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Development and Applicability of a Risk Assessment Tool for Hospital-Acquired Mobility Impairment in Ambulatory Older Adults

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Abstract

Background: Mobility loss is common in hospitalized older adults, and resources to prevent mobility impairment are finite. Our goal was to use routinely collected data to develop a risk assessment tool that identifies individuals at risk of losing the ability to walk during hospitalization on the first hospital day. Second, we determined if the tool could inform the use of mobility-preserving interventions.

Methods: We included patients admitted to a general medical service, aged ≥65 years, who walked occasionally or frequently on admission (Braden Scale Activity subset >=3). Patients were considered to have a new mobility impairment if, at discharge, their ability to walk was severely limited or nonexistent or they were confined to bed (Braden Scale Activity subset <3). We used predictors available on the first hospital day to develop (2017-18 cohort) and validate (2019 cohort) a risk assessment tool. We determined the association between predicted risk and therapy use in the validation cohort to highlight the model's clinical utility.

Results: 5542 patients were included (median age 76 years, 48% women); 7.6% were discharged unable to walk. The model included 5 predictors: age, medication administrations, Glasgow Coma Scale verbal score, serum albumin, and urinary catheter presence. In the validation cohort, the model discriminated well (c-statistic 0.75) and was strongly associated with hospital-acquired mobility impairment (lowest decile 1%, highest decile 25%). In the validation cohort, therapy consultation ordering increased linearly with predicted risk; however, observed mobility impairment increased exponentially.

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Author contributions: Dr. Shah had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors listed have contributed sufficiently to the project to be included as authors, and all those who are qualified to be authors are listed in the author byline.

Conclusion: The tool assesses the risk of mobility impairment in all ambulatory hospitalized older adults on the first hospital day. Further, it identifies at-risk older adults who may benefit from mobility interventions.

INTRODUCTION

Often overlooked, mobility is vital to the care of the hospitalized older adult. Immobility is associated with falls, pressure injuries, delirium, and discharge to rehabilitation facilities.[1–5] Yet immobility remains highly prevalent in U.S. hospitals—most patients spend less than 3% of the day standing or walking.[6,7] Older adults are particularly susceptible to the ill effects of immobility; one in three patients over the age of 65 years loses the ability to independently perform one or more activities of daily living following hospital admission.[8,9] Worse yet, functional impairment can persist well after discharge.[10,11]

While programs to improve mobility are promising, targeting is a hurdle to widespread adoption. Mobility programs have been shown to prevent hospital-acquired disability, from intensive care units to general medical floors to those admitted for arthroplasty.[12–15] While effective, such programs are challenging to implement in hospitals because resources are finite—there are too few therapists, ACE unit beds, and mobility program staff for all hospitalized older adults. In acute care settings, identifying which patients are most likely to develop hospital-acquired disability enables targeting finite resources.

Multiple instruments and models have been developed to predict inpatient loss of function; however, none can reasonably support universal risk assessment.[16–21] Existing instruments use demographics, social characteristics, clinical features (e.g., lab values, comorbidities), and functional assessments (e.g., cognitive assessment using the Mini-Mental Status Exam). While useful, the current landscape lacks a tool that relies solely on routinely collected electronic medical record (EMR) data and does not require added clinician input. Such a tool could support universal risk assessment. To reduce this gap, we addressed two objectives. First, we developed a tool to predict new mobility impairment in all ambulatory hospitalized older adults in the first 24 hours of hospital admission using available EMR data. Second, we determined if the risk assessment tool could meaningfully inform clinicians' use of therapy consultations.

METHODS

Study cohort and Data

We examined all patients admitted to the Hospital Medicine Service, a general medical service, at the University of California San Francisco Hospital over three years before the COVID19 pandemic (Jan 1, 2017, through Dec 31, 2019). We included adults aged ≥65 years who were observed by their bedside nurse as ambulatory on their first hospital day (i.e., the first 24 hours of admission). Mobility was assessed using the activity subscale of the Braden Scale for Predicting Pressure Sore Risk.[22] The Braden Activity Subscale (BAS) asks nurses to observe patients' mobility and categorize their mobility as: Bedfast (1), Chairfast (2), Walks occasionally (3), Walks frequently (4) (Supplementary Appendix S1). Bedside nurses measured the Braden Score once a shift (2-3 shifts per day) as part of routine

care at the study site. We averaged these to obtain a daily score. Patients were included and considered ambulatory if their mean score was ≥3 in the first 24 hours of admission (i.e., walked occasionally or frequently). Potential predictors were obtained using electronic medical record data, including nursing evaluation data. We excluded patients with missing outcome data (<1%) (Supplementary Appendix S2).

Outcome Measurement

We defined new-onset hospital-acquired mobility impairment as a change from "Walking Occasionally" or "Walking Frequently" (i.e., BAS >=3) on admission to "Chairfast" or "Bedfast" in the 24 hours before discharge (i.e., BAS <3). This represents a meaningful change in function and, in prior studies, was a strong predictor of mortality in hospitalized older adults.[23]

Potential Predictors

We sourced potential predictors using the World Health Organization International Classification for Function, Disability and Health conceptual model for disability[24] that were also available on the first hospital day (i.e., first 24 hours of admission). We identified demographic factors (age, self-reported race and gender, insurance status), clinical factors (transfer admission, unique inpatient medication count, and count of medication administrations, mental status using the Glasgow Coma Scale [GCS][25], serum creatinine, serum albumin, NPO status), and environmental factors (peripheral intravenous lines, gastric tube, urinary catheter). Medication administrations combine unique medications with frequency to reflect complexity.[26] No patients were missing age, sex, insurance status, admit source, peripheral intravenous lines status, medication count, medication administrations, urinary catheter status, gastric tube status, or NPO status. Patients with missing, unknown, or other self-reported race were categorized together, and these values were not imputed. When GCS scores, serum creatinine, or serum albumin were not recorded on the first hospital day, they were assumed to be normal. We detail missingness rates and imputation rationale in Supplementary Appendix S3.

Model development, validation, and test characteristics

We used 2017 and 2018 data to develop the prediction model. We determined the functional form of continuous variables by assessing linear, log, exponential, and clinically meaningful categorization against the outcome; we used the functional form with the lowest Bayesian Information Criterion (Supplementary Appendix S4). We created 1000 bootstrapped samples with replacement of the development set. Using hospital-acquired mobility impairment as the outcome, we fit a logistic regression model using backward selection with a P value of <0.05 for a predictor to stay in the model. We then selected predictors that appeared in more than 60% of the bootstrap sample models. We then validated the model using calendar year 2019 data. We determined the model's discrimination (c-statistic) and calibration (calibration slope and intercept) in the validation data.[27] We and others have used this approach for model development and validation in prior studies.[28]

Model application

We sought to determine if the risk assessment tool could supplement clinical decision-making. To determine clinicians' perception of risk, we measured the association of therapy consultation orders (Physical or Occupational Therapy) on the first hospital day with predicted risk strata in the validation cohort. We inferred that, among other reasons, physicians worried about mobility decline would order a Physical or Occupational Therapy consultation. To assess if the risk assessment model identifies patients at risk beyond clinical concern, we examined the association of predicted risk strata and observed mobility impairment in patients who did not have a therapy consultation ordered on the first hospital day.

We report all results with 95% confidence intervals. We performed analyses using SAS 131 9.4 (Cary, NC) and R 4.0.2 (Vienna, Austria). The TRIPOD checklist can be found in Supplementary Appendix S5. The UCSF Committee on Human Research approved the 133 analyses for this study and waived the requirement for patient consent (No. 16-20781).

RESULTS

Patient characteristics

9947 adults aged ≥65 years were admitted to the general medical service, of which 5542 (56%) met inclusion criteria by walking occasionally or frequently on the first hospital day. In the development cohort, the median age was 76 years (interquartile range [IQR], 69, 84), and 50% were women (Table 1). 7.6% were discharged with a new mobility impairment. On the first hospital day, the median number of medication administrations was 29 (IQR 19, 42), and 33% were made NPO. Patient characteristics were similar when comparing the development and validation cohorts.

Predictors and validation measures

The final risk assessment tool included 5 variables to predict inpatient mobility impairment: age, medication administration count, GCS verbal, albumin, and urinary catheter placement (Supplementary Appendix S6). The risk model was modestly well calibrated—observed and expected mobility impairment in the validation cohort were highly correlated (R^2 0.95, Supplementary Appendix S7); however, the risk model underpredicted risk in the two highest deciles. In the lowest decile of the validation cohort, the observed mobility impairment was 1.0% (predicted 1.0%), and the highest observed mobility impairment was 24.6% (predicted 18.6%). The risk model discriminated well with an AUC of 0.75 (95% CI 0.71 to 0.79) in the validation cohort (Supplementary Appendix S8).

Clinical utility

Figure 1 and Figure 2 together demonstrate that the risk assessment tool can supplement clinical decisions to target therapy resources. Figure 1 shows the association between the predicted risk of mobility impairment and therapy consultation orders on the first hospital day in the validation cohort. The rate of therapy ordering on the first hospital day increased by an absolute 2.1% for every 5^{th} percentile increase in predicted risk, demonstrating a linear response to predicted risk.

Figure 2 illustrates how the model may identify patients at risk for mobility impairment beyond clinical concern. Figure 2 plots the rate of mobility impairment by predicted risk in patients who did not have a therapy consult placed on the first hospital day. The loess regression demonstrates a curvilinear relationship where the rate of observed mobility impairment increases exponentially after the 70th percentile of predicted risk. For example, in the 95th percentile group, among the 28% of patients who did not have a therapy consult on the first day, 30% were discharged with a new mobility impairment.

DISCUSSION

In this study, we developed and validated a risk assessment tool to predict hospital-acquired mobility impairment in older adults who could walk on admission. The model allows universal risk assessment using routinely collected data on the first hospital day. The model performed well and demonstrated potential clinical application when tested in a validation cohort that was one year removed from the derivation cohort.

Several potential use cases exist for this risk assessment tool that uses routinely collected data in the electronic health record. First, in this study, the tool identified patients with a greater-than-average risk of mobility loss who nevertheless did not have a therapy consultation ordered on the first hospital day. Targeting therapy consultations and mobility programs to this population may be particularly beneficial in staving off mobility impairment. Targeting is salient because hospital rehabilitation services and mobility programs are usually finite resources. Beyond therapy consultations, identifying at-risk individuals could alert clinicians to the best practices for preventing hospital-acquired disability, like avoiding bed rest orders, counseling patients to mobilize safely, limiting psychoactive medication use, reducing tether use, and attending to nutrition.[9] Finally, because this model can be automated, it could be used as a “prescreen” for hospital-acquired disability models that are more accurate but require patient-reported data and therefore are more resource intensive to administer. For instance, this model could identify intermediate and high-risk patients for risk assessment with more accurate instruments that rely on cognitive assessments (e.g., Mini-Mental State Examination) and functional assessments (e.g., mobility 2 weeks before admission).[16–21]

The study results also provided insight into physicians’ risk assessment of mobility impairment. The study results indicated that while clinicians increased rates of therapy consultation ordering in those at increased risk, the increase was inadequate for those at the highest risk. That is, we observed that ordering therapy consultations reflected an assumption that mobility impairment risk increased linearly when, in fact, the risk increased exponentially. This finding redemonstrated exponential growth bias, a well-described cognitive bias described as the “pervasive tendency to linearize exponential functions when assessing them intuitively.”[29] Properly implemented into clinical workflows, this risk assessment tool may mitigate this cognitive risk misestimation.

This study has important limitations. First, this tool was designed for ambulatory older adults who constituted most, but not all, older adults admitted to the study site’s general medical service. Second, the risk factors in the risk assessment tool are not necessarily

causal; it should not be taken to mean that addressing the predictor will reduce mobility loss. Third, this tool was developed and validated in a single academic center. The development and validation cohort were separated by a year, providing some assurance as to the generalizability of the model.[30] Future external validation studies, particularly in community hospitals, will more completely define the generalizability of the model. Fourth, this risk assessment tool only accounts for mobility loss observed in the hospital and not mobility loss after discharge. Future efforts should consider models that bridge hospitalization and home or SNF. Fifth, while the risk assessment tool was modestly well calibrated in the validation cohort, it under-predicted risk in the highest deciles. Thus, while the tool performs well at risk stratification, caution should be used if absolute risk estimations are needed. Finally, this risk assessment tool requires a mobility assessment on admission. While most U.S. hospitals collect the Braden Score, this model will be difficult to use in hospitals where no mobility assessment is done on admission.

In conclusion, we developed a tool to assess the risk of new mobility impairment on the first hospital day in ambulatory older adults. The risk assessment tool uses data from the electronic medical record and does not require additional patient or clinician input. The tool demonstrated the ability to inform clinicians' use of therapy resources.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Conflict of Interest Disclosure:

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Key Points

- Identifying which hospitalized patients are at-risk for mobility impairment is vital because hospital-acquired mobility impairment is common, and resources to mitigate lost mobility are finite.
- Most risk assessment tools require patient or clinician input and thus cannot reasonably support universal risk assessment.
- In this study, we developed a risk assessment tool that, on their first hospital day, can identify hospitalized older adults at risk of losing mobility and demonstrated that it could supplement clinical decision-making.

Why does this matter?

Hospital-acquired mobility impairment is common and under-addressed. While interventions to prevent mobility loss exist, targeting these limited resources is challenging. We developed a risk assessment tool to identify older adults at risk for hospital-acquired mobility impairment early in their hospitalization. Determining which hospitalized older adults are at-risk can aid in targeting mobility-preserving interventions.

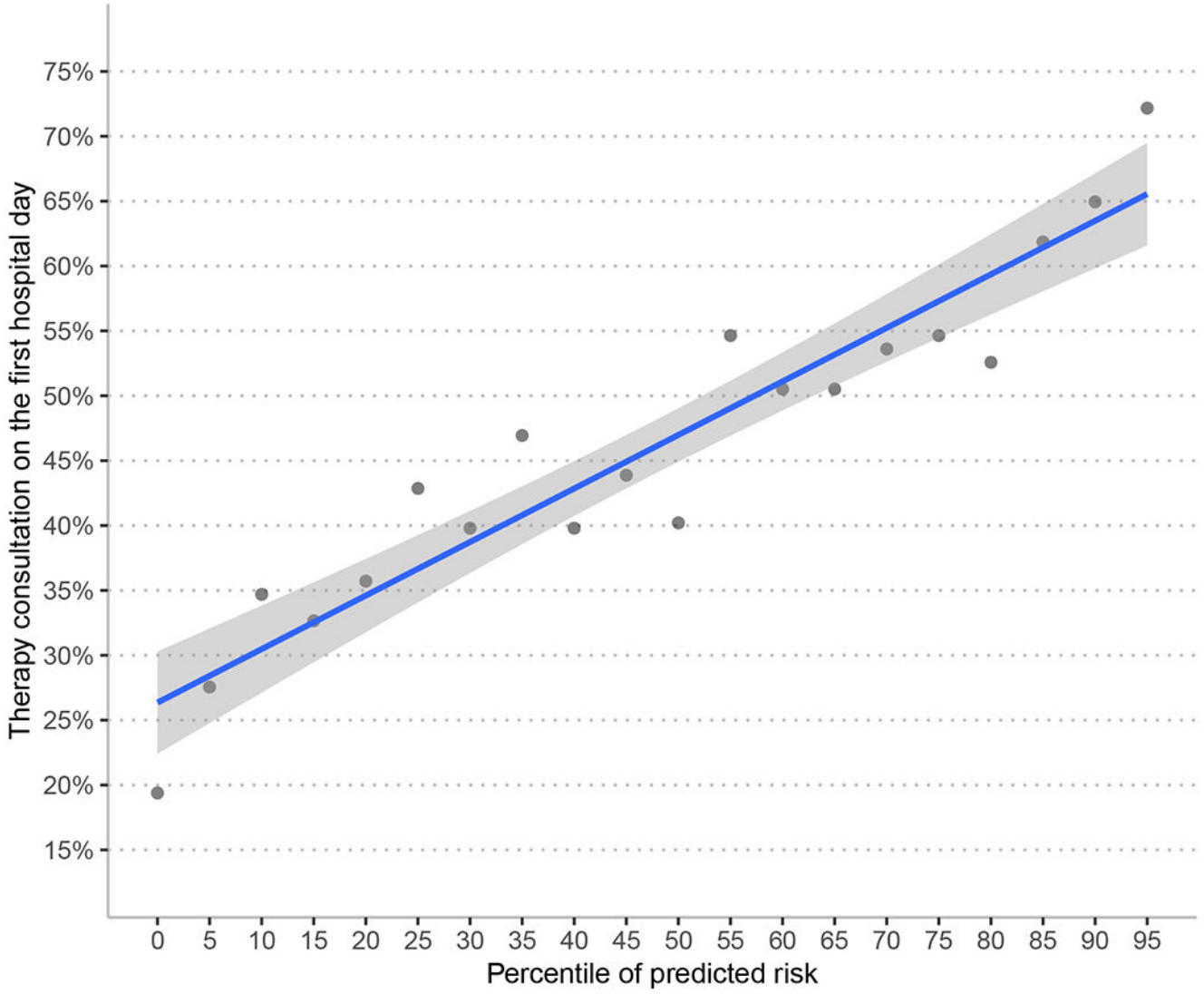

Figure 1: Physical or occupational therapy consultation ordering on the first hospital day by predicted risk, validation cohort

This analysis was performed in the validation data set. The graph displays the therapy consultation order rate on the first hospital day by ventile (i.e., a group that spans 5 percentiles) of predicted risk. The best-fit line is from a linear regression; the shaded area represents the 95% confidence interval of the best-fit line. The rate of therapy ordering increases by an absolute 2.1% (95% CI 1.7 to 2.5%) for every 5th percentile increase in predicted risk. At the lowest predicted risk percentile (i.e., intercept), 24% of patients have a therapy consultation ordered.

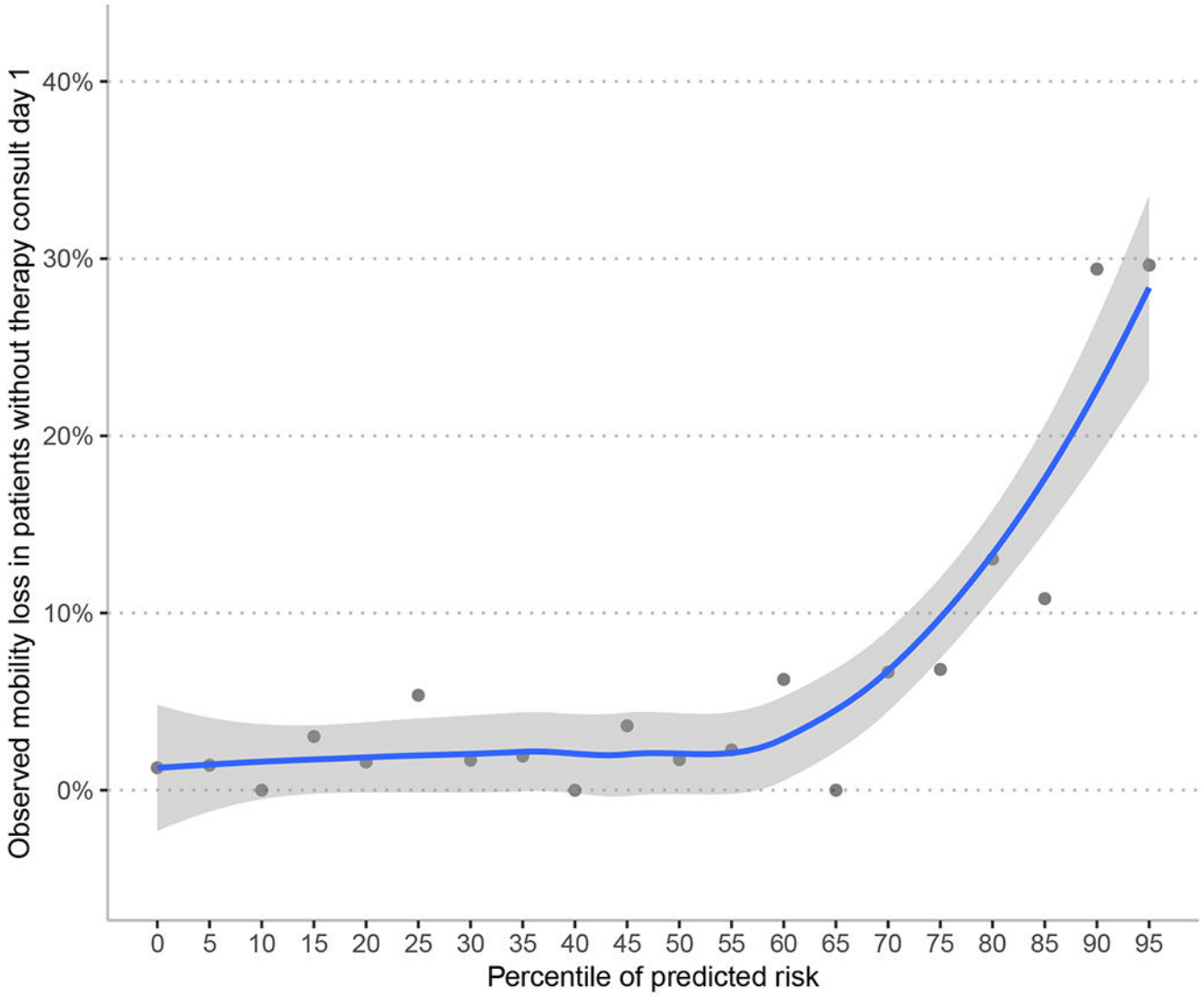

Figure 2: Mobility impairment by predicted risk among those without a therapy consultation order on the first hospital day, validation cohort

The analysis was performed in the validation data among those who did not have a therapy consultation order on the first hospital day. Line fit using a loess regression with a 90% span and weighted by the number of observations in each ventile (i.e., a group that spans 5 percentiles) of predicted risk.

Table 1:

Baseline patient characteristics of the derivation and validation cohorts

	Development cohort (n = 3570)	Validation cohort (n = 1950)
Sociodemographic		
Age, median (IQR)	76 (69, 84)	75 (69, 83)
Marital status, % (no.)		
Married	50% (1778)	51% (994)
Divorced	9% (310)	9% (178)
Widowed	20% (708)	17% (337)
Single	21% (734)	21% (417)
Other/Unknown/Declined	1% (40)	1% (24)
Race, % (no.)		
White or Caucasian	48% (1721)	51% (1000)
Asian	30% (1078)	28% (537)
Black or African American	9% (323)	8% (160)
Other/Unknown/Declined	13% (448)	13% (253)
Patient gender, % (no.)		
Men	50% (1800)	54% (1049)
Women	50% (1770)	46% (901)
Insurance status, % (no.)		
Medicare	73% (2620)	72% (1406)
Medicare Advantage	17% (600)	17% (337)
Commercial	5% (192)	5% (103)
Medicaid	4% (158)	5% (104)
Clinical		
Admit Source, % (no.)		
Community	97% (3462)	96% (1871)
Transfer	3% (108)	4% (79)
Peripheral IV Count, median (IQR)	1 (1, 2)	1 (1, 2)
Unique medication count, median (IQR)	7 (4, 10)	7 (4, 10)
Medication administrations, median (IQR)	29 (19, 42)	29 (19, 42)
GCS Eyes, % (no.)		
Normal (score = 4)	97% (3468)	97% (1890)
Abnormal (score < 4)	3% (102)	3% (60)
GCS Verbal, % (no.)		
Normal (score = 5)	90% (3570)	88% (1708)
Abnormal (score < 5)	10% (367)	12% (242)
GCS Motor, % (no.)		
Normal (score = 6)	99% (3524)	98% (1915)
Abnormal (score < 6)	1% (46)	2% (35)
Serum creatinine (mg/dL), median (IQR) *	0.94 (0.72 - 1.34)	0.95 (0.73 - 1.31)
Serum albumin (g/dL), median (IQR) **	4.0 (3.3 - 4.0)	4.0 (3.2 - 4.0)

	Development cohort (n = 3570)	Validation cohort (n = 1950)
Patient has a urinary catheter, % (no.)		
Yes	6% (201)	5% (99)
No	94% (3369)	95% (1851)
Patient has a feeding tube, % (no.)		
Yes	2% (58)	1% (14)
No	98% (3512)	99% (1936)
Patient made NPO, % (no.)		
Yes	35% (1255)	38% (750)
No	65% (2315)	62% (1200)

IQR—interquartile range, IV—intravenous catheter, GCS—Glasgow coma score, NPO—nil per os (i.e., nothing through the mouth)

*Patients without a serum creatinine value on the first hospital day were assumed to have normal creatinine (1.0 mg/dL)

**Patients without a serum albumin value on the first hospital day were assumed to have normal albumin (4.0 g/dL)