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The Kaiser Permanente inpatient risk adjustment methodology was valid in an external patient population

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Abstract

Objectives: Accurately predicting hospital mortality is necessary to measure and compare patient care. External validation of predictive models is required to truly prove their utility. This study assessed the Kaiser Permanente inpatient risk adjustment methodology for hospital mortality in a patient population distinct from that used for its derivation.

Study Design and Setting: Retrospective cohort study at two hospitals in Ottawa, Canada, involving all inpatients admitted between January 1998 and April 2002 ($n = 188{,}724$). Statistical models for inpatient mortality were derived on a random half of the cohort and validated on the other half.

Results: Inpatient mortality was 3.3%. The model using original parameter estimates had excellent discrimination (c-statistic 89.4, 95% confidence interval [CI] 0.891−0.898) but poor calibration. Using data-based parameter estimates, discrimination was excellent (c-statistic 0.915, 95% CI 0.912−0.918) and remained so when patient comorbidity was expressed in the model using the Elixhauser Index (0.901, 0.898−0.904) or the Charlson Index (0.894, 0.891−0.897). These models accurately predicted the risk of hospital death.

Conclusion: The Kaiser Permanente inpatient risk adjustment methodology is a valid model for predicting hospital mortality risk. It performed equally well regardless of methods used to summarize patient comorbidity.

Keywords: Prognostic index; In-hospital mortality; Logistic regression; Discrimination; Calibration; Accuracy; Risk adjustment; Hospital mortality; Statistics; Administrative databases

1. Introduction

Accurately measuring hospital mortality risk is necessary to measure quality of care and fairly compare health care providers and institutions. This requires a model that accurately predicts hospital mortality risk based on routinely collected data that are available for all patients before their admission. Two such indexes have been derived but without validation [1,2]. Recently, Escobar et al. derived and internally validated the only published model to predict hospital mortality from patient-level data available at the point of admission for all patients [3]. However, external validation is necessary to prove that the model function is not idiosyncratic to the patients, the physicians, the institutions, or the data system used to derive and internally test the model [4].

In this short report, we externally validated the Kaiser Permanente inpatient risk adjustment methodology. We also determined whether other patient comorbidity measures could be used to express chronic illness burden in these risk models.

2. Methods

2.1. Study setting

This study took place at The Ottawa Hospital (TOH), a tertiary-care teaching facility with two hospitals that averaged 20,000 admissions annually during the study period. TOH functions within a publicly funded health care system is the sole trauma center for the region, and it provides most of the region's oncological care. Further details of the validation study facility, and its comparison to the original study sites, are presented in Appendix B.

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2.2. Patients

We replicated inclusion criteria used in the original article [3] by including all hospital admissions, including same-day surgeries. As in the derivation study, we excluded patients with age ⩽ 15 years ($n = 31{,}052$) and delivery-related obstetrical admissions ($n = 68{,}352$). We also excluded patients who were transferred from or to other hospitals ($n = 1{,}018$) because we could not get admission data or mortality status, respectively, for these patients. We started patient observation in January 1998 to ensure that patients had at least 2 years of comorbidity data from inpatient records. Patient observation ended in April 2002 when our hospital changed from diagnostic coding with International Classification of Diseases (ICD)-9-CM (as in the derivation study) to ICD-10-CA. Throughout this study, the unit of analysis is the hospitalization.

2.3. Kaiser Permanente inpatient risk adjustment methodology

Details of the Kaiser Permanente inpatient risk adjustment methodology are provided elsewhere [3]. To summarize, these methods were derived and internally validated on almost 260,000 hospitalizations at 17 hospitals belonging to the Kaiser Permanente Health Plan. The risk adjustment model included six covariates including patient age; patient sex; admission urgency (i.e., elective or emergent) and service (i.e., medical or surgical); admission diagnosis; severity of acute illness as measured by the Laboratory-based Acute Physiology Score (LAPS); and chronic comorbidities as measured by the COmorbidity Point Score (COPS). The service to which patients were admitted determined whether they were under a medical or surgical service. Hospitalizations were grouped by admission diagnosis, and logistic regression models were created in which age was expressed as a squared natural spline and interaction terms between age, LAPS, and COPS were included. The final model had excellent discrimination (c-statistic 0.88) and calibration (P-value of Hosmer–Lemeshow statistic for the entire cohort 0.66). Details of the model can be attained from the Internet (www.lww-medicalcare.com) or from Dr Escobar (gabriel.escobar@kp.org).

2.4. Validation

Methods used for the Kaiser Permanente inpatient mortality risk model were replicated in our study population with two exceptions. First, our data system does not collect comorbidity information for outpatient visits. We therefore only used diagnoses from previous hospitalizations and diagnoses for the current admission that were categorized as ‘‘chronic.’’ Second, our institution uses troponin-T instead of troponin-I. We translated the troponin-I cutpoints used to calculate the LAPS into ‘‘number of times normal’’ and applied this ‘‘unit-less’’ measure to generate the troponin-T cutpoints.

We generated four predictive models to predict hospital mortality. The logit for model A was calculated by summing the original model's [3] intercept and parameter estimates multipled by our parameter values. The expected probability of death in hospital was then calculated as the reciprocal of $1 + e^{-(\text{logit})}$. Model B used the same variables as model A but with parameter estimates calculated from the data of this study, using logistic regression. In the final two models, we substituted the COPS with the Elixhauser score [5] (model C) or the total Charlson Comorbidity Score (model D). The Charlson score was determined using ICD-9 diagnostic codes cited by Quan et al [6] using weights from Schneeweiss et al [7].

Similar to the original study, all models were generated separately for each admission condition. However, admission diagnoses in models B through D that had quasicomplete separation of data points, thereby preventing maximum likelihood estimation, were grouped together. As was the case in the original report, we assumed that observations from the same patient were conditionally independent for the purposes of modeling. In models B through D, a random half of the cohort was used for model derivation with the other half used for validation.

2.5. Model assessment

Model discrimination (i.e., its ability to distinguish who did and did not die in hospital) was measured using the c-statistic with 95% confidence intervals (CIs) [8]. Model calibration (i.e., the accuracy of predicted death rates) was measured with the Hosmer–Lemeshow statistic [9] and by plotting the model-based expected mortality rate against the observed mortality rate. Within each risk decile, expected rates were deemed significantly different from observed rates if they were outside of the 95% CI of the observed mortality rate that was calculated using exact methods [10]. We also plotted observed vs. expected mortality rates after the latter was used to group patients in 10% intervals. For models B through D, we only used the validation portion of the cohort for model assessment.

3. Results

Between January 1998 and April 2002, 188,724 adult admissions to TOH met our inclusion criteria (Table 1). The mean age of the patient was 55 years (standard deviation [SD] 19) and 47% were male. Sixty-four percent of hospitalizations were emergent, and 29% were under surgical services. Patients died in 3.3% of hospitalizations. The derivation ($n = 94{,}237$) and the validation group ($n = 94{,}488$) did not differ significantly (Appendix A).

Our patient population differed extensively from that in the original study (Table 1). Our study group was notably younger, and their acuity of illness (as measured by the LAPS) was lower. However, more than 80% of our cohort