samples



ROC indicates receiver operating characteristic.

tive figures, although it included death as part of the outcome measure.[16]

The model that showed the greatest capacity for discrimination (ROC curve of 0.83) included individual variables such as self-perceived health status, visual impairment, mean scores on physical activity, and need for assistance in activities of daily living. This model showed better discrimination than another model from the same population using only administrative data (0.77).[29]

The inclusion of a classification of morbidity groups or comorbidity indexes according to the consumption of resources, such as the Adjusted Clinical Groups[28] or Clinical Risk Groups,[30] could improve the models obtained here. However, models based on hospital cost do not seem to obtain better results than those based on morbidity and use of health services.[31]

The strengths of this study include the general population sample over age 64 years and the use of different databases. It is also one of the first studies on predictive models carried out in Spain.

Among the limitations of this study, certain individual variables (ie, Charlson or Elixhauser index; variables related to admission such as admission for emergency, hour of admission, or patient follow-up visits with primary care physician after discharge from the index admission) that could improve the predictive level were lacking and should be included in future studies. In addition, admissions and readmissions of residents in the area to other hospitals in Catalonia or outside Catalonia were not included because of the lack of hospital data outside the study area. However, it is not expected that this would have significantly influenced the final results, since it is likely that most emergency admissions would occur in the area where a person resides. According to data from the 2008 Catalonian hospital discharge database, the hospitalization rate for the area's total population was 96/1000.[32] In our study, taking into account all admissions in the area, the hospitalization rate was 86/1000 (in the population ≥15 years old, excluding obstetric causes); hence, we think that any underestimation would be low. On the other hand, we could not identify those few deaths occurring in 2008 that were not connected to the index admission. Nevertheless, these would not be expected to have a significant impact on the results. Future studies could identify these deaths and apply Cox proportional hazards analysis.[33] It should also be noted that an external validation performed in the same population can favor the good discriminating power shown by a model; hence, it would be advisable to perform the validation in another population. Another limitation may be that categorization of the variables was partly based on their distribution in the study population; this issue should be examined in future studies. Finally, generalization of the results is limited to areas

with similar healthcare models and populations with similar characteristics.

In conclusion, aged persons who have respiratory and cardiac comorbidities and who use the hospital care services more often have a higher probability of hospital admission and readmission in the future. Despite the limitations of the study, the predictive model that was developed showed acceptable results in terms of validity and reliability.

In the future, it might be possible to implement proactive interventions in real time in at-risk patients detected by the predictive model. Application of these interventions could have considerable impact on the care of patients with high comorbidity. Comparative studies investigating the effectiveness of these interventions in reducing hospitalizations should be carried out. The Catalan and Spanish healthcare system, which is oriented toward primary care, should be considered when implementing any intervention. This system makes it easier than other healthcare systems to treat health problems by ongoing, comprehensive, and coordinated care.

Acknowledgments

We thank the staff from the Pla d'Innovació d'Atenció Primària i Salut Comunitària of the Catalan Health Department for their collaboration, especially Blanca Rodríguez-Muntaner and Lourdes Camp. Thank you also to Ana Hernandez, MD, from Bellvitge Hospital, who provided the data.

Author Affiliations: From Agència d'Informació, Avaluació i Qualitat en Salut (SL-A, LR), Barcelona, Spain; Centro de Investigación Biomédica en Red de Epidemiología y Salud Pública (SL-A, LR), Madrid, Spain; DAP Costa Ponent, Gerencia Territorial Metropolitana Sud, ICS (JCC), Barcelona, Spain; SAP Baix Llobregat Litoral, Gerencia Territorial Metropolitana Sud, ICS (JF), Catalonia, Spain; Hospital Viladecans, Gerencia Territorial Metropolitana Sud, ICS (JLC), Catalonia, Spain; Institut Municipal d'Investigació Mèdica (LR), Barcelona, Spain.

Funding Source: None.

Author Disclosures: This study was approved on June 30, 2010, by the Comitè d'Ètica d'Investigació Clínica of IDIAP Jordi Gol. The authors (SL-A, JCC, JF, JLC, LR) report no relationship or financial interest with any entity that would pose a conflict of interest with the subject matter of this article.

Authorship Information: Concept and design (SL-A, JCC, JLC, LR); acquisition of data (JCC, JF, JLC); analysis and interpretation of data (SL-A, JCC, JLC, LR); drafting of the manuscript (SL-A, JCC, LR); critical revision of the manuscript for important intellectual content (JCC, LR); statistical analysis (SL-A, JLC); provision of study materials or patients (JCC, JF, JLC); administrative, technical, or logistic support (SL-A, JCC, JF, LR); and supervision (JCC, JLC, LR).

Address correspondence to: Sílvia López-Aguilà, MPH, Agència d'Informació, Avaluació i Qualitat en Salut, AIAQS, Carrer de Roc Boronat, 81-95 (2a planta), 08005 Barcelona, Spain. E-mail: slopeza@aatrm.catsalut.cat.

REFERENCES

1. Reuben DB, Keeler E, Seeman TE, Sewall A, Hirsch SH, Guralnik JM. Development of a method to identify seniors at high risk for high hospital utilization. *Med Care.* 2002;40(9):782-793.

2. Kim H, Ross JS, Melkus GD, Zhao Z, Boockvar K. Scheduled and unscheduled hospital readmissions among patients with diabetes. *Am J Manag Care.* 2010;16(10):760-767.

3. Coleman K, Austin BT, Brach C, Wagner EH. Evidence on the Chronic Care Model in the new millennium. *Health Aff (Millwood).* 2009;28(1):75-85.

4. Coleman K, Mattke S, Perrault PJ, Wagner EH. Untangling practice redesign from disease management: how do we best care for the chronically ill? *Annu Rev Public Health.* 2009;30:385-408.

5. Feachem RG, Sekhri NK, White KL. Getting more for their dollar: a comparison of the NHS with California's Kaiser Permanente. *BMJ.* 2002;324(7330):135-141.

6. Tanaka M, Yamamoto H, Kita T, Yokode M. Early prediction of the need for non-routine discharge planning for the elderly. *Arch Gerontol Geriatr.* 2008;47(1):1-7.

7. Soeken KL, Prescott PA, Herron DG, Creasia J. Predictors of hospital readmission: a meta-analysis. *Eval Health Prof.* 1991;14(3):262-281.

8. Novotny NL, Anderson MA. Prediction of early readmission in medical inpatients using the Probability of Repeated Admission instrument. *Nurs Res.* 2008;57(6):406-415.

9. Pacala JT, Boult C, Reed RL, Aliberti E. Predictive validity of the Pra instrument among older recipients of managed care. *J Am Geriatr Soc.* 1997;45(5):614-617.

10. Lee JS, Schwindt G, Langevin M, et al. Validation of the triage risk stratification tool to identify older persons at risk for hospital admission and returning to the emergency department. *J Am Geriatr Soc.* 2008;56(11):2112-2117.

11. SPARRA: Scottish Patients at Risk of Readmission and Admission. Edinburgh, UK: National Services Scotland, National Health Services; 2006.

12. SPARRA: Scottish Patients at Risk of Readmission and Admission. Edinburgh, UK: National Services Scotland, National Health Services; 2008.

13. Billings J, Dixon J, Mijanovich T, Wennberg D. Case finding for patients at risk of readmission to hospital: development of algorithm to identify high risk patients. *BMJ.* 2006;333(7563):327.

14. Smith DM, Katz BP, Huster GA, Fitzgerald JF, Martin DK, Freedman JA. Risk factors for nonelective hospital readmissions. *J Gen Intern Med.* 1996;11(12):762-764.

15. Anderson MA, Hanson KS, DeVilder NW, Helms LB. Hospital readmissions during home care: a pilot study. *J Community Health Nurs.* 1996;13(1):1-12.

16. van Walraven C, Dhalla IA, Bell C, et al. Derivation and validation of an index to predict early death or unplanned readmission after discharge from hospital to the community. *CMAJ.* 2010;182(6):551-557.

17. Starfield B. *Primary Care: Balancing Health Needs, Services, and Technology*. New York: Oxford University Press; 1998.

18. Starfield B, Shi L, Macinko J. Contribution of primary care to health systems and health. *Milbank Q.* 2005;83(3):457-502.

19. Macinko J, Starfield B, Shi L. The contribution of primary care systems to health outcomes within Organization for Economic Cooperation and Development (OECD) countries, 1970-1998. *Health Serv Res.* 2003;38(3):831-865.

20. *Activitat Assistencial de la Xarxa Sanitària de Catalunya. Registre del Conjunt Mínim Bàsic de Dades (CMBD).* Barcelona, Spain: Divisió de Gestió de Registres d'Activitat, Departament de Salut, Generalitat de Catalunya; 2009.

21. Buie VC, Owings MF, DeFrances CJ, Golosinskiy A. *National Hospital Discharge Survey: 2006 Summary.* Series 13, Number 168. Washington, DC: National Center for Health Statistics; December 2010. www.cdc.gov/nchs/data/series/sr_13/sr13_168.pdf. Accessed July 29, 2011.

22. Hosmer DW, Lemeshow S. *Applied Logistic Regression.* 2nd ed. New York: John Wiley & Sons, Inc; 2000.

23. Suárez García FM, Jiménez Torres F, Peiró S, et al. Variabilidad en las hospitalizaciones de las personas mayores en el Sistema Nacional de Salud. *Atlas Var Pract Med SNS.* 2010;4(1):299-313.

24. Inoriza JM, Coderch J, Carreras M, et al. Measurement of morbidity attended in an integrated health care organization [in Spanish]. *Gac Sanit.* 2009;23(1):29-37.

25. Librero J, Peiró S, Ordiñana R. Chronic comorbidity and outcomes of hospital care: length of stay, mortality, and readmission at 30 and 365 days. *J Clin Epidemiol.* 1999;52(3):171-179.

26. National Health Service (NHS). *Combined Predictive Model: Final Report.* London, UK: NHS; 2006.

27. Sylvia ML, Shadmi E, Hsiao CJ, Boyd CM, Schuster AB, Boult C. Clinical features of high-risk older persons identified by predictive modeling. *Dis Manag.* 2006;9(1):56-62.

28. Starfield B, Weiner J, Mumford L, Steinwachs D. Ambulatory care groups: a categorization of diagnoses for research and management. *Health Serv Res.* 1991;26(1):53-74.

29. Coleman EA, Min SJ, Chomiak A, Kramer AM. Posthospital care transitions: patterns, complications, and risk identification. *Health Serv Res.* 2004;39(5):1449-1465.

30. Rice N, Smith PC. Capitation and risk adjustment in health care financing: an international progress report. *Milbank Q.* 2001;79(1): 81-113.

31. Forrest CB, Lemke KW, Bodycombe DP, Weiner JP. Medication, diagnostic, and cost information as predictors of high-risk patients in need of care management. *Am J Manag Care.* 2009;15(1):41-48.

32. *Activitat Assistencial de la Xarxa Sanitària de Catalunya. Registre d l Conjunt Mínim Bàsic de Dades (CMBD).* Barcelona, Spain: Divisió de Gestió de Registres d'Activitat, Departament de Salut, Generalitat de Catalunya; 2008.

33. Berry SD, Ngo L, Samelson EJ, Kiel DP. Competing risk of death: an important consideration in studies of older adults. *J Am Geriatr Soc.* 2010;58(4):783-787. ■