LACE+ - an extension of a validated index to predict early death or unplanned readmission following hospital discharge using administrative data

Carl van Walraven[1,2]**,** MD, MSc is a senior scientist in Clinical Epidemiology at the Ottawa Hospital Research Institute (OHRI), adjunct scientist at the Institute for Clinical Evaluative Sciences (ICES), and associate professor of Medicine at the University of Ottawa. Email: carlv@ohri.ca

Jenna Wong, MSc is a methodologist in Clinical Epidemiology at OHRI and an analyst at ICES. Email: jewong@ohri.ca

Alan J. Forster[1,2]**,** MD, MSc is a senior scientist in Clinical Epidemiology at OHRI, adjunct scientist at ICES, and associate professor of Medicine at the University of Ottawa. Email: aforster@ohri.ca

1. Ottawa Hospital Research Institute and Institute for Clinical Evaluative Sciences, 1053 Carling Avenue, Ottawa, K1Y 4E9, Canada
2. Department of Medicine, University of Ottawa, 1053 Carling Avenue, Ottawa, K1Y 4E9, Canada

Corresponding author: Carl van Walraven; 1053 Carling Avenue, Administrative Services Building, 1st floor, Room 1003; Ottawa ON; K1Y 4E9; Phone: 613-761-4903; Fax: 613-761-5355; email: carlv@ohri.ca (e-mail address to be published)

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ABSTRACT

Background: Death or urgent readmission following hospital discharge is a common, adverse event that can be used to compare outcomes of care between institutions. To help adjust for such comparisons, we used administrative data to derive and validate an extension of the LACE index, a previously validated index for 30-day death or urgent readmission.

Methods: We randomly selected 500 000 medical and surgical patients discharged to the community from an Ontario hospital between 1 April 2003 and 31 March 2009. We derived a logistic model on a random 250 000 patients and modified the final model into an index scoring system (the LACE^{+} index). We validated the LACE^{+} index on the remaining patients and compared its performance with that of the original LACE index.

Results: Within 30 days of discharge to the community, 33 825 (6.8%) patients died or were urgently readmitted. In addition to the variables included in the LACE index (**L**ength of stay, **A**cuity of admission, **C**omorbidity, and **E**mergency department use in the six months prior to admission), the LACE^{+} index included: patient age and sex; teaching status of discharge hospital; acute diagnoses and procedures performed during the index admission; number of days on alternative level of care during the index admission; and the number of elective and urgent hospitalizations in the year prior to the index admission. The LACE+ index was very discriminative (C-statistic of 0.7708), was well calibrated across most of its range of scores, and had a model performance that exceeded the LACE index.

Interpretation: The LACE+ index can predict the risk of post-discharge urgent readmission or death using administrative data. Its performance exceeds the LACE index and allows analysts to accurately estimate the risk of important post-discharge outcomes.

INTRODUCTION

Death or urgent readmission following hospital discharge is a relatively common event that is costly to the healthcare system and has obvious important effects on patient health. Being able to accurately identify patients at high risk of these adverse post-discharge outcomes could help elucidate the mechanisms involved in early death or readmission. Accurately adjusting for the risk of post-discharge death or urgent readmission will permit valid inter-hospital comparisons based on this outcome.

Several risk prediction models for hospital readmission have been published [1-4]. Three of these models [1-3] are cumbersome because they require community-level or socio-economic information (i.e. community-level admission rates, ethnicity, education, postal code, or marital status) that are difficult or impractical to obtain or apply. One model (the LACE index [4]) included variables whose values could be determined using either primary data or information from administrative databases. The LACE index predicted the risk of death or urgent readmission within 30 days of hospital discharge among medical and surgical patients using four variables: **L**ength of hospital stay, **A**cuity of admission, **C**omorbidity, and **E**mergency department use in the six months prior to admission. The LACE index was externally validated and had good calibration. Its discrimination was only fair (C-statistic of 0.684) though equivalent to that of other previously published, more complicated models [1-3].

The LACE index was derived on a small sample of patients (approximately 2500). This could partly explain the small number of variables in the model as well as the limited amount of information about the index hospitalization. In this study, we determined whether we could use administrative data from a large, population-based sample to extend and improve the LACE index. We wanted to develop an index for researchers and analysts to better predict the risk of post-discharge outcomes using administrative data.

METHODS:

Study design

This was a cohort study of 500 000 randomly selected patients discharged alive to the community from a medical or surgical service at an Ontario hospital. We derived the risk index on a randomly selected 250 000 patients and validated the index on the remaining 250 000 patients. This study was approved by the TOH Research Ethics Board.

Data sources

We used four population-based administrative databases that captured data on all Ontarians. The Discharge Abstract Database (DAD) recorded all non-psychiatric hospitalizations. The Ontario Mental Health Reporting System (OMHRS) captured all inpatient mental health encounters that occurred after 2006 (prior to this, mental hospitalizations were captured in the DAD). The National Ambulatory Care Reporting System (NACRS) recorded all emergency room visits. The Registered Patient Database (RPDB) recorded the death date for all Ontarians.

Study population

We used the DAD to identify all adult discharges to the community from medical and surgical services in acute-care Ontario hospitals between 1 April 2003 and 31 March 2009. We chose this study period to ensure sufficient availability of data in the population-based databases to create the model covariates and determine the study outcome for all patients. We excluded same day surgeries because these are similar to outpatient surgeries and involve patients whose characteristics may differ from inpatients. To identify patients transferred between acute care hospitals, we linked the hospitalizations together and considered them a single admission; approximately 4% of hospitalizations involved a transfer between different acute care hospitals. We excluded psychiatric and obstetrical admissions since they were not included in the original derivation of the LACE index [4]. We also excluded admissions where the patient was

ineligible for health care coverage in Ontario during the follow-up period because post-discharge outcomes would not be captured for these patients.

After identifying all eligible admissions, we randomly selected one admission per patient and then randomly selected 500 000 patients.

Potential predictors of 30-day death or urgent readmission

We first created the four LACE index predictors: **L**ength of the index hospitalization (in days); **A**cuity of the index admission (categorized as urgent or planned); **C**omorbidity of the patient (expressed using the Charlson score); and **E**mergency department utilization (expressed as the number of visits to the emergency department in the six months prior to the index admission). Hospital length of stay and admission urgency was determined using the DAD. The Charlson score was calculated using the International Classification of Disease and Related Health Problems, Tenth Revision, Canada (ICD-10-CA) codes cited by Quan *et. al* [5]. The number of visits to an emergency department in the six months prior to the index admission was determined by linking to NACRS.

We captured important acute diagnoses and procedures performed during the index admission with a validated index that used Case Mix Group (CMG) codes [unpublished van Walraven, Wong, and Forster]. CMGs aggregate acute care inpatients with similar clinical and resource-utilization characteristics and are assigned using an algorithm developed (and revised yearly) by the Canadian Institute for Health Information (CIHI). This CMG index assigned a score that ranged from -6 to 7 to certain CMG codes which were independently associated with 30-day death or urgent readmission independent of the LACE score. We determined the CMG code for all patients using the 2008 CMG algorithm applied to all hospitalizations.

Finally, we also created the following covariates for each hospitalization using the DAD: patient age and sex; number of urgent and elective hospitalizations in the year prior to the index admission (expressed as separate variables); number of days in an intensive care unit (ICU) during the index admission; number of days with alternative level of care (ALC) status during the index admission (a status assigned to patients who remain in hospital but are no longer receiving active medical care); and teaching status of

the hospital from which the patient was discharged. We further divided non-teaching hospitals into "large" (≥100 beds) and "small" (<100 beds) hospitals. We chose a longer look-back period of one year for previous hospitalizations (compared to six months for previous emergency department visits) because hospitalizations are less common than emergency room visits and because we separated previous hospitalizations into urgent and elective. We determined the number of days spent in an ICU using validated special care unit codes for ICU treatment [6].

Outcome

The primary outcome in this study was death or urgent readmission within 30 days of hospital discharge. We determined death status by linking to RPDB. We determined urgent readmission status by linking to DAD and OMHRS. We included readmissions regardless of their diagnosis as long as they were categorized as 'urgent' (i.e. 'unplanned') and were not preceded by an earlier 'non-urgent' (i.e. 'planned') readmission.

Derivation of the LACE$^+$ index

We first derived a logistic regression model for 30-day death or urgent readmission using a randomly selected 250 000 patients. We entered all candidate covariates into an initial multivariable model and then performed variable selection (with a significance level of $\alpha = 0.05$) using methods described by Sauerbrei and Royston [7]. These methods combined backward selection with a systematic process of identifying the optimal first-degree fractional polynomial transformation for continuous covariates. Once we identified all significant covariates, we came up with a list of candidate interaction terms, added them jointly to the model, and used backward selection to remove interactions with a *p*-value greater than or equal to 0.0001.

We then used methods described by Sullivan *et al.* [8] to modify the final logistic model into a risk index (which we refer to as the "LACE+" index). The number of points assigned to each binomial variable equaled the covariate's regression coefficient divided by the constant (the categorical variable in the model with the smallest absolute value) and rounded to the nearest integer. For continuous variables, we first categorized the

variable using decile cut-points. The number of points assigned to each category equaled the difference in regression units between its mid-point and the mid-point of the reference category divided by the constant and rounded to the nearest integer. We combined continuous variable categories that were assigned the same number of points. The reference category for each variable in the model was assigned 0 points.

Assessment and validation of the LACE$^+$ index

Using the remaining 250 000 patients (the validation set), we assessed the ability of the LACE$^+$ index to predict 30-day death or urgent readmission. We first calculated each patient's total LACE$^+$ score. We then fit a logistic regression model with 30-day death or urgent readmission as the outcome and the LACE$^+$ score as the independent predictor. We assessed the model's discrimination using the C-statistic with 95% confidence intervals [9] and assessed overall calibration using the Hosmer-Lemeshow (H-L) goodness-of-fit test [10]. We further assessed calibration by comparing the expected to observed event rate within 10-point strata. The expected risk of death or urgent readmission for each patient was calculated as the inverse of $1 + e^{-(\text{intercept} + \beta * \text{score})}$, where β was the coefficient of the LACE$^+$ index in the regression model. The expected and observed event rates were considered similar if the expected rate was within the exact 95% CI [11] around the observed rate.

In the validation set, we compared the performance of the original LACE index with the LACE$^+$ index using the Integrated Discrimination Improvement (IDI) and the Net Reclassification Improvement (NRI) [12]. The IDI is the discrimination slope (the mean predicted risk in patients with the event minus that of patients without the event) of a model with the LACE$^+$ index as the independent predictor minus the discrimination slope of a model with the LACE index as the independent predictor. An IDI above zero indicates improved discrimination (i.e. a larger separation in mean predicted risk between events and nonevents) with the LACE$^+$ index. The NRI measured the amount of correct reclassification (i.e. predicted risk moving upwards for events and downwards for non-events) when the predicted risk of death or urgent readmission from the LACE$^+$ index was compared to that from the LACE index. The NRI equals the proportion of correct minus incorrect reclassifications among events (i.e. patients who died or were urgently

readmitted) plus the proportion of correct minus incorrect reclassifications among non-events. An NRI above zero indicates improved risk prediction with the new model. Because no established risk categories for early death or urgent readmission exist, we calculated a category-less NRI [13] where "upward" reclassification was defined as a higher event risk predicted by the LACE$^+$ index and "downward" reclassification was defined as a lower event risk predicted by the LACE$^+$ index.

RESULTS:

Of approximately 6.5 million hospitalizations that occurred in Ontario during the study period, nearly 3.3 million were eligible for the study (Figure 1). These hospitalizations involved more than 1.8 million individuals of which 500 000 were randomly selected for the study.

Table 1 describes the study cohort. Patients were middle-aged and had few documented chronic comorbidities. Approximately one-third had visited the emergency department in the last 6 months; fewer had been hospitalized urgently (14%) or electively (6%) in the last year. Approximately half of admissions occurred at a large, non-teaching hospital. In nearly one-third of hospitalizations, the patient had an acute diagnosis or procedure associated with an increased (CMG score >0) or decreased (CMG score <0) risk of 30-day death or urgent readmission. Patients were uncommonly admitted to an ICU (11%) or designated ALC (2%) during their index admission. Following discharge to the community, 6.8% of patients died or were urgently readmitted within 30 days. Only 0.7% of patients died within 30 days without a prior urgent readmission. The derivation and validation sets were virtually identical (Table 1).

With the exception of the number of days in an ICU, all covariates were associated with 30-day death or urgent readmission at the univariate level (Table 2). Of the continuous covariates, all except the number of days on ALC were modeled using either a logarithmic, square root, inverse, or squared transformation (Table 2 and Figure 2). We jointly offered six interaction terms to this model (age and: Charlson score; number of urgent admissions in the previous year; CMG score; length of stay; admission urgency and CMG score; Charlson score and number of urgent admissions in the

previous year), of which three were ultimately retained because they had a *p*-value less than 0.0001.

We then modified the final logistic model into a scoring index for 30-day death or urgent readmission (Table 3). For patient age, the number of points assigned depended on the Charlson score and number of urgent admissions in the previous year. The final LACE$^+$ score had a possible value that ranged from -17 to 114. In the validation set, the LACE$^+$ score distribution was skewed slightly to the right (Figure 3).

The LACE$^+$ index was significantly associated with the risk of 30-day death or urgent readmission; the odds ratio for a 1-point increase in the LACE$^+$ index was 1.045 (95% CI 1.044-1.045). The index was very discriminative, indicated by a C-statistic of 0.7708 (95% CI 0.7671-0.7745), which significantly exceeded that of the LACE index (C-statistic 0.7375, 95% CI 0.7336-0.7414). The H-L statistic for the LACE$^+$ index was 42.18 ($p<.0001$, 8 degrees of freedom), suggesting poor calibration (the H-L statistic for the LACE index was 13.38, $p = 0.099$, suggesting good calibration). However, the calibration graph comparing the observed and expected event rate within risk strata showed very similar observed and expected rates in all but the highest risk strata (Figure 3). These high-risk strata comprised only 1.5% of the validation set (Table 4). Across all risk strata, the overall expected was identical to the observed rate (Table 4).

The LACE$^+$ index was significantly associated with each outcome separately. For 30-day death, the odds ratio for a 1-point increase in the LACE$^+$ index was 1.068 (95% CI 1.066-1.069). The index had excellent discrimination (C-statistic 0.883, 95% CI 0.879-0.888) for 30-day death, but the H-L test suggested it was poorly calibrated (H-L statistic of 113.89, $p<.0001$). For 30-day urgent readmission, the odds ratio for a 1-point increase in the LACE$^+$ index was 1.045 (95% CI 1.044-1.045). The index had good discrimination (C-statistic 0.753, 95% CI 0.749-0.757) for 30-day urgent readmission, but poor calibration (H-L statistic of 62.07, $p<.0001$).

The IDI and NRI both indicated that the LACE$^+$ index was significantly better at predicting 30-day death or urgent readmission compared to the original LACE index. The IDI was 0.020 (95% CI 0.019-0.021) on the absolute scale and 16.7% (15.1%-18.3%) on the relative scale, both suggesting improved overall discrimination with the

LACE$^+$ index. The NRI was 0.329 (95% CI 0.314-0.344), indicating that a significantly higher proportion of patients were correctly reclassified with the LACE$^+$ index.

DISCUSSION

In this study, we derived and internally validated a new index (LACE+) for 30-day death or urgent readmission that can be calculated with administrative data. This index had excellent discrimination and was well calibrated across most of its score range.

Compared to the LACE index, LACE$^+$ captured additional information on acute conditions and procedures performed during the index admission, whether or not the patient changed from active care to an alternative level of care during the admission, the teaching status of the hospital at which the admission took place, and the number of urgent and elective hospitalizations occurring in the year prior to the admission. Although previous hospitalizations were not found to be a significant predictor of 30-day death or urgent readmission in the derivation of the LACE index [4], the fact that previous hospitalizations were a significant independent predictor in this study was likely due to a longer look-back period and a larger sample size. When these new covariates were combined with the predictors from the LACE index, we found that the ability to predict risk of 30-day death or urgent readmission significantly improved.

Due to the large size of the validation set, we were not surprised that the H-L test for the LACE$^+$ index was highly significant. With very large sample sizes, even a slight departure from perfect fit can result in a significant H-L test [14]. Therefore, as suggested by Kramer and Zimmerman [14], we supplemented the results of the H-L test by constructing a calibration graph comparing the observed and predicted event rate within 10-point strata of the LACE$^+$ index. The calibration graph revealed close agreement between the observed and predicted event rate in all but the highest strata, which contained only a very small proportion of patients. Although the 95% CI around the observed event rate excluded the expected rate in six strata (Figure 2), many of these strata contained a large number of patients and thus had an extremely narrow CI around the observed rate (Table 4).

We used several methods to compare the performance of the LACE$^+$ index and the LACE index. The C-statistic, IDI, and NRI indicated that the performance of the LACE$^+$

index was superior. The H-L statistic, however, suggested that the calibration of the LACE index was better, but this was likely because the LACE$^+$ index had better discrimination (and calibration often worsens when discrimination improves). It should be noted that the C-statistic of 0.738 for the LACE index in this study was notably higher than the C-statistic of 0.684 reported from the external validation of the LACE index in the original study [4]. This discrepancy was most likely due to measurement error in the original study since transfer hospitalizations were not linked as a single admission (resulting instead from transfer codes in the DAD); this resulted in a higher urgent readmission rate of 7.3% in the original study (compared to 6.0% in this study).

A major advantage of the LACE$^+$ index is that all of its components can be easily readily determined using data available in Canadian administrative databases. The index therefore has great utility for researchers using such databases because it could risk adjust in analyses involving large patient populations where early death or hospital readmission is an outcome. Furthermore, the LACE+ index does not require the use of community-level or socio-economic information, which is often difficult to obtain and unavailable for certain patients.

There are several considerations to our study findings. First, because the LACE$^+$ index was derived and validated on a large, random, population-based sample from Ontario, we believe that it can be confidently applied to all Ontarian hospitalized medical and surgical patients. However, before LACE$^+$ can be applied elsewhere in Canada, the index should be validated in other provinces. Second, because we had access to population-based datasets that included information on all deaths, hospitalizations, and emergency department visits that occurred in Ontario, we were able to accurately measure death and urgent readmission status, as well as previous health care utilization characteristics. People with access to only information from a single health care institution may not be able to measure the index predictors or post-discharge outcomes as accurately and may consequently find that the LACE$^+$ index does not perform as well. Third, because the CMG code (determined by CIHI) is available for Canadian hospitalizations only, the CMG score cannot be calculated for administrative data outside of Canada. However, researchers from other countries could still apply the LACE$^+$ index by replacing the CMG score with their own similar index for acute diagnoses and

procedures. As well, because CIHI determines the CMG code using retrospectively abstracted hospital data, the inclusion of the CMG score means that the LACE+ index cannot be used using primarily collected data.

In this study, we derived and validated an accurate risk index for 30-day death or urgent readmission that could be easily measured using administrative data. This index could be used as a risk-adjustment methodology in analyses comparing post-discharge outcomes between health care providers and could also be used to identify high-risk patients for post-discharge interventions.

Author Contributions

Carl van Walraven conceived the project idea, wrote the protocol, directed the study analysis, contributed to the writing and editing of the manuscript, and is the guarantor for the study. Jenna Wong conducted the statistical analysis, produced the tables and figures, and wrote the first draft of the paper. Alan Forster helped guide the analysis and interpretation of the study results, and also critically reviewed the paper for intellectual content. All authors have read and approved the final version of the manuscript.

Competing Interests

All authors declare no competing interests.

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Figure 1: Creation of the study cohort

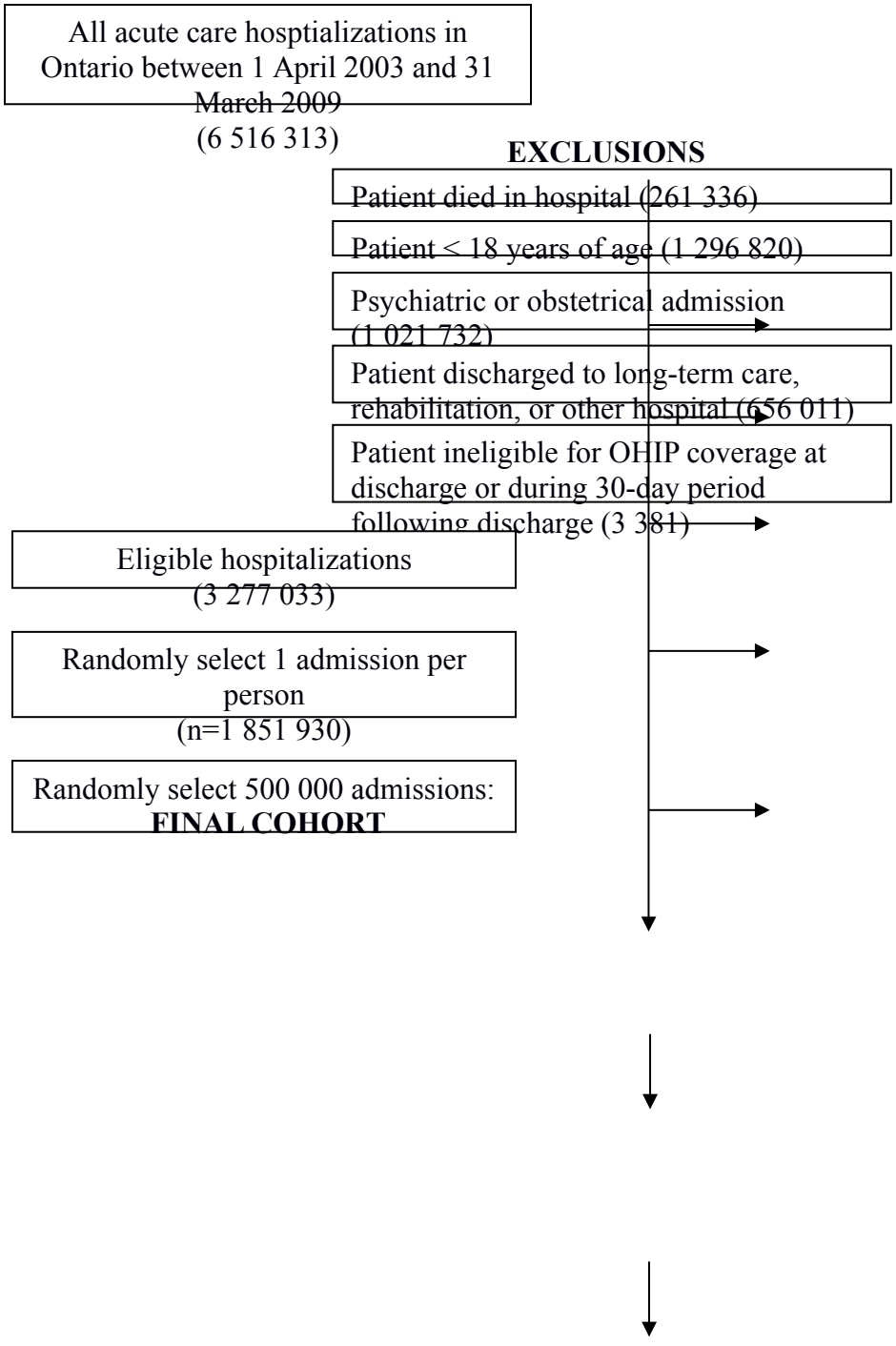
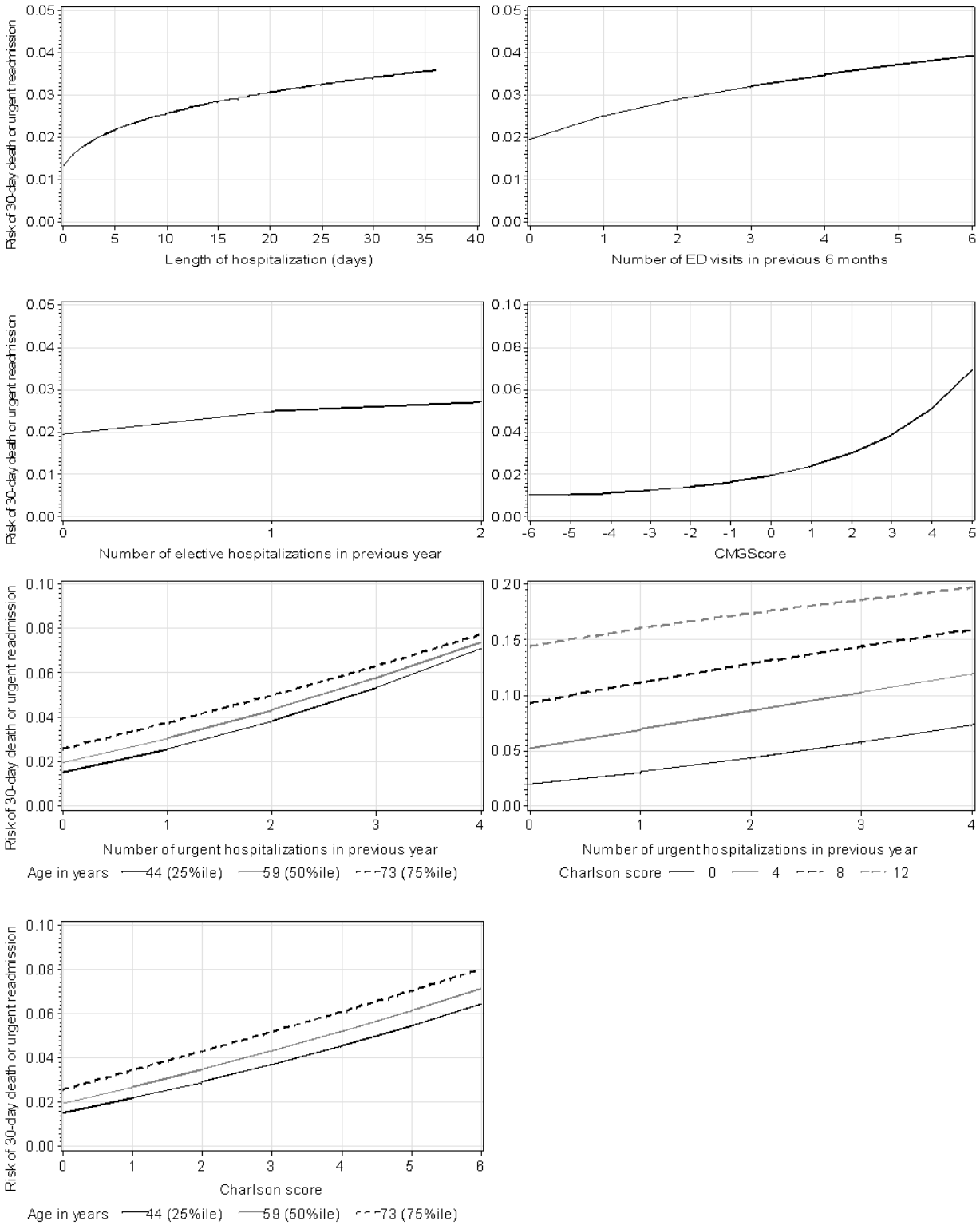


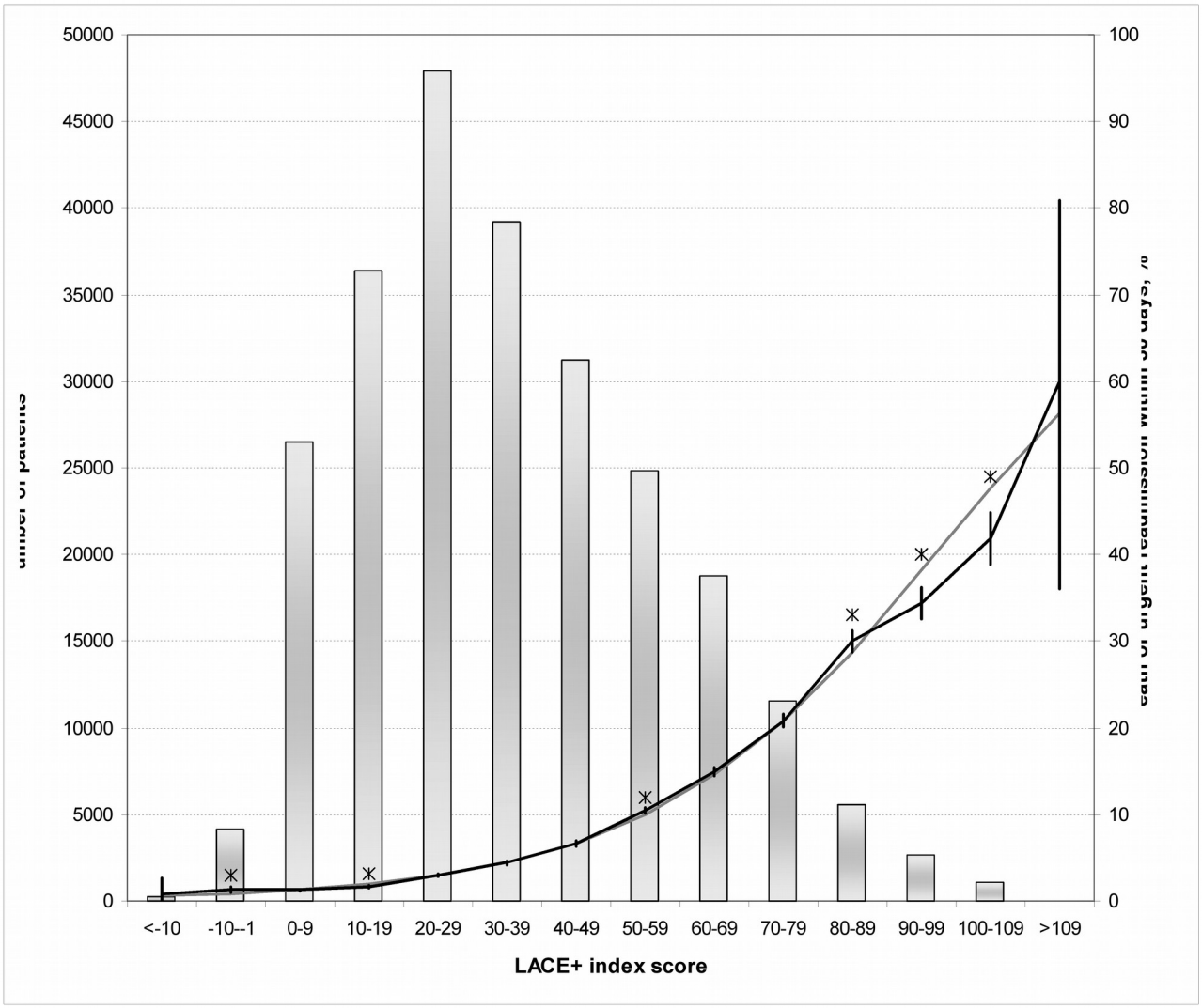
Figure 2: Association of transformed continuous covariates and interaction terms with 30-day death or urgent readmission.



The graphs above show the predicted risk of 30-day death or urgent readmission (y-axis) for different values (x-axis) of each transformed continuous covariate in the final logistic regression model. The expected risk of death or urgent readmission was calculated as the inverse of $1 + e^{-(\text{intercept} + \beta 1 * X1 + \ldots + \beta K * XK)}$, where β was the regression coefficient of each covariate (X) in the final model and *K* was the total number of covariates in the final model. In each graph, the covariate of interest was allowed to vary from the 1st to

99th percentile of observed values while the value of all other covariates was set to the median or reference value (unless otherwise noted).

Figure 3. Distribution and calibration of the LACE^{+} index by 10-point strata



Bars = number of patients in the validation set within each 10-point risk strata of the LACE^{+} index (left axis); grey line = expected event rate within each stratum (right axis); black line = observed event rate within each stratum (right axis) with 95% confidence intervals calculated using exact methods [11]; stars indicate strata where the 95% confidence interval around the observed rate excludes the expected rate

Table 1: Description of study cohort.

Characteristic*	**Overall (n= 500,000)**	**Derivation (n=250,000)**	**Validation (n=250,000)**
Predictors:			
- Mean age (SD)	57.9 (18.4)	57.9 (18.4)	57.9 (18.5)
- Male	239 590 (47.9)	120 031 (48.0)	119 559 (47.8)
- Charlson Index > 0	124 447 (24.9)	62 368 (24.9)	62 079 (24.8)
- Median length of stay (IQR)	3 (2-6)	3 (2-6)	3 (2-6)
- Emergent admission	321 977 (64.4)	160 990 (64.4)	160 987 (64.4)
- ≥1 ED visit in previous 6 months	188 315 (37.7)	94 255 (37.7)	94 060 (37.6)
- ≥1 urgent admission in previous year	69 975 (14.0)	35 000 (14.0)	34 975 (14.0)
- ≥1 elective admission in previous year	30 750 (6.2)	15 200 (6.1)	15 550 (6.2)
- CMG score			
> 0	78 053 (15.6)	39 142 (15.7)	38 911 (15.6)
< 0	69 151 (13.8)	34 554 (13.8)	34 597 (13.8)
- Admitted to an ICU during index admission	56 840 (11.4)	28 351 (11.3)	28 489 (11.4)
- Median length of stay in ICU† (IQR)	3 (2-4)	3 (2-4)	3 (2-4)
- Switched to ALC status during index admission	9 458 (1.9)	4 661 (1.9)	4 797 (1.9)
- Median number of days on ALC‡	7 (3-15)	7 (3-15)	7 (3-15)
- Discharge institution			
Teaching hospital	159 580 (31.9)	79 850 (31.9)	79 730 (31.9)
Large non-teaching hospital (≥100 beds)	269 247 (53.8)	134 469 (53.8)	134 778 (53.9)
Small non-teaching hospital (<100 beds)	71 173 (14.2)	35 681 (14.3)	35 492 (14.2)
Outcomes:			
- Death or urgent readmission in 30 days	33 825 (6.8)	16 820 (6.7)	17 005 (6.8)
- Urgent readmission in 30 days	30 234 (6.0)	15 044 (6.0)	15 190 (6.1)
- Death in 30 days§	3 591 (0.7)	1 776 (0.7)	1 815 (0.7)

SD = standard deviation; IQR = interquartile range; ED = emergency department; CMG = case mix group; ICU = intensive care unit; ALC = alternative level of care

*unless otherwise indicated, the number (proportion, %) is provided.
†among patients admitted to an ICU during index admission
‡among patients switched to ALC during index admission
§not preceded by an urgent readmission

Table 2. Final risk prediction model

COVARIATE*	PARAMETER ESTIMATE	STANDARD ERROR	ADJUSTED ODDS RATIO (95% CI)†
- Male	0.10422	0.01690	1.11 (1.07-1.15)
- Urgent admission	0.60273	0.02333	1.83 (1.75-1.91)
- Discharge institution			
Teaching vs. small non-teaching hospital	-0.01328	0.02600	0.97 (0.94-1.04)
Large vs. small non-teaching hospital	-0.06150	0.02384	0.94 (0.90-0.99)
- Age^2	0.00032	0.00002	-
- Log(length of stay)	0.28249	0.01147	-
- $Charlson\ score^{0.5}$	1.32586	0.07319	-
- Log(Number of ED visits in previous 6 months)	0.37177	0.01622	-
- Number of urgent admissions in previous $year^{0.5}$	1.81390	0.09126	-
- Number of elective admissions in previous $year^{-1}$	-0.50616	0.05751	-
- CMG $score^2$	0.01393	0.00031	-
- Number of days on ALC status	-0.01033	0.00209	0.99 (0.99-0.99)
- Age^2 x $Charlson\ score^{0.5}$	-0.00005	0.00001	-
- Age^2 x Number of urgent admissions in previous $year^{0.5}$	-0.00011	0.00001	-
- $Charlson\ score^{0.5}$ x Number of urgent admissions in previous $year^{0.5}$	-0.31468	0.04856	-

ED = emergency department; CMG = case mix group; ALC = alternative level of care; CI = confidence interval; small non-teaching hospital = non-teaching hospital with <100 beds; large non-teaching hospital = non-teaching hospital with ≥100 beds

*In the final risk prediction model, male and urgent admission were expressed as binary variables. Discharge institution was a categorical variable with three levels expressed using two binary variables (with small non-teaching hospitals designated as the reference level). All other covariates were expressed as continuous variables using the transformations specified above. Before applying the transformations, a value of 1 was added to the original value of length of stay, Charlson score, number of previous ED visits, number of previous urgent admissions, and number of previous elective admissions to ensure each covariate's domain was > 0. For the CMG score, a value of 7 was added to the original covariate value before applying the transformation.
†The adjusted odds ratio is shown for covariates that are not transformed and not involved in an interaction term. The association of these covariates with 30-day death or urgent readmission is presented in Figure 2.

Table 3. LACE^{+} scoring system to predict risk of 30-day death or urgent readmission

PREDICTOR	POINTS
Male	3
Emergent admission	15
Discharge institution	
Teaching hospital	-3
Large non-teaching hospital*	-1
Length of stay (days)	
<1	0
1	2
2	3
3	4
4	5
5-6	6
7-10	7
>10	9
CMG score	
<-2	-13
-2 - -1	-6
0	0
1-2	8
>2	24
Number of days on ALC status	
0	0
>0	-1
Number of ED visits in previous 6 months	
0	0
1	3
>1	6
Number of elective admissions in previous year	
0	0
>0	6

	Points by Charlson score and number of urgent admissions in previous year					
	Previous urgent admissions = 0			Previous urgent admissions > 0		
PREDICTOR	**Charlson 0**	**Charlson 1**	**Charlson >1**	**Charlson 0**	**Charlson 1**	**Charlson > 1**
Age (years)						
<32	0	10	30	25	33	48
32-40	2	12	31	26	34	48
41-46	5	15	34	27	35	49
47-52	7	16	34	28	35	48
53-58	9	17	35	29	35	48
59-64	12	20	38	30	36	49
65-69	15	23	40	32	38	50
70-75	18	26	42	33	39	50
76-80	20	27	42	35	40	50
>80	27	33	47	38	42	51

*non-teaching hospital with ≥100 beds

Table 4. Expected and observed probability of 30-day death or urgent readmission in the validation population by 10-point strata of the LACE+ index

LACE+ SCORE	N	PROBABILITY OF DEATH OR URGENT READMISSION WITHIN 30 DAYS	
		EXPECTED, %	OBSERVED, % (95% CI)
<-10	264	0.60	0.76 (0.09-2.71)
-10 - -1	4160	0.88	1.27 (0.96-1.66)
0-9	26458	1.28	1.25 (1.12-1.39)
10-19	36409	1.93	1.63 (1.50-1.76)
20-29	47889	2.93	2.93 (2.78-3.08)
30-39	39210	4.42	4.41 (4.21-4.62)
40-49	31193	6.69	6.64 (6.37-6.92)
50-59	24824	9.93	10.46 (10.08-10.84)
60-69	18784	14.54	14.93 (14.43-15.45)
70-79	11538	20.70	20.77 (20.03-21.52)
80-89	5553	28.70	29.98 (28.78-31.21)
90-99	2641	38.22	34.38 (32.57-36.23)
100-109	1057	47.62	41.82 (38.82-44.86)
>109	20	56.35	60.00 (36.05-80.88)
TOTAL	**250000**	**6.80**	**6.80 (6.70-6.90)**

CI = confidence interval, N = number of patients

The expected probability was calculated as the predicted risk of 30-day death or urgent readmission from the LACE+ score summed across all patients within each stratum and divided by the number of patients in the stratum. The observed probability was calculated as the number of patients within each stratum who had the outcome divided by the number of patients in the stratum. The 95% confidence intervals around the observed probability were calculated using exact methods [11].