Age-Related Differences in the Rate, Timing, and Diagnosis of 30-Day Readmissions in Hospitalized Adults With Asthma Exacerbation

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BACKGROUND: Reducing hospital readmissions has attracted attention from many stakeholders. However, the characteristics of 30-day readmissions after asthma-related hospital admissions in adults are not known. It is also unclear whether older adults are at higher risk of 30-day readmission.

OBJECTIVES: To investigate the rate, timing, and principal diagnosis of 30-day readmissions in adults with asthma and to determine age-related differences.

METHODS: Retrospective cohort study of adults hospitalized for asthma exacerbation using the population-based inpatient samples of three states (California, Florida, and Nebraska) from 2005 through 2011. Patients were categorized into three age groups: younger (18-39 years), middle aged (40-64 years), and older (≥ 65 years) adults. Outcomes were 30-day all-cause readmission rate, timing, and principal diagnosis of readmission.

RESULTS: Of 301,164 asthma-related admissions at risk for 30-day readmission, readmission rate was 14.5%. Compared with younger adults, older adults had significantly higher readmission rates (10.1% vs 16.5%; OR, 2.15 [95% CI, 2.07-2.23]; $P < .001$). The higher rate attenuated with adjustment (OR, 1.19 [95% CI, 1.13-1.26]; $P < .001$), indicating that most of the age-related difference is explained by sociodemographics and comorbidities. For all age groups, readmission rate was highest in the first week after discharge and declined thereafter. Overall, only 47.1% of readmissions were assigned respiratory diagnoses (asthma, COPD, pneumonia, and respiratory failure). Older adults were more likely to present with non-respiratory diagnoses (41.7% vs 53.8%; $P < .001$).

CONCLUSIONS: After asthma-related admission, 14.5% of patients had 30-day readmission with wide range of principal diagnoses. Compared with younger adults, older adults had higher 30-day readmission rates and proportions of nonrespiratory diagnoses.

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KEY WORDS: adults; asthma exacerbation; COPD; readmission

ABBREVIATIONS: HCUP = Healthcare Cost and Utilization Project; ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification; SID = State Inpatient Databases

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Asthma remains an important public health problem in the United States, affecting 26 million Americans.¹ Asthma exacerbation accounts for a substantial portion of this burden (eg, 347,000 hospital admissions in 2013), with a direct cost of \$2.2 billion annually.² Despite the public health importance, post-hospitalization outcomes, such as 30-day readmission, have attracted surprisingly little attention in adults with asthma. By contrast, 30-day readmissions have been the focus of national improvement efforts for several other diseases, such as heart failure and COPD.³⁻⁵ To the best of our knowledge, no studies have examined this issue after asthma-related hospital admissions in adults.

Although asthma affects individuals across the entire age spectrum, older adults with asthma represent a distinct phenotype.⁶ The limited literature has reported a higher in-hospital morbidity and mortality in older adults hospitalized for asthma exacerbation.⁷ However, it is

unknown whether, compared with younger adults, older adults hospitalized for asthma exacerbation are at higher risk of readmission within 30 days after hospital discharge. Additionally, it is also unknown whether, in the post-hospital period, older adults are vulnerable to a wide range of acute events requiring readmission, which is called post-hospital syndrome.^{3,8} Determining age-related differences in the incidence and characteristics of readmission would inform targeted management strategies to improve outcomes and curb health-care utilization in adults with asthma.

In this context, we used large, population-based, multipayer databases from three US states to investigate the rate, timing, and principal diagnosis of 30-day readmissions in hospitalized adults with asthma exacerbation. We hypothesized that older adults have a higher rate of readmission than younger adults, different timing of readmission, and a broad range of readmission diagnoses besides asthma.

Methods

Study Design and Setting

We conducted a retrospective cohort study using the data from the Healthcare Cost and Utilization Project (HCUP) State Inpatient Databases (SIDs). The data from California, Florida, and Nebraska SIDs from 2005 through 2011 were used. The HCUP is a family of health-care databases developed through a federal-state-industry partnership and sponsored by the Agency for Healthcare Research and Quality. HCUP includes the largest collection of longitudinal hospital care data in the United States, with all-payer, encounter-level information. The SID includes all inpatient discharges from short-term, acute care, nonfederal, general, and other specialty hospitals. Additional details of the HCUP SID can be found elsewhere.⁹ These three states were selected for their geographic distribution, high data quality, and chiefly because their databases contain unique patient identifiers that enable follow-up of specific patients across years. The study period was chosen based on the availability of databases. The institutional review board of Massachusetts General Hospital approved this study (2013P002545).

Study Population

Using the hospital admission data from all three states, we identified all adult patients (aged ≥ 18 years) with a principal discharge diagnosis of asthma exacerbation, as defined by the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis code of 493.xx. We excluded patients who left the hospital against medical advice, those who were transferred to another acute care facility, those who died in-hospital, and out-of-state residents.

Measurements

The databases contain information on patient characteristics, including demographics (age, sex, and race/ethnicity), primary insurance type, estimated household income, urban-rural status, ICD-9-CM diagnoses, hospital length-of-stay, and patient comorbidities. Quartile classifications of estimated median household income of residents in the patient's ZIP code were examined. Urban-rural status of the patient residence was defined according to the National Center for

Health Statistics.¹⁰ To adjust for potential confounding by patient mix, COPD (codes, 492.21, 492.22, 491.8, 491.9, 492.8, 493.20-493.22, and 496)¹¹ and Elixhauser comorbidity measures¹² were derived from the ICD-9-CM diagnosis codes in any previous hospital admissions within 1 year before the index hospital admission or during the index hospital admission.

Primary Exposure

The primary exposure variable was patient age. Because of potential overlap and misclassification with COPD, patients were categorized into three age groups:^{13,14} younger adults (18-39 years), middle-aged adults (40-64 years), and older adults (≥ 65 years).

Outcome Measures

The primary outcome measure was readmission attributable to any cause within 30 days of discharge from the index hospital admission for asthma exacerbation. For the current analysis, we considered only the first readmission within 30 days, similar to the Center for Medicare & Medicaid Services' hospital readmission measures¹¹ and previous research on other diseases.^{3,15,16} Additional readmissions within a 30-day period were not counted as index hospital admission while, whereas subsequent admissions occurring after 30 days of discharge were counted as index hospital admissions if they met the inclusion criteria.

The secondary outcome measures were the timing of readmissions occurring each day over the 30-day period and principal diagnosis of readmissions. To make data presentation and interpretation more meaningful, the principal diagnoses ($> 14,000$ ICD-9-CM diagnosis codes) were further consolidated into 285 mutually exclusive diagnostic categories using the Agency for Healthcare Research and Quality Clinical Classifications Software,¹⁷ as done previously.^{18,19}

Statistical Analysis

Baseline characteristics were compared across the age groups using χ^2 and Fisher exact tests for categorical variables and the Mann-Whitney *U* test for continuous variables. To determine the association of age with the rate of 30-day readmission, we initially fit Cox proportional

hazards models. However, these models did not satisfy the proportionality of hazards assumption by evaluating log cumulative hazards plots and Schoenfeld residual plots. Therefore, in the models, we fit three logistic regression models with sequential adjustment for potential confounders. First, we constructed an unadjusted model that included only age as the independent variable (model 1). Second, we fit a multivariable model adjusting for sex, race/ethnicity, primary insurance, quartiles for household income, residential status, state, hospital length of stay, and calendar year (model 2). Finally, we fit another multivariable model adjusting for the selected variables mentioned previously and 29 comorbidities (COPD and Elixhauser comorbidity measures) (model 3). These variables were chosen based on biological

plausibility and a priori knowledge.²⁰⁻²² Hospital length of stay was modeled as a categorical variable based on the distribution of data and previous literature.²¹ Hospital length of stay was modeled as a categorical variable based on the distribution of data and previous literature.²¹ Discharge dispositions (eg, transfer to chronic care facilities) were not adjusted because these were considered as intermediates in the association of interest. For all models, we used the generalized estimating equations to account for within-subject repeated measurements over time. In the sensitivity analysis, we repeated the models excluding patients with any coexisting diagnosis of COPD. All analyses used R 3.1.3 software and SAS 9.4 (SAS Institute, Cary, NC). All *P* values were two-tailed, with *P* < .05 considered statistically significant.

Results

Among the 47.5 million hospitalizations in California, Florida, and Nebraska between 2005 and 2011, we identified 301,164 hospital admissions at risk for 30-day readmissions (195,104 adult patients). Of the 301,164 index hospital admissions, 46,433 (15.4%) were among younger adults, 141,980 (47.1%) among middle-aged adults, and 112,751 (37.4%) among older adults. Patient characteristics differed across the age groups (Table 1). For example, in comparison with younger adults, older adults were more likely to be non-Hispanic white and from areas with the highest quartile for household income and have a longer hospital length of stay (all *P* < .001). Likewise, older adults were more likely to have comorbidities (eg, COPD, heart failure [both *P* < .001]; e-Table 1).

Rate of 30-Day Readmission

There were a total of 43,583 all-cause 30-day readmissions, which yielded an overall crude rate of 14.5% (95% CI, 14.3%-14.6%). Specifically, the readmission rate was 10.1% (95% CI, 9.8%-10.4%) for younger adults, 14.3% (95% CI, 14.1%-14.4%) for middle-aged adults, and 16.5% (95% CI, 16.3%-16.8%) for older adults. Table 2 summarizes the association of age with the rate of 30-day readmission. In the unadjusted model (model 1), compared with younger adults, the rate of 30-day readmission was higher both in middle-aged adults (OR, 1.61 [95% CI, 1.55-1.67]; *P* < .001) and older adults (OR, 2.15 [95% CI, 2.07-2.23]; *P* < .001).

In multivariable model (model 2), adjustment for demographic factors, socioeconomic status, hospital length of stay, and calendar year attenuated the age-related differences in readmission rate (OR, 1.45 [95% CI, 1.40-1.51] in middle-aged adults; OR, 1.43 [95% CI, 1.36-1.50] in older adults; both *P* < .001; Table 2, e-Table 2). With an additional adjustment for

29 comorbid conditions, the difference further attenuated (OR, 1.22 [95% CI, 1.17-1.27] in middle-aged adults; OR, 1.19 [95% CI, 1.13-1.26] in older adults; both *P* < .001). In the sensitivity analysis excluding patients with coexisting COPD (*n* = 232,391), the results were similar (Table 2, e-Table 3).

Timing and Principal Diagnosis of Readmission

The daily percentages of all readmissions differed significantly across the age groups (*P* < .001; Fig 1). In younger adults, the daily percentages were highest between days 2 and 3 after discharge, with a gradual decline thereafter. In middle-aged and older adults, those were highest in days 6 and 7 after discharge, with a gradual decline thereafter. Across all age groups, the first 2 weeks after discharge accounted for more than one-half of 30-day readmissions.

Overall, the most frequent readmission diagnosis was asthma exacerbation (28.9%), followed by COPD (12.6%), pneumonia (6.5%), and respiratory failure (4.8%); the other nonrespiratory etiologies accounted for 47.1%. The frequent readmission diagnoses differed by age group (Fig 2, e-Table 4). For example, on readmission, younger adults were more likely to present with asthma exacerbation compared to older adults (46.9% vs 19.4%; *P* < .001). By contrast, older adults were more likely to present with nonrespiratory diagnoses (41.7% vs 53.8%; *P* < .001).

Discussion

In this population-based study of more than 300,000 hospital admissions for asthma exacerbation, we found that approximately 15% had readmissions within 30 days after discharge. We also found that, compared with younger adults, older adults had a 60% higher rate of readmission. The higher readmission rate in older adults attenuated with multivariable adjustment, suggesting that the age-related difference was largely

TABLE 1] Characteristics of Index Hospital Admissions for Asthma Exacerbation, According to Age Group

Characteristics ^a	Younger Adults (18-39 y) n = 46,433	Middle-Aged Adults (40-64 y) n = 141,980	Older Adults (≥ 65 y) n = 112,751	P Value
Male sex	14,787 (30.5)	38,714 (26.8)	32,801 (29.0)	< .001
Race/ethnicity				< .001
Non-Hispanic white	19,261 (41.5)	68,318 (48.1)	63,504 (56.3)	
Non-Hispanic black	11,656 (25.1)	35,731 (25.2)	12,021 (10.7)	
Hispanic	9,327 (20.1)	23,996 (16.9)	20,946 (18.6)	
Asian or Pacific Islander	714 (1.5)	3,310 (2.3)	8,772 (7.8)	
Native American	65 (0.1)	167 (0.1)	81 (0.1)	
Others	828 (1.8)	2,497 (1.8)	2,472 (2.2)	
Primary health insurance				< .001
Medicare	3,810 (8.2)	31,574 (22.2)	10,132 (8.9)	
Medicaid	15,341 (33.0)	39,356 (27.7)	5,118 (4.5)	
Private	14,390 (31.0)	45,704 (32.2)	5,338 (4.7)	
No insurance	8,342 (18.0)	13,004 (9.2)	317 (0.3)	
No charge	1,474 (3.2)	3,640 (2.6)	82 (0.1)	
Others	3,070 (6.6)	8,690 (6.1)	568 (0.5)	
Quartiles for median household income				< .001
1 (lowest)	16,580 (35.7)	52,992 (37.3)	33,876 (30.0)	
2	12,339 (26.6)	36,065 (25.4)	28,488 (25.3)	
3	10,131 (21.8)	30,444 (21.4)	27,226 (24.1)	
4 (highest)	6,661 (14.3)	19,639 (13.8)	21,787 (19.3)	
Patient residence				
Metropolitan	44,212 (95.2)	135,058 (95.1)	107,167 (95.0)	.35
Non-metropolitan	2,221 (4.8)	6,922 (4.9)	5,583 (5.0)	
State				< .001
California	22,124 (47.6)	71,212 (50.2)	59,434 (52.7)	
Florida	23,063 (49.7)	67,839 (47.8)	50,998 (45.2)	
Nebraska	1,246 (2.7)	2,929 (2.1)	2,319 (2.1)	
Hospital length of stay				< .001
< 2 d	13,425 (28.9)	24,190 (17.0)	11,191 (9.9)	
2-4 d	25,856 (55.7)	76,997 (54.2)	55,265 (49.0)	
> 4 d	7,152 (15.4)	40,790 (28.7)	46,281 (41.1)	
Any comorbidities ^b	27,994 (60.3)	120,935 (85.2)	106,709 (94.6)	< .001
Selected comorbidities ^c				
COPD	2,672 (5.8)	30,322 (21.4)	35,779 (31.7)	< .001
Congestive heart failure	846 (1.8)	13,311 (9.4)	25,972 (23.0)	< .001
Diabetes without chronic complications	4,570 (9.8)	37,414 (26.4)	32,176 (28.5)	< .001
Diabetes with chronic complications	339 (0.7)	5,252 (3.7)	6,285 (5.6)	< .001
Renal failure	362 (0.8)	4,848 (3.4)	12,971 (11.5)	< .001
Obesity	10,285 (22.2)	38,431 (27.1)	17,219 (15.3)	< .001
Depression	3,556 (7.7)	19,738 (13.9)	12,406 (11.0)	< .001
Drug abuse	3,571 (7.7)	8,942 (6.3)	753 (0.7)	< .001

Data are expressed as No. (%).

^aPercentages do not sum up to 100% because of missing data.^bAny comorbidity was defined as COPD or at least 1 Elixhauser comorbidity measure.^cFull information of comorbidities is presented in [e-Table 1](#).

TABLE 2] Associations of Age With Rate of 30-Day Any-Cause Hospital Admissions

Models ^a	Younger Adults (18-39 y)		Middle-Aged Adults (40-64 y)		Older Adults (≥65 y)	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Primary analysis						
Unadjusted model (model 1)	1 (reference)	...	1.61 (1.55-1.67)	< .001	2.15 (2.07-2.23)	< .001
Multivariable model (model 2) ^b	1 (reference)	...	1.45 (1.40-1.51)	< .001	1.43 (1.36-1.50)	< .001
Multivariable model (model 3) ^c	1 (reference)	...	1.22 (1.17-1.27)	< .001	1.19 (1.13-1.26)	< .001
Sensitivity analysis with excluding patients with coexisting COPD						
Unadjusted model (model 1)	1 (reference)	...	1.41 (1.35-1.47)	< .001	1.98 (1.90-2.07)	< .001
Multivariable model (model 2) ^b	1 (reference)	...	1.31 (1.25-1.36)	< .001	1.34 (1.26-1.42)	< .001
Multivariable model (model 3) ^c	1 (reference)	...	1.19 (1.14-1.25)	< .001	1.21 (1.14-1.28)	< .001

Full multivariable models for primary and sensitivity analyses included in e-Tables 2 and 3.

^aAll models adjusted for within-subject correlations by using the generalized estimating equation.

^bAdjusted for sex, race/ethnicity, primary insurance, quartiles for household income, residential status, state, hospital length of stay, and calendar year.

^cAdjusted for comorbidities (COPD and Elixhauser comorbidity measures) in addition to the selected variables in the model 2.

explained by sociodemographics and comorbidities. Additionally, across the age groups, readmission rate was highest in the first week after discharge with most readmissions occurring in the first 2 weeks. We also found that approximately half of readmissions (47%) were due to diagnoses unrelated to the index admissions for asthma exacerbation, with older adults having a higher proportion of nonrespiratory diagnoses (eg, heart failure).

This study is, to the best of our knowledge, the first investigation of 30-day readmissions after asthma exacerbation in US adults. Previous studies examining post-hospital outcomes following asthma exacerbation have focused solely on children.²³⁻²⁶ Few studies have examined adults hospitalized with asthma exacerbation; however, these studies looked only at longer time intervals after discharge (≥1-year intervals).^{21,27,28} For example, Delmas et al²⁹ examined readmissions for asthma in French patients (aged 2-44 years), and demonstrated that the 1-year readmission was higher in patients aged 35 to 44 years. However, readmissions during a longer time intervals might be unrelated to the index hospital admission. By contrast, the 30-day period after hospital admission is a critical period because 30-day readmissions account, in general, for more than one-third of the annual admissions for medical conditions in the United States and impose

significant physical and psychosocial burden on patients.³⁰ Within the limited literature, McCaul et al⁸ examined the South Australia administrative data of hospitalized patients (aged 1-49 years), and reported that the 28-day readmission rate for asthma was 9% in 1996. Our study of US adult population demonstrated a higher rate of 30-day readmission (10% in younger adults, 14% in middle-aged adults). The reasons for the difference are likely multifactorial, such as differences in study population, setting, study period, health-care system (eg, access to the ambulatory care), or any combination of these factors.

In this study, we found that, in comparison with younger adults, older adults had a 60% higher rate of 30-day readmission. With the sequential adjustment, a large part of the association of age with readmission rate was explained by the differences in demographics, socioeconomic status, and hospital length of stay (model 2). Furthermore, we also found that older adults had a higher comorbidity burden, which further explained the age-related differences in 30-day readmission rates (model 3). Nevertheless, advanced age remained an independent predictor of readmission. The latter finding suggests that there are other factors predisposing older adults to readmission following asthma exacerbation. The underlying mechanism linking advanced age to readmissions is complex, such as higher morbidity

Figure 1 – Timing of all-cause readmissions per day (0-30) after an asthma-related hospitalization, according to age group. The percentage of readmissions occurring on each day, over the 30 days following discharge among all readmissions, is depicted by age group. In younger adults, the daily percentages were highest between days 2 and 3 after discharge, with a gradual decline thereafter. In middle-aged and older adults, those were highest in days 6 and 7 after discharge, with a gradual decline thereafter. The fitting lines represent the smoothing spline curve in each age group.

during the hospital admission for asthma exacerbation (eg, a longer hospital length-of-stay, higher use of mechanical ventilation),^{6,7} reduced lung elastic recoil leading to higher propensity of airway collapse,³¹ poorer

response to bronchodilators,³² and suboptimal longitudinal asthma management³³ in older adults. All of these factors may contribute to a greater vulnerability after hospital discharge in older adult population and merit further study.

Hospital readmission is a very complex construct involving emergency care, inpatient care, transitions of care, outpatient management by the patient and healthcare providers, and the post-discharge environment (eg, social and community factors).³⁴ We found that, across the age groups, readmission rate was highest in the first week after discharge with most readmissions occurring in the first 2 weeks, which is an intense period of recovery and transition for the patient. Reduction of readmission in this early period likely requires optimal inpatient interventions, such as smoking cessation assistance, initiation or modification of asthma controllers (eg, inhaled corticosteroids³⁵), and discharge planning (eg, provision of action plan,^{36,37} early outpatient follow-up³⁸).

We also uncovered a wide variety of diagnoses for readmission within 30-days after hospital discharge from an asthma-related hospitalization. Indeed, approximately one-half of readmission diagnoses were due to the diagnoses unrelated to the primary reason for the index admission (ie, asthma exacerbation). This observation is in agreement with the previous

Figure 2 – Most frequent principal diagnoses at 30-day readmission, according to age group. The frequent readmission diagnoses differed by age group. For example, compared with younger adults (aged 18-39 years), the older adults (aged ≥65 years) were less likely to present with asthma (46.9% vs 19.4%; $P < .001$), but more likely to present with COPD (2.4% vs 14.5%; $P < .001$), pneumonia (5.0% vs 7.5%; $P < .001$), respiratory failure (3.9% vs 4.7%; $P < .001$), and the other nonrespiratory diagnoses (41.7% vs 53.8%; $P < .001$).

studies that reported acquired vulnerability to myriad conditions after hospital admission, post-hospital syndrome,^{3,8} in a variety of disease conditions (eg, COPD, pneumonia, heart failure).³⁰ Additionally, we found that, compared with younger adults, older adults had a higher proportion of nonrespiratory admissions. The underlying mechanisms of higher vulnerability in older population are currently unclear. Potential explanations include nutritional deprivation,³⁹ loss of physical functioning,⁴⁰ delirium,⁴¹ and an interplay between patient- and community-level factors⁸ in the older adult population. Although further research is needed, preventive strategies to address these overlapping explanations will need to be multifaceted and target many aspects of inpatient and post-hospital asthma care (eg, the use of asthma nurse-initiated multifaceted interventions including provision of asthma education, psychosocial support, an individualized self-management plan, social services to facilitate discharge planning, home visits⁴²).

Potential Limitations

Our study has several potential limitations. First, we used administrative claims rather than clinical data; therefore, there might be a potential misclassification of encounters (eg, misdiagnosis of asthma and COPD in the older adults). However, the HCUP data are thought to be accurate and are widely used to estimate diagnoses and admission frequency.^{7,16,18,20} Furthermore, we conducted the sensitivity analysis that excluded all patients with coexistent COPD, and the results did not materially change. Second, the 30-day interval is somewhat arbitrary, especially with a lack of biologic evidence. However, such evidence (to indicate a definitive time window for readmission analyses) is currently lacking in adults with asthma; therefore, we used the 30-day interval set by the Center for Medicare & Medicaid Services for other diseases (eg, COPD, heart failure). Third, because of the unavailability of mortality data, we were unable to account for the competing risk of mortality on readmissions. However, because older adults with

asthma have higher mortality,^{7,43} accounting for the competing risk would have, if anything, made the differences in readmission rate more pronounced. Fourth, as with any observational study, the association of advanced age with higher rate of 30-day readmission does not necessarily prove causality and might be confounded by unmeasured factors (eg, the severity of asthma exacerbation at the index hospital admission, inpatient acute management, outpatient chronic management, access to ambulatory care after hospital discharge). Finally, our data are not a random sample of all US patients with asthma. Although some might question the broader applicability of these findings, the three analyzed states are geographically dispersed and represent approximately 20% of the US population, thereby supporting the generalizability of our inferences.

Conclusions

By using large, population-based data of more than 300,000 hospital admissions for asthma exacerbation, we found that approximately 15% of patients had readmissions within 30 days after hospital discharge. We also found that, compared with younger adults, older adults had a 60% higher rate of readmission. Additionally, we found that the readmission rate was highest in the first week after discharge and that approximately one-half of readmissions were due to diagnoses unrelated to the index admissions, with older adults having a higher proportion of nonrespiratory diagnoses. For clinicians, our data underscore the importance of continued efforts to improve inpatient and post-hospital care in patients with asthma. Furthermore, for researchers, these observations should facilitate further investigations to identify underlying mechanisms of age-relegated differences in readmission outcomes. Finally, the observed large burden of readmission should encourage policymakers to develop integrated and multifaceted strategies aimed at reducing readmissions in already stressed health-care system.

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Additional information: The e-Tables can be found in the Supplemental Materials of the online article.

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