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## Pre- and post-discharge risk factors for hospital readmission among patients with diabetes

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### Abstract

**Background**—Hospital readmission within 30 days of discharge (30-d readmission) is an undesirable outcome. Readmission of patients with diabetes is common and costly. Most of the studies that have examined readmission risk factors among diabetes patients did not include potentially important clinical data.

**Objectives**—To provide a more comprehensive understanding of 30-d readmission risk factors among patients with diabetes based on pre-discharge and post-discharge data.

**Research Design**—In this retrospective cohort study, **48** variables were evaluated for association with readmission by multivariable logistic regression.

**Subjects**—17,284 adult diabetes patients with 44,203 hospital discharges from an urban academic medical center between January 1, 2004 and December 1, 2012

**Measures**—The outcome was all-cause 30-d readmission. Model performance was assessed by C statistic.

**Results**—The 30-d readmission rate was 20.4%, and the median time to readmission was 11 days. A total of **27** factors were statistically significantly **and independently** associated with 30-d readmission ( $p < 0.05$ ). The C statistic was 0.82. The strongest risk factors were lack of a post-discharge outpatient visit within 30 days, hospital length-of-stay, prior discharge within 90 days,

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discharge against medical advice, sociodemographics, comorbidities, and admission laboratory values. A diagnosis of hypertension, pre-admission sulfonylurea use, admission to an intensive care unit, gender and age were not associated with readmission **in univariate analysis**.

**Conclusions**—There are numerous risk factors for 30-d readmission among patients with diabetes. Post-discharge factors add to the predictive accuracy achieved by pre-discharge factors. A better understanding of readmission risk may ultimately lead to lowering that risk.

### Keywords

readmissions; diabetes; epidemiology

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## INTRODUCTION

Hospital readmission is an undesirable outcome that may be preventable. Recently, increasing attention is being focused on readmission of patients with diabetes. Diabetes affects a substantial proportion of hospitalized patients and is associated with considerable costs. Patients with diagnosed diabetes account for more than 8 million discharges/year in the US, approximately 25% of all discharges.<sup>1</sup> In 2012, total US hospital cost attributable to diabetes patients was \$124 billion, with 30-day (30-d) readmissions contributing at least \$20 billion.<sup>2,3</sup> The best estimates of 30-d readmission rates among those with diabetes are 16.0 to 20.4%,<sup>4–8</sup> and readmission is 17% more likely among patients with diabetes compared to those without.<sup>5</sup>

A thorough understanding of readmission risk factors is needed to identify high risk individuals and reduce readmission rates. Most of the studies that have examined readmission risk factors among diabetes patients did not include potentially important clinical data such as laboratory values and medication use history.<sup>3–7,9,10</sup> In a prior study that did examine such factors, the development and validation of the Diabetes Early Readmission Risk Indicator (DERRI) was presented.<sup>8</sup> Because the DERRI was designed as a predictive tool for use at the point-of-care in hospitalized patients before discharge, neither post-discharge information nor a comorbidity index were included. Furthermore, the number of predictors retained in the model was limited to maximize ease-of-use. Lastly, the study sample was split into development and validation datasets. To provide a more comprehensive understanding of 30-d readmission risk factors based on pre-discharge and post-discharge data, the entire DERRI sample of hospitalized patients with diabetes was analyzed for associations of sociodemographic, clinical and administrative variables with readmission.

In addition to the variables previously evaluated in the DERRI development study, the following 4 variables were examined based on published data suggesting association with readmission among diabetes patients: having a follow up appointment within 30 days of discharge, hospital length of stay (LOS), Charlson comorbidity index,<sup>11</sup> and discharge status from the index hospitalization.<sup>3</sup> Lastly, year of index discharge was included in the model to adjust for potential changes in readmission rates during the study period.

## METHODS

### Study Sample

In this retrospective cohort study, electronic medical records of 17,284 patients with 44,203 hospital discharges between January 1, 2004 and December 1, 2012 from an urban academic medical center (Boston Medical Center, Boston, MA) were analyzed. Boston Medical Center is the largest safety net hospital and busiest emergency services center in New England, with approximately 500 beds. Inclusion criteria were a diagnosis of diabetes defined by an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code of 250.xx associated with hospital discharge or the presence of a diabetes-specific medication on the preadmission medication list. Exclusion criteria were patients younger than 18 years on the day of an index admission, discharge by transfer to another hospital, discharge from an obstetric service, inpatient death, outpatient death within 30 days of discharge, missing data or lacking 30 days of follow up after discharge. Readmission that occurred within 8 hours after an index discharge was considered false positive and merged with the discharge to avoid counting in-hospital transfer as a readmission. During the study period, patients received usual care. There was no systematic diabetes-focused intervention for discharge procedures other than inpatient consultation of the diabetes management team as requested by the primary hospital providers. The Boston Medical Center and Temple University Institutional Review Boards approved the protocol.

### Definition of Variables

A total of **48** variables were evaluated for association with all-cause hospital readmission within 30 days of index discharge (Supplemental Table). This included variables previously evaluated to develop a predictive model of readmission.<sup>8</sup> Additionally, the following 4 variables were examined based on literature review: having a follow up appointment within 30 days of discharge, hospital length of stay (LOS), Charlson comorbidity index,<sup>11</sup> and discharge status from the index hospitalization.<sup>3</sup> This version of the Charlson index is a measure of comorbidity burden associated with inpatient death based on a set of 17 specific conditions that does not include any of the conditions used as covariates in the present study. **Because the Charlson index includes chronic lung disease, malignant neoplasm, and the macrovascular complications of diabetes, these 3 factors were not included in the multivariable analysis.** Lastly, year of index discharge was included in the model to adjust for potential changes in readmission rates during the study period. Variables based on ICD-9-CM codes were defined as previously reported.<sup>8</sup> Data were collected during the course of routine clinical care in the electronic medical record.

Variables were based on information at the time of the index admission. In general, the first laboratory values available during the 24 hours before the time of admission were used. The serum albumin level closest to the time of admission was used, up to 30 days before or during the admission. Most extreme blood glucose level was based on capillary point-of-care or venous values during the entire hospitalization.

## Statistical Analysis

Summaries of categorical variables included counts and percentages, while means and standard deviations (SD) or medians and interquartile ranges (IQR) were used for continuous variables. Readmitted patients were compared to non-readmitted patients by chi-square tests for categorical variables and 2-sample *t*-tests or Wilcoxon rank sum tests for continuous variables. Non-normally distributed continuous variables, i.e., admission serum creatinine and LOS, were log transformed for modeling procedures.

Univariate analyses were performed for all variables to determine those associated with 30-d readmission. Variables associated with readmission at the  $P < 0.1$  level in univariate analyses were selected for multivariable modelling. Multivariable logistic regression with generalized estimating equations (GEE) and best subset selection was performed to determine the adjusted associations of the variables with all-cause 30-d readmission.<sup>12,13</sup> The GEE method accounts for clustering of repeated observations, in this case, multiple discharges per patient. Variables **independently** associated with 30-d readmission at the  $P < 0.05$  level were retained in the **multivariable** model. Model performance was evaluated by the C statistic to represent the area under the receiver operating characteristic curve, for which higher values represent better discrimination.<sup>14</sup> All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC). A *P* value less than 0.05 was considered statistically significant.

## RESULTS

A total of 9034 (20.4%) discharges out of the 44203 index discharges in the study were associated with 30-d readmission for any cause. The study cohort is well-distributed across age and sex (Table 1). A majority of the discharges were among patients who were unmarried, educated at a high-school level or less, disabled, retired, or unemployed, insured by Medicare or Medicaid, overweight or obese, and lived within 5 miles of the hospital. This is an ethnically diverse sample, with 45.5% of discharges identified as black, 15.5% as Hispanic, and 32.8% as white. Pre-admission diabetes therapy included sulfonylureas for 15.2%, metformin for 28.1%, insulin therapy for 37.5% of all discharges. No microvascular complications were present in nearly 70% of discharges. In contrast, a majority discharges were of patients with at least 1 macrovascular complication. Other common comorbidities were depression, hypertension, chronic obstructive pulmonary disease (COPD) or asthma, cardiac dysrhythmias, and anemia. The median LOS was 3.6 days.

Univariate analysis identified numerous factors associated with the risk of 30-d readmission (Table 1). Those not associated with 30-d readmission were a diagnosis of hypertension, pre-admission sulfonylurea use, admission to an intensive care unit, gender and age.

A total of **27** factors were found to be statistically significantly associated with 30-d readmission in multivariable analysis (Table 2). The most striking predictor was not having a follow up visit within 30 days after the index discharge, which was associated with a 5.74-fold increased odds of readmission [OR 5.74 (5.35-6.15) 95% CI]. The next strongest predictor was having a discharge within 90 days before the index admission, which was associated with 76% increased odds of readmission [OR 1.76 (1.64-1.89) 95% CI]. Females had 10% lower odds of readmission than males [OR 0.90 (0.84-0.96) 95% CI]. Blacks,

Hispanics, and patients of other races/ethnicities were **10%** [OR 0.90 (0.83-0.98) 95% CI], 14% [OR 0.86 (0.77-0.95) 95% CI] and **28%** [OR 0.72 (0.62-0.83) 95% CI] less likely to be readmitted than whites. Disabled [OR 1.55 (1.35-1.78) 95% CI], retired [OR 1.46 (1.28-1.67) 95% CI], or unemployed [OR 1.26 (1.10-1.44) 95% CI] patients were at **26%** to **55%** greater odds of readmission than employed individuals. With respect to pre-admission diabetes therapy, insulin use was associated with 14% greater odds of readmission [OR 1.14 (1.06-1.22) 95% CI], while thiazolidinedione use was associated with 16% lower odds [OR 0.84 (0.75-0.95) 95% CI]. An extreme blood glucose value <40 or >300 mg/dL (<2.2 or >16.6 mmol/L) during hospitalization was associated with **20%** greater odds of readmission [OR 1.20 (1.10-1.31) 95% CI]. Several admission laboratory values were associated with 30-d readmission: low or high white blood cell count (27% [OR 1.27 (1.12-1.45) 95% CI] or 19% increased odds [OR 1.19 (1.11-1.28) 95% CI]), low serum albumin (14% increased odds [OR 1.14 (1.07-1.22)]), low serum sodium (19% increased odds [OR 1.19 (1.10-1.30) 95% CI]), higher serum creatinine (8% increased odds per **the log of a 1 unit** increase [OR 1.08 (1.03-1.14) 95% CI]) and higher hematocrit (11% lower odds per 5% increase [OR 0.89 (0.86-0.92) 95% CI]). In addition to a high comorbidity burden according to the Charlson comorbidity index, several comorbidities were independently associated with a significantly increased risk of readmission, specifically, schizophrenia or a mood disorder, gastroparesis, cardiac dysrhythmias, anemia, and fluid or electrolyte disorders. Compared to those discharged home, patients discharged against medical advice (AMA) had **60%** greater odds of being readmitted [OR 1.60 (1.32-1.94) 95% CI]. Similarly, being discharged AMA in the year prior to the index admission was associated with a 27% increased odds of being readmitted [OR 1.27 (1.03-1.58) 95% CI]. Discharges with longer LOS were more likely to be followed by a readmission than discharges with shorter LOS [OR 1.14 (1.09-1.19) 95% CI]. The C statistic was 0.82. Among the 30-d readmissions, the median time to readmission was 11 days (Figure 1).

## DISCUSSION

In this retrospective cohort study of 44,203 discharges of patients with diabetes, **48** sociodemographic, clinical and administrative variables were evaluated for associations with all-cause 30-d readmission. In multivariable analysis, numerous risk factors for 30-d readmission were identified. The strongest risk factors were as follows: lacking an outpatient visit after discharge, duration of hospital LOS, prior discharge within 90 days before the index admission, current or prior discharge AMA, employment status of disabled, retired, or unemployed, race/ethnicity, health insurance coverage, **comorbidity burden**, and **abnormal** admission laboratory values.

Model performance was very good based on a C statistic of 0.82.<sup>15</sup> This is a considerable improvement over the C statistic of the DERRI, which was 0.70 in the training sample and 0.69 in the internal validation sample.<sup>8</sup> The DERRI is a prediction tool designed for use in hospitalized patients prior to discharge. Therefore, it was based on information obtainable on the day of admission, was limited to as few predictors as possible, and did not include a comorbidity index. In contrast, the current study provides a more comprehensive analysis that describes both pre-discharge and post-discharge risk factors for 30-d readmission, as

well as a comorbidity index to adjust for the burden of comorbid conditions. All the predictors contained in the DERRI were confirmed to be associated with readmission, independent of the numerous additional risk factors included in the model. Notably, variables based on post-discharge information, i.e., outpatient follow up, LOS, and discharge status, were highly associated with readmission risk.

Our model compares favorably to the performance of other models of readmission risk. The range of C statistic among models specifically developed in patients with diabetes is 0.64 to 0.82.<sup>9,10,16–18</sup> A recent systematic review of models that predict 28-d or 30-d readmission of any patients reported a C statistic range of 0.21 to 0.88, with only 5 studies reporting a C statistic greater than 0.8.<sup>19</sup>

Of particular interest is the finding that an extreme high or low blood glucose level is associated with 30-d readmission. This confirms and extends previous work that showed a secondary hospital diagnosis of hypoglycemia was associated with 30-d readmission.<sup>20</sup> To our knowledge, the only other study to examine inpatient glycemic control and readmission was in patients with diabetes hospitalized for heart failure.<sup>21</sup> Increasing mean blood glucose and increasing A1c was associated with readmission for heart failure 30 to 90 days after hospital discharge.

Previous evidence on an association of race/ethnicity with readmission risk among patients with diabetes is conflicting, with some studies showing that blacks and Hispanics are at increased risk compared to whites and others reporting no difference in risk.<sup>5,7,9,16,17,22–24</sup> Our finding that blacks and Hispanics had lower odds of readmission compared to whites adds to the conflicting evidence base. Differences in study populations and the specific sets of covariates analyzed may account for the different findings across studies.

Admission serum sodium, creatinine, albumin, white blood cell count and hematocrit were each independently associated with 30-d readmission, suggesting that admission laboratory values can provide important readmission risk information. Whether these tests function as markers of illness or are causally related to readmission remains unknown. Higher creatinine levels have been associated with readmission risk among patients hospitalized with heart failure.<sup>25</sup> Inpatient laboratory tests have also been included in a readmission risk prediction model developed in unselected hospitalized patients in Maine, but the specific tests were not reported.<sup>26</sup> We are unaware of other studies, most of which are based on administrative data, providing as extensive an evaluation of the relationship of inpatient laboratory values with 30-d readmission among patients with diabetes. **Another** risk factor that **has** not been reported among diabetes patients **is** receiving a blood transfusion, which was associated with lower odds of readmission. As with the laboratory tests, it is uncertain whether **this factor** causes readmissions.

The relationship between post-discharge outpatient follow-up and readmission among patients with diabetes has been uncertain, with prior studies reporting increased, decreased or U-shaped risk.<sup>10,16,24</sup> We found that lack of an outpatient visit within 30 days was associated with a nearly 6-fold increased odds of readmission. This is consistent with a large study that reported more than half of Medicare patients who were initially hospitalized for a



medical condition then readmitted within 30 days did not have outpatient follow up before the readmission.<sup>27</sup> Absence of outpatient follow-up may reflect poor health literacy, socioeconomic barriers, and/or a poor state of health, all of which could contribute to readmission risk.<sup>28</sup> Investigating reasons why patients fail to have outpatient follow-up may identify potential leverage points for intervention. It is worth noting that poor health literacy and social determinants of health are relatively unmodifiable, which raises questions about the extent to which hospitals should be penalized for excess 30-d readmission rates.

We found that 50% of 30-d readmissions occurred within 11 days after discharge. To our knowledge, time to readmission among patients with diabetes has not been previously reported. A study of unselected hospitalized patients in Maine found that more than 50% of patients readmitted within 30 days experienced readmission by 15 days post-discharge.<sup>26</sup> Whether or not there is a difference in the timing of readmission between patients with and without diabetes remains unknown. Interventions to reduce readmission risk should take this timing into account.

There are a few limitations of this study of patients at a single urban academic medical center. Results may not be generalizable to other populations. Data on potential readmission risk factors such as hemoglobin A1c, diabetes type or duration, admitting service, and medications recommended upon discharge were not available. Furthermore, inferences about causality based on these retrospective, observational data are limited. Lastly, readmissions at other hospitals were not captured. However, it is unlikely that a substantial proportion of patients were readmitted elsewhere given that the readmission rate in the study sample is on the higher end of the range for reported readmission rates of patients with diabetes. These limitations are balanced by a relatively large sample size and a well-characterized population that allowed for the evaluation of **numerous** sociodemographic, administrative and clinical factors.

Whether identification of these risk factors can be translated into lower readmission risk for diabetes patients remains a key unanswered question. These findings may lead to 2 strategies for reducing readmission risk that hospitals could consider to reduce their exposure to financial penalties. One is improving currently available readmission risk prediction tools to identify higher risk patients for intervention. It is clear that adding risk factors to the DERRI would improve its predictive accuracy. Increasing the number of factors, however, would increase the burden on users to collect and enter the additional data. Tools based on more comprehensive models than the DERRI may require integration in electronic health record systems to be useable and practical at the point-of-care for individual patients. A potentially automatable claims-based algorithm to predict all-cause 30-day readmission among patients with type 2 diabetes has been reported,<sup>9</sup> however, based on our findings, it is likely that adding clinical data would improve predictive accuracy.

The second way our findings may be translated into reducing readmission risk is by considering the risk factors that are both modifiable and plausible as causal agents. For example, statin therapy was associated with lower readmission risk, and perhaps this could be a consideration in favor of initiating a statin upon discharge. There is substantial opportunity for improving adherence to guidelines regarding statin therapy, as one study

found that nearly half of patients with diabetes and 35% of patients with diabetes and a history of cardiovascular disease do not take a statin.<sup>29</sup> Higher hematocrit levels and blood transfusion were associated with lower readmission risk, whereas a diagnosis of anemia was associated with higher risk. It is possible that managing anemia may confer protection against readmission, which could become a factor in favor of performing blood transfusion among patients who have borderline indications. Likewise, high or low blood glucose levels were associated with higher risk of readmission, and optimizing glycemic control may protect against readmission risk. Hospital discharge is an often missed opportunity to adjust diabetes therapy, and these data suggest another reason why diabetes therapy should be optimized at discharge.<sup>30</sup> Given that lack of outpatient follow-up within 30 days was a very strong risk factor for readmission, it is plausible that receiving outpatient follow-up may reduce readmission risk. Patients with diabetes could be prioritized to receive outpatient follow-up within 10 days, based on the median time to readmission of 11 days. Improving outpatient follow-up is particularly attractive as an intervention for hospitals because it is more of a systems-based practice issue than the other more individual-level care issues discussed above. One small study of 100 indigent patients with diabetes suggests that post-discharge follow-up within 5 days of discharge may reduce readmission risk.<sup>31</sup> Additional research, ideally adequately-powered randomized controlled trials, would be required to test these hypotheses.

In conclusion, this relatively large retrospective cohort study of patients with diabetes identified numerous risk factors for all-cause 30-d readmission in a model with very good discrimination. A number of previously reported risk factors were confirmed, and several novel risk factors were identified, including inpatient blood transfusion, admission albumin and white blood cell count, and use of statins and glucocorticoids. Post-discharge factors add to the predictive accuracy achieved by pre-discharge factors. Hospital readmission among patients with diabetes poses a large burden on healthcare systems and is associated with great personal and financial costs. A better understanding of readmission risk may ultimately lead to lowering that risk by improving interventions to reduce readmission risk as well as targeting of interventions to high risk patients.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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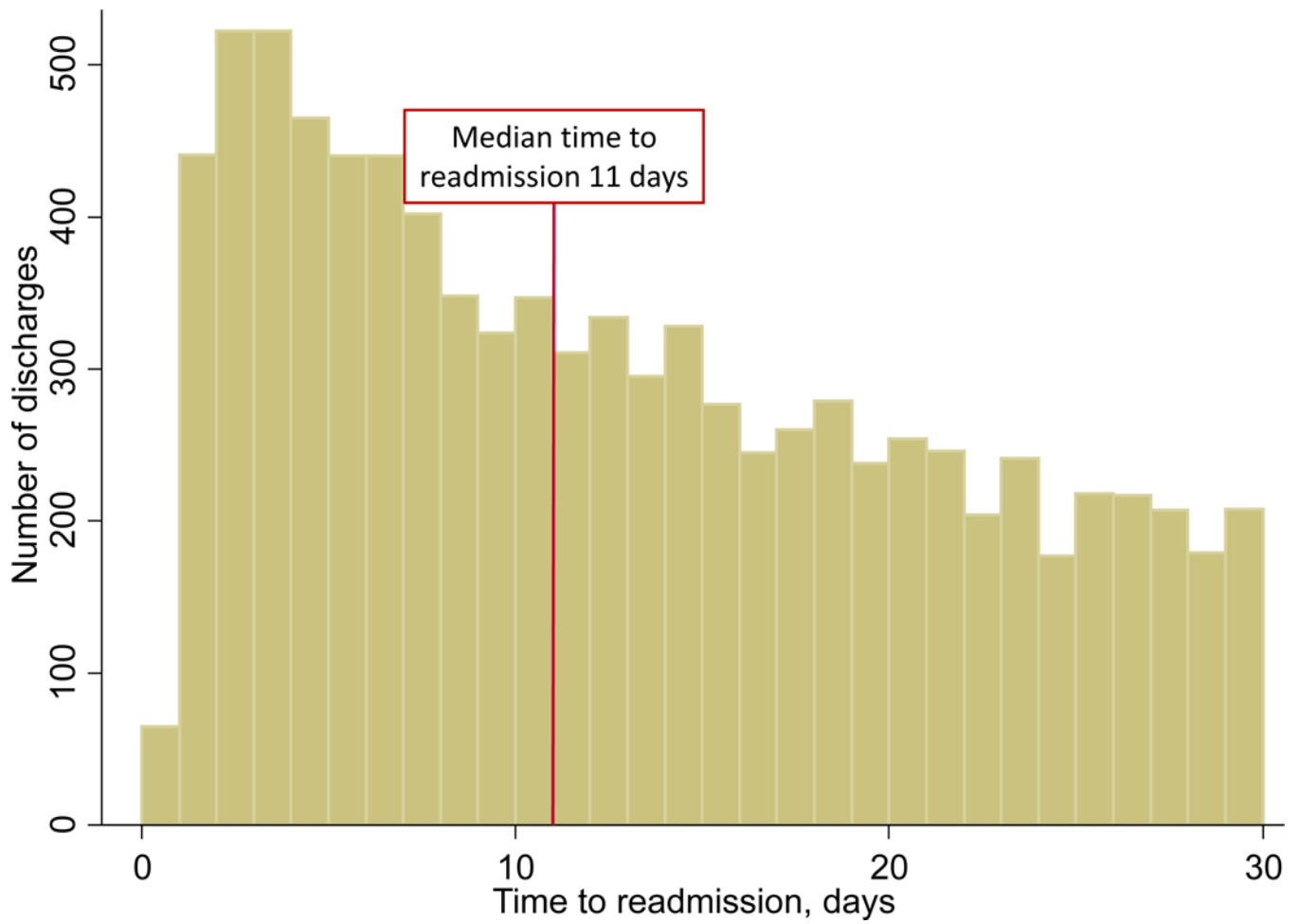
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**Figure 1.** Time to readmission among the 9,034 readmissions within 30 days of discharge (median 11, IQR 5 - 19 days). IQR, interquartile range

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**Table 1**

Characteristics of hospitalized patients with diabetes by 30-d readmission status

Variable	All discharges N=44203	Followed by readmission N=9034	No readmission N=35169	P value
<b>New Variables</b>				
<b>Hospital</b>				
Length-of-stay (days), median (IQR)	3.6 (2.1, 6.3)	3.5 (2.1, 6.1)	4.0 (2.5, 7.1)	<0.001
Charlson comorbidity index				<0.001
0	2054 (4.7)	317 (3.5)	1737 (4.9)	
1-2	12459 (28.2)	1840 (20.4)	10619 (30.2)	
3-4	10177 (23.0)	1876 (20.8)	8301 (23.6)	
5-6	4839 (11.0)	1186 (13.1)	3653 (10.4)	
>6	14674 (33.2)	3815 (42.2)	10859 (30.9)	
<b>Post-discharge</b>				
Outpatient visit				<0.001
Yes	20044 (45.4)	2886 (32.0)	17158 (48.8)	
No	12939 (29.3)	5680 (62.9)	7259 (20.6)	
Not documented	11220 (25.4)	468 (5.2)	10752 (30.6)	
Year of discharge				<0.001
2004	4198 (9.5)	822 (9.1)	3376 (9.6)	
2005	4253 (9.6)	791 (8.8)	3462 (9.8)	
2006	4433 (10.0)	848 (9.4)	3585 (10.2)	
2007	5215 (11.8)	1016 (11.3)	4199 (11.9)	
2008	5461 (12.4)	1076 (11.9)	4385 (12.5)	
2009	5851 (13.2)	1161 (12.9)	4690 (13.3)	
2010	5774 (13.1)	1167 (12.9)	4607 (13.1)	
2011	5057 (11.4)	1241 (13.7)	3816 (10.9)	
2012	3961 (9.0)	912 (10.1)	3049 (8.7)	
Discharge status of index admission				<0.001
Home	25740 (58.2)	4719 (52.2)	21021 (59.8)	
Home with nursing care	8456 (19.1)	1939 (21.5)	6517 (18.5)	
Sub-acute facility	8790 (19.9)	2023 (22.4)	6767 (19.2)	
Against medical advice	924 (2.1)	302 (3.3)	622 (1.8)	
Other	293 (0.7)	51 (0.6)	242 (0.7)	
<b>Previously studied variables</b>				
<b>Sociodemographic/Administrative</b>				
Age				0.12
<50 years	8455 (19.1)	1826 (20.2)	6629 (18.9)	
50 – 59 years	10216 (23.1)	2129 (23.6)	8087 (23.0)	
60 – 69 years	11466 (25.9)	2352 (26.0)	9114 (25.9)	

Variable	All discharges N=44203	Followed by readmission N=9034	No readmission N=35169	P value
70+ years	14066 (31.8)	2727 (30.2)	11339 (32.2)	
Gender				0.083
Female	22286 (50.4)	4421 (48.9)	17865 (50.8)	
Male	21917 (49.6)	4613 (51.1)	17304 (49.2)	
Race/ethnicity				<0.001
Black	20126 (45.5)	4598 (50.9)	15528 (44.2)	
Hispanic	6856 (15.5)	1403 (15.5)	5453 (15.5)	
White	14504 (32.8)	2638 (29.2)	11866 (33.7)	
Other or not documented	2717 (6.2)	395 (4.4)	2322 (6.6)	
English speaking				<0.001
Yes	35858 (81.1)	7500 (83.0)	28358 (80.6)	
No	8345 (18.9)	1534 (17.0)	6811 (19.4)	
Education level				<0.001
Less than high school	6058 (13.7)	1311 (14.5)	4747 (13.5)	
Any high school	24243 (54.8)	5499 (60.9)	18744 (53.3)	
Some college	2976 (6.7)	602 (6.7)	2374 (6.8)	
College graduate	6724 (15.2)	1125 (12.5)	5599 (15.9)	
Not documented	4202 (9.5)	497 (5.5)	3705 (10.5)	
Employment				<0.001
Disabled	9505 (21.5)	2709 (30.0)	6796 (19.3)	
Employed	4317 (9.8)	458 (5.1)	3859 (11.0)	
Retired	16985 (38.4)	3496 (38.7)	13489 (38.4)	
Unemployed	12046 (27.3)	2254 (25.0)	9792 (27.8)	
Other or not documented	1350 (3.1)	117 (1.3)	1233 (3.5)	
Insurance status				<0.001
Medicaid	9747 (22.1)	2342 (25.9)	7405 (21.1)	
Medicare	22118 (50.0)	4758 (52.7)	17360 (49.4)	
None	2297 (5.2)	259 (2.9)	2038 (5.8)	
Private	10041 (22.7)	1675 (18.5)	8366 (23.8)	
Home zip code				<0.001
8 km from hospital	13738 (31.1)	2169 (24.0)	11569 (32.9)	
<8 km from hospital	30465 (68.9)	6865 (76.0)	23600 (67.1)	
Marital status				<0.001
Married	13780 (31.2)	2592 (28.7)	11188 (31.8)	
Single	29526 (66.8)	6329 (70.1)	23197 (66)	
Other or not documented	897 (2.0)	113 (1.3)	784 (2.2)	
<b>Pre-admission clinical</b>				
Pre-admission sulfonylurea use				0.44
Yes	6697 (15.2)	1403 (15.5)	5294 (15.1)	

Variable	All discharges N=44203	Followed by readmission N=9034	No readmission N=35169	P value
No	37506 (84.9)	7631 (84.5)	29875 (85.0)	
Pre-admission metformin use				<0.001
Yes	12400 (28.1)	2054 (22.7)	10346 (29.4)	
No	31803 (72.0)	6980 (77.3)	24823 (70.6)	
Pre-admission thiazolidinedione use				<0.001
Yes	3008 (6.8)	466 (5.2)	2542 (7.2)	
No	41195 (93.2)	8568 (94.8)	32627 (92.8)	
Pre-admission insulin use				<0.001
Yes	16555 (37.5)	4388 (48.6)	12167 (34.6)	
No	27648 (62.6)	4646 (51.4)	23002 (65.4)	
Pre-admission glucocorticoid use				<0.001
Yes	4320 (9.8)	1215 (13.5)	3105 (8.8)	
No	39883 (90.2)	7819 (86.5)	32064 (91.2)	
Pre-admission blood pressure meds				<0.001
None	12274 (27.8)	1903 (21.1)	10371 (29.5)	
ACE-i or ARB	21352 (48.3)	4639 (51.4)	16713 (47.5)	
Non-ACE or ARB	10577 (23.9)	2492 (27.6)	8085 (23.0)	
Pre-admission statin use				0.0066
Yes	21153 (47.9)	4507 (49.9)	16646 (47.3)	
No	23050 (52.2)	4527 (50.1)	18523 (52.7)	
Discharged 90 days prior to index admission				<0.001
Yes	14168 (32.1)	4740 (52.5)	9428 (26.8)	
No	30035 (68.0)	4294 (47.5)	25741 (73.2)	
Discharge status 1 year prior to index admission				<0.001
Home	15798 (35.7)	3904 (43.2)	11894 (33.8)	
Home with nursing care	5792 (13.1)	1583 (17.5)	4209 (12.0)	
Sub-acute facility	5320 (12.0)	1448 (16.0)	3872 (11.0)	
Against medical advice	666 (1.5)	238 (2.6)	428 (1.2)	
No discharge recorded	16627 (37.6)	1861 (20.6)	14766 (42.0)	
<b>Hospital</b>				
Body mass index				0.0018
<18.5 kg/m <sup>2</sup>	1038 (2.4)	265 (2.9)	773 (2.2)	
18.5 – 24.9 kg/m <sup>2</sup>	7412 (16.8)	1663 (18.4)	5749 (16.4)	
25.0 – 29.9 kg/m <sup>2</sup>	12377 (28)	2480 (27.5)	9897 (28.1)	
30.0 kg/m <sup>2</sup>	23376 (52.9)	4626 (51.2)	18750 (53.3)	
Blood transfusion given				0.022
Yes	6052 (13.7)	1468 (16.3)	4584 (13.0)	
No	38151 (86.3)	7566 (83.8)	30585 (87.0)	



Variable	All discharges N=44203	Followed by readmission N=9034	No readmission N=35169	P value
Parenteral or enteral nutrition				<0.001
Yes	1592 (3.6)	434 (4.8)	1158 (3.3)	
No	42611 (96.4)	8600 (95.2)	34011 (96.7)	
Diabetes inpatient consultation				0.0055
Yes	5697 (12.9)	1072 (11.9)	4625 (13.2)	
No	38506 (87.1)	7962 (88.1)	30544 (86.9)	
Current infection, <sup>a</sup>				<0.001
Yes	9975 (22.6)	2206 (24.4)	7769 (22.1)	
No	34228 (77.4)	6828 (75.6)	27400 (77.9)	
Current complication of device, graft, or implant				<0.001
Yes	1820 (4.1)	506 (5.6)	1314 (3.7)	
No	42383 (95.9)	8528 (94.4)	33855 (96.3)	
Current fluid or electrolyte disorder				<0.001
Yes	8913 (20.2)	2265 (25.1)	6648 (18.9)	
No	35290 (79.8)	6769 (74.9)	28521 (81.1)	
White blood cell count				<0.001
Low <4.0 × 10 <sup>9</sup> L	2019 (4.6)	594 (6.6)	1425 (4.1)	
Normal 4.0 – 11.0 × 10 <sup>9</sup> L	33932 (76.8)	6694 (74.1)	27238 (77.5)	
High >11.0 × 10 <sup>9</sup> L	8252 (18.7)	1746 (19.3)	6506 (18.5)	
Hematocrit (%), mean (SD)	33.7 (5.29)	34.0 (5.27)	32.4 (5.14)	<0.001
Serum albumin				<0.001
40+ g/L	15049 (34.1)	2627 (29.1)	12422 (35.3)	
<40 g/L	23586 (53.4)	5558 (61.5)	18028 (51.3)	
Not documented	5568 (12.6)	849 (9.4)	4719 (13.4)	
Serum sodium				<0.001
Low <135 mmol/L	4743 (10.7)	1257 (13.9)	3486 (9.9)	
Normal 135 – 145 mmol/L	39026 (88.3)	7680 (85)	31346 (89.1)	
High >145 mmol/L	434 (1)	97 (1.1)	337 (1.1)	
Serum potassium				<0.001
Low <3.1 mmol/L	540 (1.2)	127 (1.4)	413 (1.2)	
Normal 3.1 – 5.3 mmol/L	40345 (91.3)	7980 (88.3)	32365 (92.0)	
High >5.3 mmol/L	3318 (7.5)	927 (10.3)	2391 (6.8)	
Serum creatinine (mg/dL), median (IQR)	1.0 (0.7,1.4)	0.9 (0.7, 1.3)	1.1 (0.8, 2.0)	<0.001
Most extreme blood glucose level				<0.001
2.2 – 3.8 or 10.1 – 16.6 mmol/L	19234 (43.5)	4101 (45.4)	15133 (43.0)	
3.9 – 10.0 mmol/L	16128 (36.5)	2842 (31.5)	13286 (37.8)	
<2.2 or >16.6 mmol/L	8841 (20.0)	2091 (23.2)	6750 (19.2)	
Urgent or emergent admission				<0.001

Variable	All discharges N=44203	Followed by readmission N=9034	No readmission N=35169	P value
Yes	38145 (86.3)	8198 (90.8)	29947 (85.2)	
No	6058 (13.7)	836 (9.3)	5222 (14.9)	
Intensive care admission				0.15
Yes	7078 (16.0)	1498 (16.6)	5580 (15.9)	
No	37125 (84.0)	7536 (83.4)	29589 (84.1)	
DKA or HHS ever				<0.001
Yes	3220 (7.3)	918 (10.2)	2302 (6.6)	
No	40983 (92.7)	8116 (89.8)	32867 (93.5)	
Microvascular complications, <sup>b</sup>				<0.001
0	30854 (69.8)	5247 (58.1)	25607 (72.8)	
1	8227 (18.6)	2095 (23.2)	6132 (17.4)	
2	3294 (7.5)	1017 (11.3)	2277 (6.5)	
3	1828 (4.1)	675 (7.5)	1153 (3.3)	
Macrovascular complications, <sup>c</sup>				<0.001
0	19301 (43.7)	3223 (35.7)	16078 (45.7)	
1	12716 (28.8)	2528 (28.0)	10188 (29.0)	
2	8840 (20.0)	2218 (24.6)	6622 (18.8)	
3	2647 (6.0)	840 (9.3)	1807 (5.1)	
4	699 (1.6)	225 (2.5)	474 (1.4)	
Schizophrenia or mood disorder ever				<0.001
Yes	13112 (29.7)	3436 (38.0)	9676 (27.5)	
No	31091 (70.3)	5598 (62.0)	25493 (72.5)	
Gastroparesis ever				<0.001
Yes	2100 (4.8)	770 (8.5)	1330 (3.8)	
No	42103 (95.3)	8264 (91.5)	33839 (96.2)	
Pancreatitis ever				<0.001
Yes	2387 (5.4)	710 (7.9)	1677 (4.8)	
No	41816 (94.6)	8324 (92.1)	33492 (95.2)	
Hypertension ever				0.6
Yes	32532 (73.6)	6681 (74.0)	25851 (73.5)	
No	11671 (26.4)	2353 (26.1)	9318 (26.5)	
COPD or asthma ever				<0.001
Yes	10433 (23.6)	2614 (28.9)	7819 (22.2)	
No	33770 (76.4)	6420 (71.1)	27350 (77.8)	
Cardiac dysrhythmias ever				<0.001
Yes	10546 (23.9)	2642 (29.3)	7904 (22.5)	
No	33657 (76.1)	6392 (70.8)	27265 (77.5)	
Malignant neoplasm ever				<0.001

Variable	All discharges N=44203	Followed by readmission N=9034	No readmission N=35169	P value
Yes	4406 (10.0)	1166 (12.9)	3240 (9.2)	
No	39797 (90.0)	7868 (87.1)	31929 (90.8)	
Anemia ever				<0.001
Yes	18264 (41.3)	5128 (56.8)	13136 (37.4)	
No	25939 (58.7)	3906 (43.2)	22033 (62.7)	
Drug abuse				0.045
Never	35424 (80.1)	7104 (78.6)	28320 (80.5)	
History	6942 (15.7)	1505 (16.7)	5437 (15.5)	
Current	1837 (4.2)	425 (4.7)	1412 (4.0)	

Data are N (%) unless otherwise specified. COPD, chronic obstructive pulmonary disease; DKA, diabetic ketoacidosis; HHS, hyperglycemic hyperosmolar syndrome;

<sup>a</sup>Pneumonia, urinary tract infection, septicemia, skin or subcutaneous infection;

<sup>b</sup>Retinopathy, neuropathy, nephropathy;

<sup>c</sup>Coronary artery disease, heart failure, stroke, peripheral vascular disease; IQR, interquartile range; SD, standard deviation.

**Table 2**

Risk factors for all-cause 30-d readmission in multivariable model<sup>a</sup>

Predictor	Odds Ratio (95% CI)	P value
<b>New Variables</b>		
Outpatient visit (vs. Yes)		
No		<0.001
Not documented		<0.001
Discharge status of index admission (vs. Home)		
Against medical advice		<0.001
Home with nursing care		
Sub-acute facility		
Other		
Charlson comorbidity index (vs. 0)		
>6		
5 – 6		
3 – 4		
1 – 2		
Length-of-stay (days)(log)		<0.001
<b>Previously studied variables</b>		
<b>Sociodemographic/Administrative</b>		
Employment status (vs. Employed)		
Disabled		<0.001
Retired		<0.001
Unemployed		
Other or unknown		
Insurance status (vs. Private)		
Medicaid		
Medicare	0.95 (0.88-1.0 3)	
None		
Home zip code <8 km from hospital	1.11 (1.0 3-1.20)	
Race/ethnicity (vs. White)		
Black		
Hispanic	0.86 (0.77-0.9 5)	
Other		<0.001
Female (vs. Male)	0.90 (0.84-0.96)	0.002 8
<b>Pre-admission clinical</b>		
Discharged within 90 days before admission		<0.001
Discharge status 1 year prior to index admission		

Predictor	Odds Ratio (95% CI)	P value
Against medical advice	1.27 (1.03-1.58)	
Home with nursing care		
Sub-acute facility		
No discharge recorded		
Pre-admission glucocorticoid use		
Pre-admission insulin use	1.14 (1.06-1.22)	<0.001
Pre-admission thiazolidinedione use		
<b>Hospital</b>		
Gastroparesis ever		<0.001
White blood cell count (vs. Normal)		
Low <4.0 × 10 <sup>9</sup> L		<0.001
High >11.0 × 10 <sup>9</sup> L	1.19 (1.11-1.28)	<0.001
Serum sodium (vs. Normal)		
Low <135 mmol/L	1.19 (1.10-1.30)	<0.001
High >145 mmol/L		
Most extreme blood glucose level (vs. 3.9 – 10.0 mmol/L)		
<2.2 or >16.6 mmol/L		<0.001
2.2 – 3.8 or 10.1 – 16.6 mmol/L	1.07 (1.00-1.15)	
Urgent or emergent admission		
Serum albumin (vs. 40 g/L)		
<40 g/L	1.14 (1.07-1.22)	<0.001
Unknown	0.94 (0.85-1.04)	0.26
Anemia ever		<0.001
Schizophrenia or mood disorder ever	1.12 (1.04-1.21)	
Current fluid or electrolyte disorder		
Cardiac dysrhythmias ever		
Serum creatinine (mg/dL)(log)		
Blood transfusion given	0.90 (0.82-0.97)	
Hematocrit (per 5% increase)		<0.001

<sup>a</sup>Adjusted for year of discharge

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