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Hospital mortality prediction for intermediate care patients: Assessing the generalizability of the Intermediate Care Unit Severity Score (IMCUSS)[☆]

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Abstract

Purpose: The Intermediate Care Unit Severity Score (IMCUSS) is an easy to calculate predictor of in-hospital death, and the only such tool developed for patients in the intermediate care setting. We sought to examine its external validity.

Materials and methods: Using data from patients admitted to the intermediate care unit (IMCU) of an urban academic medical center from July to December of 2012, model discrimination and calibration for predicting in-hospital death were assessed using the area under the receiver operating characteristic (AUROC) and the Hosmer-Lemeshow goodness-of-fit chi-squared (HL GOF χ^2) test, respectively. The standardized mortality ratio (SMR) with 95% confidence intervals (95% CI) was also calculated.

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Conflicts of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jcrc.2018.05.009>.

Results—The cohort included data from 628 unique admissions to the IMCU. Overall hospital mortality was 8.3%. The median IMCUSS was 10 (Interquartile Range: 0–16), with 229 (36%) patients having a score of zero. The AUROC for the IMCUSS was 0.72 (95% CI: 0.64–0.78), the HL GOF $\chi^2 = 30.7$ ($P < 0.001$), and the SMR was 1.22 (95% CI: 0.91–1.60).

Conclusions: The IMCUSS exhibited acceptable discrimination, poor calibration, and underestimated mortality. Other centers should assess the performance of the IMCUSS before adopting its use.

Keywords

Intermediate care; Stepdown care; Progressive care; Outcome prediction score; Mortality prediction

1. Introduction

Intermediate care units (IMCUs), also known as progressive care units, high dependency units, transitional care units or step-down units, were developed to manage patients whose clinical needs exceed what typically can be provided on standard hospital units, but do not require all of the human and technical resources of an intensive care unit (ICU) [1]. Despite their increasing prevalence in the United States and Europe [2–4], the value of IMCUs on patient outcomes and costs has been questioned [5,6]. Evaluations of IMCUs are challenging due, in part, to heterogeneity that stems from differences in staffing models, regional needs, institutional missions, clinical expertise, and physical resources, in addition to inherent differences in patient characteristics [1]. An outcome prediction model that is valid across the range of mortality risk encountered in IMCUs, regardless of heterogeneous approaches to organization and staffing, would improve comparisons of different models of intermediate care and may assist quality improvement efforts [1,7,8].

Outcome prediction models have been developed and validated for use in the ICU, with some applied to the intermediate care setting [9–17]. Of the measures used in the IMCU setting, performance characteristics have been described for the Acute Physiology and Chronic Health Evaluation Score version II (APACHE II) and the Simplified Acute Physiology Score version II (SAPS II) and version 3 (SAPS 3), with SAPS II performing the best [9,10,12,14,18–20]. A relatively new score, the Intermediate Care Unit Severity Score (IMCUSS), was developed specifically for use in the IMCU setting [21]. The IMCUSS is calculated from nine dichotomized variables with point values assigned based on the strength of their association with in-hospital death (Table 1). All variables are readily available at the time of IMCU admission. In a single 9-bed IMCU in Spain, the IMCUSS predicted in-hospital death as well as the SAPS II with good discrimination and calibration. Area under the receiver operating characteristic (AUROC) was 0.8 (95% confidence interval [CI]: 0.73–0.87) and the standardized mortality ratio (SMR) was 0.89 (95% CI: 0.59–1.19). By design, the burden of data collection for the IMCUSS is low, making it an appealing tool to characterize in-hospital mortality risk among IMCU patients. However, there is no published assessment of its external validity. The purpose of this study is to perform an initial assessment of the external validity of the IMCUSS in a well-characterized IMCU in the United States [11].

2. Methods

2.1. Study population

This is a retrospective study of patients 18 years of age or older admitted to an 18-bed medical IMCU, located within an urban academic medical center, between July and December of 2012. Only data related to each patient's first IMCU admission during this time period were collected. Patients could be admitted from any source, including the emergency department (ED), general medical unit, ICU, other hospitals, post anesthesia care units (PACU), or even other IMCUs in the hospital.

2.2. IMCU setting

The organization of the IMCU, including the physical layout, admission guidelines with recommendations for ICU consultation and transfer, and staffing of the unit have previously been described in detail [11]. Briefly, the IMCU is an "open" unit intended for adult medical patients. It is located in close proximity to the general medical units, but in a different building than the ICUs. All patients receive continuous pulse oximetry and cardiac monitoring (12 lead). The nurse to patient ratio is 1:3. A respiratory therapist is on site 24 h per day to support patients receiving non-invasive ventilation, high flow nasal oxygen, frequent nebulizer treatments, or airway suctioning.

2.3. Data collection

Patient level data were collected, in duplicate, by trained abstractors working independently. A third independent reviewer arbitrated any inconsistencies. Data recorded included patient demographics, date and time of admission and discharge to and from different levels of care, location prior to IMCU admission, IMCU admitting diagnosis, the site to which patients were discharged following IMCU admission, and vital status at hospital discharge. Data elements needed to calculate the IMCUSS were those available within an hour of admission to the unit. The Charlson Comorbidity Index (CCI) was calculated from data available at the time of hospital admission [22].

2.4. Outcomes

Hospital mortality was the primary outcome, consistent with the predictive focus of the IMCUSS.

2.5. Sensitivity analyses

A priori, based on historical data, we recognized that our IMCU patient population would have many more admissions from the ED (~50%) than the population from which the IMCUSS was developed (~25%). As such, we planned to assess the performance of the IMCUSS in patients admitted to the IMCU from the ED versus all other sites.

The study protocol was approved by the Institutional Review Board of Johns Hopkins University (Protocol #IRB00160106).

3. Statistical analysis

Continuous variables are reported as means with standard deviations (SD) or medians with interquartile ranges (IQR), and categorical variables as frequencies and proportions. Comparisons between survivors and nonsurvivors are made using a two-sample test of proportions, the Fisher's exact test, or the Wilcoxon rank sum test, as appropriate.

The generalizability of the IMCUSS was assessed by characterizing its accuracy in our population. Accuracy, in this case, is an assessment of how well mortality predictions match actual outcomes and is characterized by discrimination and calibration. A score with good discrimination properties will consistently assign a higher risk of death to patients that die and a lower risk to those that live. The area under the receiver operating characteristic (AUROC) characterizes a score's ability to discriminate, with an area of 0.5 expressing no discriminant value, and an area of 1.0 expressing perfect discrimination. Calibration is the ability of the score to accurately predict the proportion of patients that will experience the outcome of interest within subgroups of risk. Patients are assigned to different subgroups (typically deciles of equal size) by ranking them by predicted risk of the outcome. When there are many ties at the boundary of a quantile, the size of the groups can be uneven and fewer groups may be specified to avoid groups that are very small. Graphically, assessments of calibration demonstrate if a score tends to over- or underestimate the probability of the outcome. Further, it can show if over- or underestimation is a problem among patients with higher or lower scores. Calibration in this study was assessed using the Hosmer-Lemeshow goodness-of-fit chi-squared (HL GOF χ^2) test and inspection of calibration curves [25]. Lastly, a standardized mortality ratio (SMR = observed deaths/predicted deaths) was calculated as a global assessment of performance.

In *post-hoc* analyses, we [1] calculated SMRs for patients whose predicted risk of in-hospital death was below or above the median predicted probability of our population, and [2] assessed the performance of the IMCUSS after excluding patients admitted with "do not intubate" and/or "do not resuscitate" orders (DNI/DNR) as established limitations on care at the time hospital admission can alter patient outcomes [23,24].

All statistical analyses were performed using Stata 11.2 (College Station, TX).

4. Results

4.1. Study population

Between July and December of 2012, there were 765 admissions to the IMCU representing 628 unique patients. Patient characteristics are detailed in Table 2. Over half of patients were admitted from the ED, with 7% admitted from an ICU. The most common diagnostic categories were respiratory (30.7%), cardiac (22.1%), and non-pulmonary sepsis (12.6%). Mortality at hospital discharge was 8.3%. Of the 52 patients who died, 25% died in the IMCU, 19% died on a general medical unit, and 54% died after transfer to an ICU. IMCU patients who died (in any location) were older, had more comorbidities, were more often admitted from the medical ward, and had a higher predicted risk of in-hospital death per the

IMCUSS. They also more often had established limits on the use of life support (i.e., DNI/DNR) at the time of hospital admission (21% vs. 4%; $P < 0.001$).

4.2. IMCUSS performance

The median IMCUSS for the entire cohort was 10 (IQR: 0–16), with 229 (36%) patients having a score of zero. Although the score demonstrated acceptable discrimination (AUROC = 0.72; 95% CI: 0.64–0.78) (see Online Supplement eFigure1), it was not well calibrated for our population (HL GOF χ^2 with 7 degrees of freedom = 30.7; $P < 0.001$) (Fig. 1), and underestimated mortality (SMR = 1.22; 95% CI: 0.91–1.60). Underestimation was notable among patients whose predicted risk of death was below the population median (SMR 2.12; 95% CI: 1.31–3.23). By contrast, the IMCUSS slightly overestimated mortality among those patients whose predicted mortality was above the population median (SMR 0.95; 95% CI: 0.64–1.34).

4.3. Sensitivity analyses

Performance of the IMCUSS did not improve when we limited the analysis to patients admitted from non-ED sites to more closely resemble the cohort in the original IMCUSS study. Discrimination was fair, calibration was poor, and mortality was underestimated (Table 3; See Online Supplement eFigure 2A). Among patients admitted from the ED, discrimination was also fair, calibration was acceptable, and the SMR was close to unity, albeit with a wide confidence interval (Table 3; See Online Supplement eFigure 2B).

Lastly, when the 36 patients admitted to hospital with limitations on care (i.e.; DNI/DNR) were excluded from the analysis, discrimination changed minimally (AUROC = 0.71; 95% CI: 0.64–0.78), calibration remained poor (HL GOF χ^2 = 27.4, $P < 0.001$), and the IMCUSS continued to underestimate mortality (SMR = 1.07; 95% CI: 0.77–1.45), though to a lesser degree.

5. Discussion

Using data from a cohort of 628 patients admitted to our IMCU, we assessed the generalizability (i.e., external validity) of the IMCUSS system. The IMCUSS is the only score, to-date, specifically developed to predict in-hospital death among patients admitted to an IMCU. Its performance has not been assessed outside of the single 9-bed general purpose IMCU in Spain in which it was developed. Our IMCU is a reasonable setting in which to test the generalizability of the IMCUSS model because it too is a general purpose IMCU, with similar monitoring capabilities and nursing ratio, and serves a population of predominantly medical patients. However, despite acceptable discrimination, the IMCUSS exhibited poor calibration and substantially underestimated mortality in our patients.

There are several potential explanations for why the IMCUSS was not generalizable to our IMCU. Generalizability is characterized by reproducibility and transportability [26]. Reproducibility of the IMCUSS was assessed as part of score development using a validation cohort composed of different patients within the original IMCU population and with a bootstrapping technique, which decreased the likelihood of overfitting the model through repeated random sampling of the original population [21,27]. Our assessment is of

transportability, where we have assessed the performance of the IMCUSS in a presumably similar, but different population in a geographically distinct region, where data were collected by a different team.

The inadequate calibration of the IMCUSS in our population may be due to differences in case-mix between the original IMCUSS population and ours (Table 4). Although both units admit predominantly medical patients, there were notable differences in overall mortality and source of admission. Notably, fewer of our patients had metastatic cancer, health care related infections, used immunosuppressive therapy, or required non-invasive ventilation. Each of these features is part of the IMCUSS model, as they were more often present among patients who died in the original patient cohort. However, with the exception of metastatic cancer, the features were not associated with mortality in our population (Table 2).

Other factors also could have altered the performance of the IMCUSS in our IMCU. For instance, local factors could affect the types of patients admitted to the two units and the associated mortality. For example, the unit in which the IMCUSS was developed is a closed unit where the care of patients is directed by hospitalists and residents. This team is joined on rounds by critical care or surgical specialists, as needed, in addition to a pharmacist. The unit is adjacent to an ICU. Moreover, the nursing staff is shared with a stroke unit and a coronary care unit. The intensity of this staffing model may allow for more severely ill patients to remain in the IMCU whereas similar patients in our open unit might be transferred to the ICU. Of note, there was better agreement between observed and expected in-hospital mortality among our patients who achieved a higher score on the IMCUSS (Fig. 1). This may suggest that the IMCUSS could still be of value in intermediate care settings where patients have a higher risk of death than in our unit.

It also should be noted that “low risk” patients admitted to the Spanish IMCU (e.g.; for desensitization) were excluded from the population used to develop and validate the IMCUSS. This may have contributed to a population that was more ill and likely to die than in our population, as we did not exclude any patients. Indeed, we observed substantially lower mortality among patients in our IMCU (8% versus 20%). We also found that 229 of our patients (36%) accumulated no points (i.e. IMCUSS score = 0). Average hospital mortality among patient admitted to general purpose IMCUs is reported to range from 3% to 48%, which emphasizes the heterogeneity of these units [9,12,15,16,28,29]. Given that a stated purpose of intermediate care is the ability to provide close monitoring, regardless of the need for specific interventions [1,28], a more suitable score would be able to assess the probability of in-hospital death across a wide range of risks. Further, such a score would also perform well despite different approaches to unit organization and staffing.

As anticipated, patients were more often admitted from the ED in our study compared to the original study (51% vs. 27%). If source of admission were a significant prognostic feature for model performance, we anticipated that the IMCUSS would better predict death among our patients admitted from non-ED sources. However, the AUROC was worse in this subpopulation, calibration remained poor, and mortality was underestimated.

There are important strengths to our study. First, it is known that outcome prediction scores can fail due to variation in how data are defined and collected [30,31]. We minimized this potential error by working closely with a member of the team that developed the IMCUSS (JFL). Second, our data was obtained during a similar time period as that used to develop the IMCUSS. Hence, worse performance of the IMCUSS in our population may not be attributed to significant medical advances or changes in practice over time [7]. Third, because of the low burden of data collection, we did not have issues with missing data. Forth, our IMCU has been characterized in detail [11]. We recommend that IMCUs structured like ours, with a similar case-mix, should not consider using the current iteration of the IMCUSS.

There are also important limitations to our study. First, our results are those of a single center using one model of intermediate care delivery. It is possible that the IMCUSS could work well at other centers where intermediate care is organized differently or with a patient population that more closely reflects the original unit validating the IMCUSS. Second, whereas knowledge of prior HCRI in the Spanish population was readily available through a well-integrated electronic record of such events in the community, our knowledge of HCRI was dependent on each patient's memory of his or her medical history and our electronic record. We would not know of HCRI not reported by the patient that occurred outside of our health care system. Third, we have limited data about the post-IMCU care and its effect on hospital outcomes, a problem common to outcome prediction tools [32].

6. Conclusions

In our IMCU, the IMCUSS exhibited acceptable discrimination for in-hospital death. However, calibration was poor, and overall the model underestimated mortality. Other centers should validate the accuracy of the IMCUSS before adopting its use. At this time, it is premature to use the IMCUSS as a generalizable predictor of in-hospital death for IMCUs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Fig. 1.

Calibration of the IMCUSS in the overall population. The total number of patients (left axis) in each of seven subgroup is shown in grey bars. Calibration is characterized by a plot of observed (solid circles) and expected (open circles) in-hospital mortality (right axis) within each subgroup. With good calibration, the two curves would be superimposed. Subgroups are defined by ranking predicted risk of in-hospital death from lowest to highest and then dividing the population into subgroups (usually deciles) of increasing risk. Because there are many patients with identical risk (i.e.; ties) at the boundary between subgroups, they differ in size (i.e.; 229 patients receive no IMCUSS point and are therefore assigned the same predicted risk). Further, a smaller number of groups (seven) has been specified to avoid any one subgroup from being too small. Ranges of risk for in-hospital death for each of the seven subgroups are as follows: group 1 (1.6%–1.6%), group 2 (2.9%–2.9%), group 3 (3.8% to 4.2%), group 4 (4.6% to 62%), group 5 (6.7% to 9.7%), group 6 (10.6% to 15.0%), and group 7 (163% to 71.9%). Gaps in the range of predicted risk between subgroups occur because the IMCUSS did not assign any patients to an intervening predicted mortality risk.

Table 1

Intermediate Care Unit Severity Score (IMCUSS) mortality prediction model.

Variable	Points
Pre-IMCU LOS 7 days	6
HCRI	11
Metastatic cancer	9
Immunosuppression	6
GCS 12	10
NIV	14
Platelets 50 k	9
BUN 28 mg/dL	10
Bilirubin 4 mg/dL	9

HCRI: Health Care Related Infection.

IMCUSS: Intermediate Care Unit Severity Score.

IMCU: Intermediate Care Unit.

LOS: Length of Stay.

GCS: Glasgow Coma Scale.

NIV: Non-Invasive Ventilation.

BUN: Blood Urea Nitrogen.

Table 2

Characteristics of 628 patients admitted to the intermediate care unit.

	All Pts	Survivors	Deaths	P-value
Number of patients	628	576	52	
Age in years, median (IQR)	57 (45–67)	56 (44–66)	66 (55–76)	<0.001 ^a
Female sex, %	53	53	46	0.335 ^b
Race, %				0.003 ^c
Caucasian	37	36	60	
African American	57	58	38	
Other	6	6	2	
IMC source, %				<0.001 ^c
ED	50.8	52.8	28.9	
Floor	33.9	32.3	51.9	
ICU	7.2	7.6	1.9	
Procedure	3.7	3.8	1.9	
Other hospital	2.4	1.9	7.7	
Admitting	1.6	1.2	5.8	
IMCU	0.5	0.4	1.9	
Primary diagnosis, %				0.042 ^c
Respiratory	30.7	30.4	34.6	
Cardiac	22.1	22.4	19.2	
Non-pulmonary sepsis	12.6	11.6	23.1	
Neurological	10.7	11.1	5.8	
Gastrointestinal	9.7	9.4	13.5	
Endocrine	7.5	7.2	0.0	
Metabolic/renal	6.7	6.9	3.9	
IMCUSS, median (IQR)	10 (0–16)	9 (0–16)	16.5 (9.5–27)	<0.001 ^a
Charlson Index, median (IQR)	2 (1–4)	2 (1–4)	4 (3–6)	<0.001 ^a
Hospital mortality, %	8.3	0	100	
DNI/DNR, %	5.7	4.3	21.2	<0.001 ^c
Metastatic cancer, %	7.5	6.1	23.1	<0.001 ^c
Immunosuppression, %	17.4	16.5	26.9	0.082 ^c
NIV, %	12.4	12.3	13.5	0.826 ^c
GCS 12, %	6.4	5.2	19.2	0.001 ^c
HCRI, %	13.3	13.2	15.3	0.67 ^c
Platelets, median (IQR)	206.5 (139–276)	210.5 (145–279)	149 (88.5–220.5)	<0.001 ^a
BUN (mg/dL), median (IQR)	16 (11–32)	16 (10–29)	30.5 (16–50.5)	<0.001 ^a

	All Pts	Survivors	Deaths	P-value
Bilirubin (mg/dL), median (IQR)	0.5 (0.3–0.9)	0.4 (0.3–0.8)	0.9 (0.4–3.5)	<0.001 ^a
Hospital LOS-days, median (IQR)	6.9 (3.0–14.)	6.5 (2.8–13.7)	12.2 (6.3–19.7)	<0.001 ^a
Pre IMCU LOS-days, median (IQR)	0 (0–1.5)	0 (0–1.3)	0.6 (0–4.3)	0.007 ^a
IMCU LOS-days, median (IQR)	2.2 (1.3–3.8)	2.2 (1.4–3.7)	2.3 (1.0–4.6)	0.868 ^a
IMCU discharge site (%)				<0.001 ^c
Floor	63.9	67.9	19.2	
ICU	16.4	13	53.9	
Operating room	0.6	0.52	1.9	
Other IMCU	0.6	0.7	0.0	
Rehabilitation center	1.6	1.7	0.0	
Home	14.8	16.2	0.0	
Dead (in IMCU)	2.1	0.0	25.0	

ED: Emergency department.

ICU: Intensive care unit.

IMCU: Intermediate care unit.

IMCUSS: Intermediate care severity score.

IQR: Interquartile range.

DNI/DNR: Do not intubate/do not resuscitate.

NIV: Non-invasive ventilation.

GCS: Glasgow coma scale.

HCRI: Health care related infection.

BUN: Blood urea nitrogen.

LOS: Length of stay.

^aWilcoxon-rank sum test.

^bTwo sample test of proportions.

^cFischer's exact.

Table 3

IMCUSS performance among Non-ED and ED patients.

Source	N	SMR (95% CI)	GOF χ^2	GOF <i>P</i> -value	AUROC (95% CI)
Non-ED	309	1.35 (0.95–1.85)	30.06	<0.001	0.69 (0.61–0.78)
ED	319	0.99 (0.55–1.63)	6.24	0.3970	0.69 (0.56–0.82)

IMCUSS: Intermediate care unit severity score.

ED: Emergency department.

SMR: Standardized mortality ratio.

CI: Confidence interval.

GOF: Goodness of fit.

 χ^2 : Chi square.

AUROC: Area under receiving operating characteristic.

Table 4

Comparison between IMCU populations.

	Alegre et al. [21]	Current study
N	743	628
Female (%)	38	53
Age (years), mean (SD)	67 (15)	56 (17)
ED referral (%)	27	51
DNR order (%)	20	6
HCRI (%)	50	13
Pre IMCU LOS (days), median (IQR)	3 (0–8)	0 (0–1.3)
Metastatic cancer (%)	26	7.5
Immunosuppression (%)	44	17
NIV (%)	26	12
GCS 12 (%)	9	6
Platelets/ μ L, mean (SD)	222 (148)	218 (114)
Urea mg/dL, mean (SD)	28 (20)	24 (20)
Bilirubin mg/dL, mean (SD)	2.2 (5.0)	1.5 (4.0)

SD: Standard deviation.

ED: Emergency department

DNR: Do not resuscitate.

HCRI: Health care related infection.

IMCU: Intermediate care unit.

LOS: Length of stay.

IQR: Interquartile range.

NIV: Non-invasive ventilation.

GCS: Glasgow coma scale.