Using the Rothman index to predict early unplanned surgical intensive care unit readmissions

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BACKGROUND: The Rothman index (RI) is a numerical score calculated hourly from 26 data points in the electronic medical record by a commercial software package. Although it is purported to serve as an indicator of change in a patient's condition, it has not been extensively evaluated in the literature. Our objective was to determine whether the RI can be used to predict early surgical intensive care unit (SICU) readmissions.

METHODS: This is a single-institution, retrospective 12-month period review of all patients transferred from the SICU to the surgical floor. Patients readmitted to the SICU within 48 hours were compared with patients who did not require readmission during this time (control). Demographics and continuous RI scores were collected at admission, 24 hours before SICU transfer, and for the first 48 hours on the surgical floor or until readmission to the SICU.

RESULTS: A total of 1,152 SICU patients were transferred to the surgical floor; 27 patients were readmitted within 48 hours of transfer. Demographics were similar in both groups. The SICU length of stay was longer in the readmission group (mean [SD], 4.7 [8.1] vs. 16.5 [15.2]; $p < 0.001$). The RI immediately before SICU transfer was higher in the control group (70.4 [20.3] vs. 49.1 [20.9], $p < 0.001$) and was uniformly improved from the RI at the initial SICU admission. In comparison, readmitted patients had more variable RI trends from admission to SICU transfer (mean Δ, 6.51; range, −54.10 to 48.6), and 40.74% of readmitted patients actually had a decreased RI score on transfer. No patient with a RI score greater than 82.90 required readmission within 48 hours.

CONCLUSION: An increased RI score or a score greater than 82.90 correlates with appropriateness for SICU transfer to the surgical floor. A decreased RI score is strongly associated with SICU readmission within 48 hours and should be explored as a potential quality metric. (*J Trauma Acute Care Surg*. 2014;77: 78–82. Copyright © 2014 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Epidemiologic/prognostic study, level III.

KEY WORDS: Rothman index; surgical ICU; ICU readmission.

Readmission to the intensive care unit (ICU) is associated with increased total cost, ICU and hospital length of stay, morbidity, and mortality.[1–8] Identifying predictors of successful discharge from the ICU and the need for readmission before untoward events remains an elusive goal. Predictors of surgical ICU readmission have not been well studied, although unstable vital signs are commonly associated with readmission.[9] In a medical ICU study, the acute physiology score component of the Acute Physiology and Chronic Health Evaluation II score at the time of ICU discharge surfaced as an independent risk factor for readmission to the ICU.[10,11] The time interval between liberation from mechanical ventilation and that of ICU discharge as well as the use of organ support technologies on the day of ICU discharge have also been associated with ICU readmission.[12] At present, no single element, montage of elements, or time-based change in those elements uniformly guarantees successful discharge from the ICU without the potential for readmission.

As electronic health records become increasingly robust, many capture hundreds to thousands of data points each 24-hour interval. As such, the data are too voluminous to readily parse without electronic manipulation and formatting into usable metrics that may help guide discharge decision making. Such an effort has yielded a novel predictive index termed the *Rothman index* (RI).

The RI is an algorithm developed by data analysts, which provides a summary score of a patient's clinical condition in a user-friendly graphical display. The system uses 26 variables, including vital signs, laboratory profile data, and nursing assessments; no physician-driven data are incorporated. The score is updated with the hourly electronic medical record data load. The program uses assessments of 12 physiologic systems with binary nursing assessments indicating whether a system goal is "met" or "not met." (Fig. 1) The maximum (and optimal) score is 100. A low RI score is associated with declining or poor clinical status. In addition to the numeric score, the data are displayed as a graph with color changes correlating with the putative risk of deterioration. Red indicates a score less than 40, yellow spans scores of 40 to 65, and blue indicates the lowest risk with scores exceeding 65.

Although the RI is purported to indicate changes in a patient's condition that may be useful in guiding discharge

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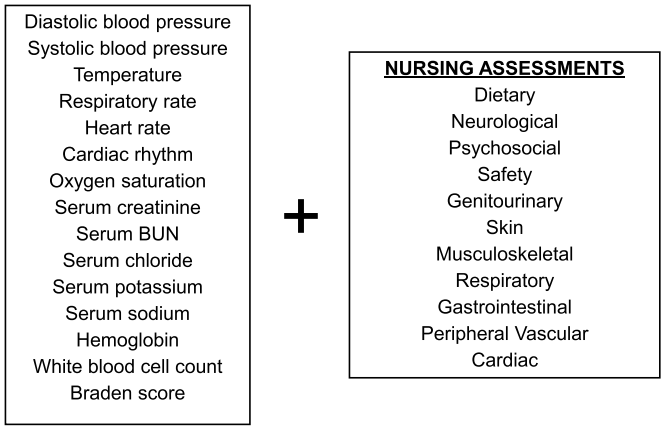

Figure 1. RI components.

decision making, the RI has not been extensively evaluated.[13,14] It remains unclear how best to use the RI in daily practice. Our hypothesis was that an RI score less than 65 would be predictive of surgical ICU readmission within the first 48 hours of ICU discharge.

PATIENTS AND METHODS

After obtaining study approval from Yale University Institutional Review Board, the RI was routinely collected throughout the surgical ICU stays of all patients at this single, academic, urban Level 1 regional resource trauma center. The surgical ICUs (SICUs) are staffed by a multidisciplinary team of intensivists (surgery, anesthesia, emergency medicine) as well as residents (surgery, anesthesia, emergency medicine) and advanced practice providers (physician assistants, advanced practice nurses) with in-house intensivist coverage. The patient population included general surgery, trauma, vascular, orthopedic, plastics, urology, transplant, gynecologic-oncology, and otolaryngology patients. The RI was not used to guide discharge decision making. A retrospective 12-month review of all patients transferred from the SICU to the surgical floor was performed. Surgical floors included all non-ICU floors; nursing ratios on these floors varied from 1:3 to 1:6. Patients readmitted to the SICU within 48 hours of transfer were compared with patients who did not require readmission during this time (control). Demographics and RI scores were collected at admission, 24 hours before SICU transfer, and for the first 48 hours on the ward or until readmission to the SICU. Data were compared using Student's t test and χ^2 analyses as appropriate.

RESULTS

Of the 1,152 SICU patients transferred to the surgical floor during the study period, 27 patients were readmitted within 48 hours, creating an early readmission rate of 2.3%. Age, sex, and need for surgery were similar in both groups (Table 1). The initial SICU stay was longer in the readmission group (mean [SD], 4.7 [8.1] vs. 16.5 [15.2]; $p < 0.001$). The RI immediately before SICU transfer was higher in the control group (70.4 [20.3] vs. 49.1 [20.9]; $p < 0.001$) and was uniformly increased from the initial SICU admission RI (Fig. 2). In comparison, readmitted patients had more labile RI scores from admission to SICU transfer (mean Δ, 6.51; range, −54.10 to 48.6), and 40.74% of readmitted patients evidenced a decreased RI score at the time of transfer to the surgical floor (Fig. 3). No patient with a RI score greater than 82.90 required readmission within 48 hours.

Once on the floor, the average length of stay before readmission within 48 hours was 20.71 [13.60] hours, with a range of 3.00 hours to 46.00 hours. The mean [SD] RI score on the floor immediately before readmission was 30.31 [21.14].

DISCUSSION

Readmissions to the SICU are costly and, if predictable, potentially avoidable. Both ICU patient safety and care quality have come under intense scrutiny in an effort to improve patient outcome. As a result, some payors have proposed using readmission rates as an ICU quality indicator, much like hospital readmission rates have been used as a surrogate for facility-level care quality.[15–17] While the use of this metric is controversial, the significantly increased mortality risk in patients readmitted to an ICU warrants additional study.

The overall average ICU readmission rate is approximately 7%.[9] Early readmission rates (<48 hours) are closer to 2% and are more commonly related to progression or recurrence of the process that led to the initial ICU admission.[1,9] Later readmissions are often of cardiac or pulmonary origin or stem from a diagnosis distinct from that driving the initial ICU admission.[9,10] With the use of this framework, early readmissions may be mitigated against by improving discharge decision making, suggesting that the subsequent deterioration and readmission may be preventable. Indices such as the RI are focused on identifying such patients by combining routinely collected data elements into a trackable single score that may be displayed on an electronic health record dashboard.

Uniform SICU discharge criteria have yet to be articulated, and many criteria reflect local practice and resource allocation. While discharge criteria standardization has been identified as potentially beneficial, ICU transfer decisions are influenced by several factors, including bed availability on service-specific floors, the need for an ICU bed for other critically ill patients, and hospital staffing, including the presence or absence of an in-house intensivist. In high-volume centers, the final discharge decision may hinge on identifying the patient with the fewest ICU needs rather than based on a patient's individual readiness for the surgical floor.

Of the aforementioned factors, only nursing assessments have correlated with in-hospital and postdischarge mortality.[14]

TABLE 1. Demographics

	Control Group (n = 1,125)	Study Group (n = 27)	p
Age, mean (SD), y	56.83 (18.52)	60.19 (18.17)	0.35
Male/female	618/507	14/13	0.75
Operative vs. nonoperative	8.96	8	0.86

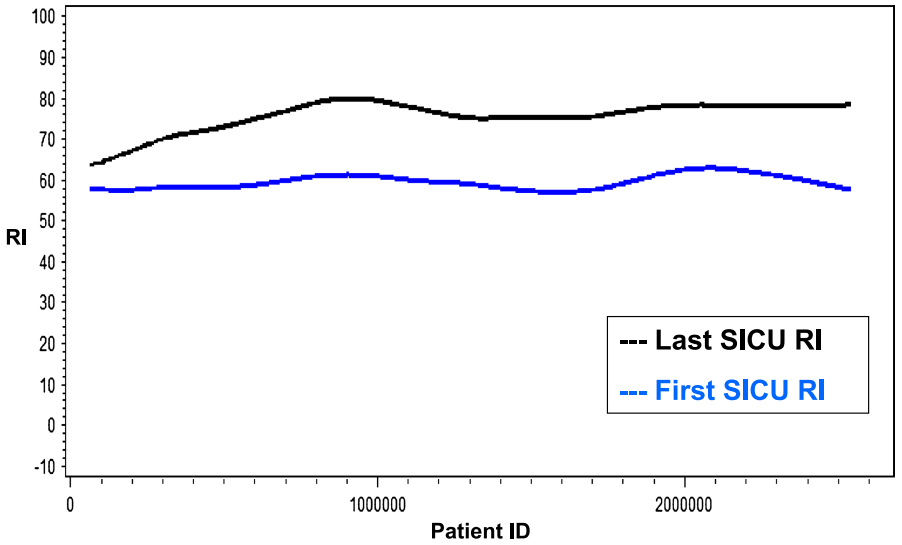

Figure 2. Control group: last SICU RI versus first SICU RI.

With the implementation of electronic medical records, these interval assessments can be entered frequently, making the assessment even more dynamic and at the same time more standardized. In particular, the nursing assessments at the time of admission to a unit and immediately before discharge from a unit are predictors of postdischarge mortality.[14]

Previous study of the RI has demonstrated a correlation between a hospital discharge score less than 70 and readmission within 30 days with one in five such patients requiring readmission.[13] By comparison, patients with discharge RI scores of 80 or greater were readmitted with only half the frequency (i.e., 1 in 10).[13] Our study carries this initial work further and is more granular by focusing on early ICU readmission in surgical patients.

No patient with an RI greater than 82.90 required readmission to our SICU during the study period, which is consistent with the designation of a score of 80 or greater as low risk. However, this score may be an unreasonable expectation for patients at the time of SICU transfer. Less than 30% of studied patients were able to achieve this score before leaving the ICU. As expected, the RI immediately before SICU discharge was higher in the patients successfully discharged without readmission than in those patients who were readmitted. The mean ICU discharge RI of 70.4, while still a "blue graph" score indicating that the patient is likely not yet ready to be discharged from the hospital, may be a more appropriate goal. It remains unclear whether absolute RI thresholds will be usable for transfer to different levels of care or if it is the trend that is more predictive of discharge appropriateness.

In the control group of patients successfully discharged to the ward, final ICU RI scores were uniformly higher than the ICU admission scores, indicating improvement in the patients' clinical

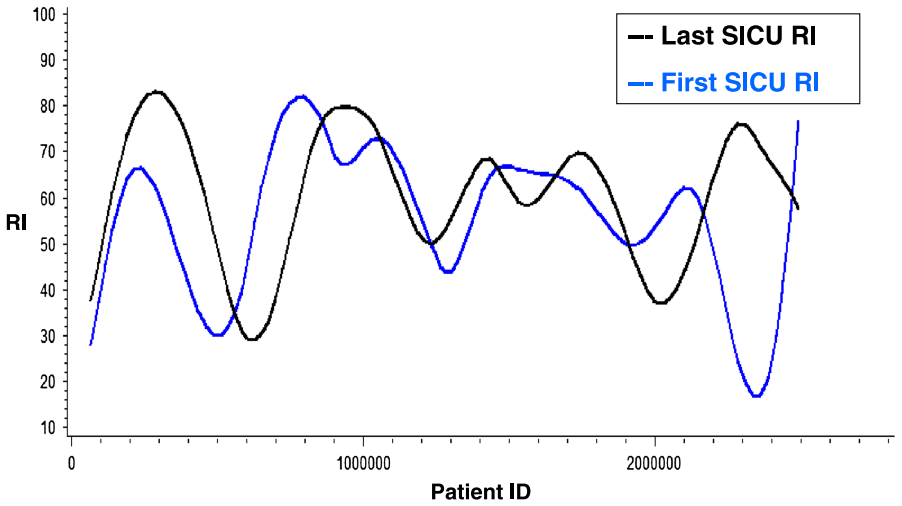

Figure 3. Study group: last SICU RI versus first SICU RI.

status as measured by the RI. In the study group, RI trends were more variable, with 40% of readmitted patients being discharged to the ward with an RI score that was lower than the admission RI score. The specific reasons for readmission were not captured, but all patients were on a surgical, but not cardiac, noncardiac thoracic, or neurosurgical service. In the initial description of the RI, the highest in-hospital mortality was associated with those patients not meeting the dietary, neurologic, psychosocial, or musculoskeletal nursing assessments. It is not clear whether any physician-driven metric could be readily incorporated into the RI and whether doing so would improve the score's performance. No difference in SICU readmission rates were noted in patients who required surgical intervention compared with patients who were managed nonoperatively. Further study would be warranted to further determine the validity of the RI as a predictor of readmission in medical (medical intensive care unit) patients as well as specific and homogeneous populations of surgical patients such as transplant or trauma.

No acceptable SICU readmission rate has been established, making absolute threshold determination problematic. Nonetheless, relative comparisons may be made within a single institution over time as well as between different facilities. A "high" readmission rate may indicate inappropriate ICU discharge. Alternatively, it may reflect an oversubscribed ICU, inadequate floor care or resources, or the use of the ICU as a safety net for patients who could be managed on the floor but for whom the ICU is perceived to provide additional benefit, such as a lower nurse-patient ratio. A "low" readmission rate may be concerning for excessively long ICU stays, resulting in unnecessary resource use and cost, but could also reflect the lack of an intermediate care unit or inadequate ward staffing or beds (especially isolation beds).

Based on the initial RI work, patients whose condition is deteriorating should have a lower score. In our readmitted patients, RI scores before ICU readmission were variable. Not all of the patient's RI scores decreased despite the mean final prereadmission RI on the floor of 30.31, a value lower than the mean pre-ICU discharge RI score. Such a low RI indicates that the assessed patients were at high risk for clinical failure. The unanswered question is whether the low RI is coupled with readily discernable clinical elements or changes that the bedside practitioner should be able to discern before the need for transfer. It is also unclear whether, and if so how, physician or advanced practice provider interventions impact the RI score. It is intuitively attractive to believe that clinical intervention would improve a patient's general condition and would be reflected in both vital signs as well as nursing assessments. However, this supposition remains to be assessed within the RI context. Perhaps, as a result of clinical care, while the mean RI declined before ICU readmission, individual patients' score trends were variable.

This study has several important limitations. First, it is a retrospective study and, as such, is limited to hypothesis generation and association discovery but not causal linkage. Second, the data were accrued from a single institution with a structure that may not reflect other resources or practice patterns. Third, the data were prospectively acquired but were retrospectively analyzed, leading to the absence of a number of desired data points that would be useful in gaining a more granular understanding of the RI specifically in focused surgical patient populations. Fourth, while the RI was not used to guide discharge decision making, the bedside clinician was not blinded to the data. However, the RI was deployed in the facility as a data point to be used to guide hospital discharge and not ICU discharge, reducing its likely impact on ICU discharge planning.

CONCLUSION

The RI provides a numeric score and color-coded graphical interface that integrates multiple data points regarding a patient's likelihood of clinical success or failure. An increasing RI score or a score greater than 82.90 correlates with appropriateness for SICU transfer to the surgical floor. A decreasing RI score is strongly associated with SICU readmission within 48 hours. Our data highlight that the RI provides an automated method of analyzing already acquired data in a way that might help guide ICU discharge planning as well as a useful metric to analyze practices with regard to safety and quality. The RI should be validated in different and focused surgical patient populations as well before being deployed for ICU discharge decision making and safety or quality analysis.

AUTHORSHIP

G.L.P. contributed to the literature search, data collection, data interpretation, writing, and editing for this study. L.J.K. contributed to the data interpretation, writing, and editing for this study. A.A.M. contributed to the data interpretation, writing, and editing for this study. F.Y.L. contributed to the data interpretation, writing, and editing for this study. K.B. contributed to the literature search, data collection, data interpretation. K.A.D. conceived of the study and contributed to the data interpretation and editing.

DISCLOSURE

The authors declare no conflicts of interest.

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