SPACELABS HEALTHCARE

White Paper

Predictive Analytics

The Rothman Index - An Intelligent Early Warning Score

Comparison of the Rothman Index with MEWS and NEWS

EXECUTIVE SUMMARY

Spacelabs Healthcare is transforming healthcare through the intelligent use of data. By providing a clear, contextual picture of patient condition at both the organizational and individual patient level, our Rothman® Index solutions enable healthcare organizations to improve clinical decision support and enhance the care delivery process. By enabling clinicians to identify and intervene earlier on at-risk patients, the Rothman Index helps address a range of clinical and operational imperatives including improving patient safety, improving performance in value-based care programs, and driving operational efficiencies.

This paper focuses on the challenges of early warning systems and provides a comparison of the Rothman Index (RI) with other early warning system scores and how the Rothman Index can provide clinicians with insights into patient condition that are early and actionable.

Early warning systems, primarily based on vital signs, have been in use since before electronic health records (EHRs) were commonplace. Most early warning systems are aimed at detecting imminent crises: tachycardia, hypotension, tachypnea, or febrile response, and their impact on outcomes has been disappointing. Today, with the increased volume of electronic health data and rapidly evolving technology, there is an opportunity to apply advanced algorithms to improve the effectiveness of early warning systems.

BASIC EARLY WARNING SYSTEMS: MEWS AND NEWS

For decades, the healthcare industry has strived to create reliable early warning systems that direct attention to patients whose deterioration may not be obvious.

For this reason, most early warning systems provided a series of output levels in an attempt to reflect changes in acuity along the continuum of deterioration. In most cases, early warning scores are implemented using a pre-determined score threshold, or cut-point. When a patient reaches that threshold a protocol is followed to ensure the escalation of care. It is relatively easy to detect deterioration when it is advanced – the real challenge these systems face is to accurately detect meaningful changes in acuity before they become serious. One of the most widespread early warning systems is the Modified Early Warning Score (MEWS). MEWS is based on a patient's respiration rate, heart rate, temperature, systolic blood pressure and level of consciousness.

Variants of this type of score have also been adapted over time for the pediatric population, including the Cardiac Children's Hospital Early Warning Score (C-CHEWS) and the more general Pediatric Early Warning Score (PEWS).[1]

In 2012, a variant of MEWS called the National Early Warning Score (NEWS) was proposed in the UK as a candidate system for standardizing early warning scoring across and was subsequently revised further to the NEWS2 score.[2] NEWS was designed to be an improvement over MEWS owing to some additions (e.g. oxygen saturation and supplemental oxygen status) and adjustments made on the basis of expert clinical opinion. One retrospective study comparing the effectiveness of NEWS against 33 other 'track and trigger' warning systems (not including the Rothman Index) found that for providing advanced warning of unplanned transfer to the ICU, cardiac arrest, or death within 24 hours, NEWS was the best overall scoring system.[3]

THE ROTHMAN INDEX: AN INTELLIGENT DATA APPROACH

The relative simplicity of MEWS, NEWS, PEWS and similar scores is rooted in an approach to patient scoring which is compatible with manual data entry and computation. And despite the increasing prevalence of electronic health records (EHR), most recent implementations of early warning systems represent either small variations or incremental advances on these basic models. In sharp distinction to such tools, the Rothman Index leverages real-time data from the EHR and predictive analytics for a new approach to early warning.

As a next-generation, EHR integrated platform that facilitates proactive intervention, the Rothman Index is a significant advancement from standard vital-sign based systems in meeting key challenges.

RICHER DATA

Most track and trigger early warning systems (including MEWS, NEWS, and other proprietary scores such as Cerner's St. John's sepsis score and Epic's Deterioration Index) focus predominantly on vital signs. In contrast, the Rothman Index incorporates the full range of body system nursing assessments. Nursing assessments are documented on patients throughout their hospital stay and reflect a significant amount of clinically meaningful information that extends beyond vital sign data. Nursing assessments have been shown to closely relate to patient outcomes and, importantly, are also important leading indicators of deterioration – providing powerful insight before the patient's physiological derangement manifests in altered vital signs.[4,5] In addition to this, the Rothman Index is designed to incorporate seven different common lab values in its scoring (sodium, potassium, creatinine, chloride, hemoglobin, blood urea nitrogen, and white blood cell count) but does not require them if they are unavailable.

MORE SOPHISTICATED COMPUTATION

Legacy scoring systems such as MEWS and NEWS take an approach that assigns discrete ranges of vital sign values into risk 'buckets'. This simplified method facilitated patient scoring in an age of manual computation, but is unnecessarily crude in an era of computer-based calculation. Rothman Index scores are computed using a patient's exact vital sign and lab result values. These quantitative inputs are therefore incorporated as part of a continuous calculation of risk to yield a more precise score that captures and reflects small variations in input parameters without losing sight of big picture trends.

INPUT COMPARISON: PEWS, MEWS, NEWS, AND ROTHMAN INDEX

Types of Data Included	PEWS (inputs vary)	MEWS (5 indicators)	NEWS (7 indicators)	Rothman Index Score (26 indicators)
Vital Signs	• Respiratory rate • Systolic BP • Diastolic BP	• Respiratory rate • Heart rate • Temperature • Systolic blood pressure	• Respiratory rate • Heart rate • Temperature • Systolic blood pressure • Oxygen Saturation (& if suppl. O_2)	• Respiratory rate • Heart rate • Temperature • Systolic blood pressure • Diastolic blood pressure • Oxygen Saturation
Lab Results	N/A	N/A	N/A	• Sodium • Potassium • Creatinine • Chloride • Hemoglobin • Blood urea nitrogen • White blood cell count
Functional Status based on Nursing Assessments	• Psychosocial • Respiratory • Cardiovascular	• Consciousness level (AVPU)	• Consciousness level or new confusion (ACVPU)	• Braden scale (pressure ulcer risk) • Cardiac • Food/nutrition • Peripheral-vascular • Psychosocial • Respiratory • Safety/fall risk • Gastrointestinal • Genitourinary • Heart rhythm • Musculoskeletal • Neurological (including GCS / consciousness level)
Sophistication of Risk Analysis	Groups clinical values into 3 risk "buckets"	Groups clinical values into 3 risk "buckets" above and below a pre-defined normal range	Groups clinical values into 3 risk "buckets" above and below a pre-defined normal range	Uses a continuous age-adjusted function to assign a precise risk value according to the exact value of each clinical input

FULLY AUTOMATED AND REAL-TIME

Spacelabs' solutions are fully integrated with the EHR and use real-time data feeds to calculate new, up-to-date Rothman Index scores as soon as new entries for any of the input variables are registered in the EHR.

No additional documentation is needed, and no extra steps are required by clinicians to generate RI scores. The burden of additional manual data entry is lifted from clinicians; this not only eliminates an opportunity for human error, but also allows clinicians to focus more of their time and energy directly on their patients. Warning rules are customized to the patient population and are pre-configured in the system to trigger warnings based on either changes in score (capturing downtrends) or thresholds in score (capturing elevated acuity), or both. There is no need for clinicians to manually determine if the Rothman Index score meets warning criteria.

GRAPHICAL CLARITY AND CONTEXT

Spacelabs' software solutions provide a clear graphical trend of the patient's condition over time, making changes and trends in the Rothman Index score easy to see. In contrast, many other early warning scores focus on a single value or threshold only provide a snapshot of the patient's acuity in the present moment. Working from a single score means that clinicians lose the powerful contextual insight that accompanies a trend over an entire patient encounter.

Generation of Rothman Index scores and warnings is not only effortless, but scores are calculated and checked against rule criteria on a continuous basis, rather than infrequently or sporadically as would be the case for MEWS, NEWS, or PEWS systems.

SPANNING THE ACUITY SPECTRUM AND MORE INTELLIGENT WARNINGS

The Rothman Index is applicable in all medical/surgical units as well as intermediate care and intensive care locations. Warnings can be configured differently based on a patient's location, to enable appropriate notifications for patients on regular nursing floors as well as those in the ICU.

Because the Rothman Index uses a real-time data feed from the EHR, its scores will follow patients through the hospital even as they are moved and transferred, ensuring a coherent picture of the patient's condition throughout the entire episode of care. Additionally, it is easy to see all the Rothman Index scores from a patient's prior admissions, providing a longitudinal view that will show any changes in trends from one admission to the next.

Perhaps even more important than how the score is portrayed is the reliability of the score in reflecting the condition of the patient. Because most early warning scores such as MEWS and NEWS are predominantly driven by vital signs, such systems are blind to the indications of physiological deterioration that frequently precede vital sign changes. Similarly, sporadic spikes in vital signs can drastically change a MEWS or NEWS score. These spikes lead to high variability in such scores from one reading to the next, exacerbating the challenge of deciphering a 'real' early warning from a passing spike in a score that is not clinically meaningful.

The large range of clinical inputs synthesized by the Rothman Index means that deviations of any one input have less impact on the overall score. The incorporation of nursing assessments and labs helps to smooth the variability that can arise when tracking vital sign data in isolation. This helps give clinicians a consistent picture and confidence that a change in a patient's Rothman Index score reflects fundamental alteration in the patient's clinical condition.

In contrast to standard early warning systems, the RI score does not only trigger warnings based on simple thresholds or cut-points. Instead a combination of changes in score that capture both gradual and abrupt deterioration events, sometimes used in conjunction with acuity based thresholds, enable the system to be geared more specifically towards the early detection of deterioration rather than just flagging patients who have already reached a state of elevated acuity. This flexibility allows for graded warnings that can be tied to appropriately graded responses.

As an example, warnings might be:
Medium Warning: Patient's RI score dropped 30% in 24 hours (captures slow deterioration)
High Warning: Patient's RI score dropped 40% in 12 hours (captures rapid deterioration)
Very High Warning: Patient's RI score fell below 20 in the last 24 hours (flags patients with very high acuity)

Various rules, which trigger the warnings, can be calibrated and adjusted based on the characteristics of any particular hospital's patient population and targeted clinical use cases.

Figure 1 shows a graph of the Rothman Index scores for a patient prior to an RRT call (black dots) and subsequent to a transfer to the ICU (red dots). Lower Rothman Index scores imply higher acuity: a Rothman Index of 100 is unimpaired; a Rothman Index of 40 is a level at which patients are typically considered for transfer to the ICU.) In contrast, the NEWS scores (green dots) are both less frequent, and far less consistent in portraying the patient's condition (higher NEWS scores imply higher acuity). Although the deterioration in the days preceding the event is clear, the scatter of green NEWS points does not provide a clear picture that the patient was in a highly acute, and increasingly serious, condition.

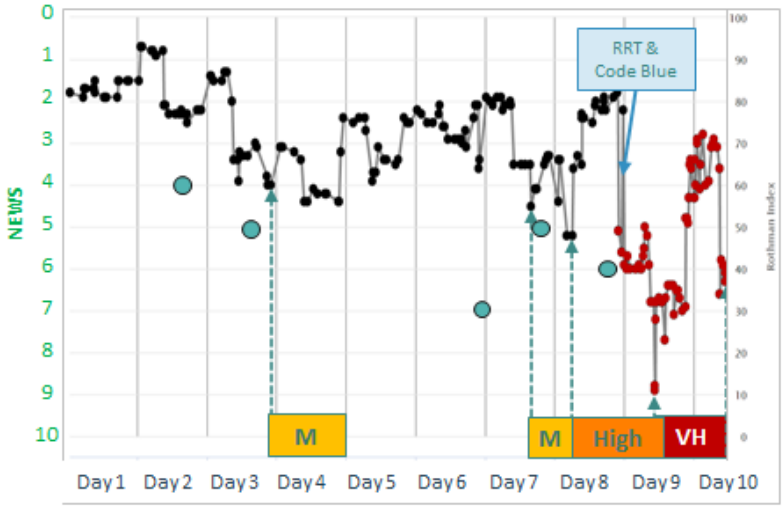


Figure 1 - Rothman Index versus NEWS

OPERATIONAL COMPARISON: PEWS, MEWS, NEWS, AND THE ROTHMAN INDEX

Types of Data Included	PEWS (inputs vary)	MEWS (5 indicators)	NEWS (7 indicators)	Rothman Index Score (26 indicators)
Visualization	Minimal visualization. Single number, sometimes color coded for acuity	Minimal visualization. Single number, sometimes color coded for acuity	Minimal visualization. Single number, sometimes color coded for acuity	Graphical visualization of patient condition, in the moment and trended over time
Units Covered	Med/Surg only	Med/Surg only	Med/Surg only	All units including ICU
Input/Calculation Approach	Nurse must enter data; sometimes automation is available through EHR	Nurse must enter data; sometimes automation is available through EHR	Nurse must enter data; sometimes automation is available through EHR	No additional data entry; automatically pulled from EMR
Frequency	3-5 points per day	3-5 points per day	3-5 points per day	10-20+ points per day
Warnings	Warnings based on thresholds passed due to vitals	Warnings based on thresholds passed due to vitals	Warnings based on thresholds passed due to vitals	Warnings based on changes in physiologic state, ability to trigger based on score and trend

COMPARISON OF THE ROTHMAN INDEX TO MEWS AND NEWS

In a head-to-head comparison of the Rothman Index to MEWS, the RI demonstrated superior sensitivity and specificity. Separate investigations have similarly sought to compare the RI to the NEWS score, including one study at a major Northeast academic medical center that included months of patient data across four hospitals, and a second study involving a three hospital system in the South Atlantic region that encompassed more than 29,000 patient visits. These studies also found that the wide range of clinical and nursing assessment data synthesized in an automated, real-time manner, enables the RI to identify at-risk patients sooner with fewer false positives.

PREDICTING 24-HOUR MORTALITY

A common measure of effectiveness is the ability to predict 24-hour mortality. To assess this measure, the Area Under the Curve (AUC) is calculated. The AUC is a combined measure of sensitivity and specificity – the likelihood of identifying patients that will die within 24 hours, but not falsely flagging those patients who won't. The average AUC values found from the studies mentioned above are shown in the table below.

Prediction of 24-hour mortality[6]

System	AUC	
Rothman Index	.93	Better
NEWS	.87	
MEWS	.82	Worse

While these numbers may not appear to vary dramatically, the difference in statistical terms is substantial and has important practical ramifications when it comes to clinical utility. The Rothman Index has the best AUC, since it uses most of the same inputs as NEWS, as well as dozens of additional clinical inputs, including nursing assessments, lab values, and heart rhythm.

Not only does the very first Rothman Index score calculated for a patient provide insight into their current acuity levels, but the first Rothman Index score also correlates well with the likelihood of important outcomes, including length of stay, costs, and readmissions. Thus, as another measure of comparative effectiveness, one can take the first Rothman Index score and the first NEWS score for a population of patients and determine how well each predicts the likelihood of patient mortality during the course of hospitalization. An analysis of data from the South Atlantic regional medical system mentioned above found that the first RI score had an AUC of 0.91 (excellent) whereas the first NEWS score had a predictive AUC of 0.81 (fair).

ACTIONABLE ALERTS

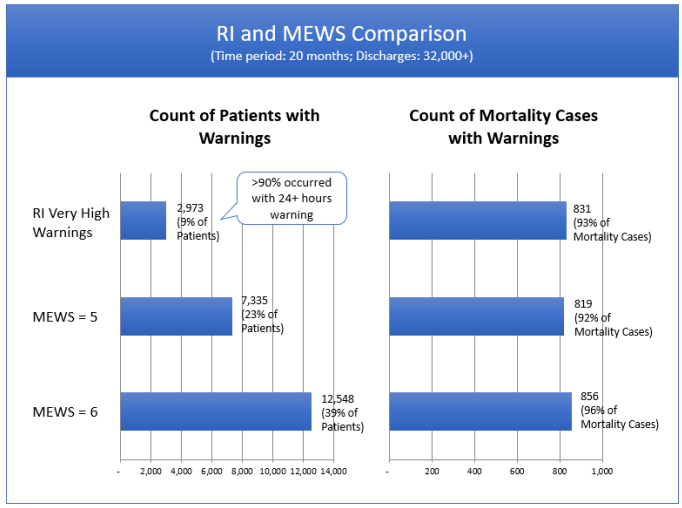
Ultimately, the most important determinant of the utility of an early warning system is how actionable it would be in practice. To assess this, Rothman Index scores and MEWS scores were calculated for all adult medical/surgical inpatients (excluding critical care patients) at a West Coast regional medical center (20 months of data covering over 32,000 patient visits was included). A Very High Warning was set for RI < 20, and threshold MEWS scores were compared in their ability to flag patients who expired during their admission. It can be seen from the figure below (Figure 2) that the number of expired patients correctly flagged by the RI warning falls somewhere between the number correctly flagged by a MEWS score of 4 and a MEWS score of 5. In other words, this particular Rothman Index warning level and these MEWS thresholds have a similar sensitivity (i.e., a similar true positive rate).

However, as Figure 2 also shows, the total number of patients that trigger a MEWS score of 5 or 4 is two to four times higher, respectively, than the number of patients who trigger the Rothman Index warning. As a simple predictor of mortality, MEWS has a much lower specificity than the Rothman Index and triggers much more often.

In practical terms, this results in a much higher false positive rate. False positives lead to alarm fatigue and undermine the value of a warning system. It is evident that in this comparison Rothman Index is a significantly better predictor of mortality. Time of prediction prior to a clinical event is also important, and this analysis showed that over 90% of Rothman Index warnings on patients who ultimately expire are triggered 24+ hours prior to the patient's death.

Results from the analysis of data provided by the South Atlantic regional medical system reflects a similar finding for NEWS (again focusing on all adult inpatients outside of the ICU). The Rothman Index not only correctly identified 27% more patients who expired during their hospital stay, but did so while flagging less than a third as many patients overall. The difference in the false positive rate is significant.

Numerous hospitals have discontinued their use of MEWS, NEWS or PEWS in favor of the Rothman Index, and have seen dramatic improvements in patient outcomes as a result. In 2020, North-Bay Health, which had been using MEWS within their Cerner EHR system decided to switch to the Rothman Index. "[MEWS] was not real-time and was not working well," said Natalie Correll-Yoder, MN, CCRN, CCNS, Clinical Nurse Specialist/Clinical Practice Manager. Heather Resseger, MSN, RN, CNL, CPHQ, Chief Nursing Officer, said, "We are a Magnet facility that emphasizes education and evidence-based practice and research. It resonates with our culture for our staff to be able to speak the same language using the RI to highlight when we need to do something to prevent an event."



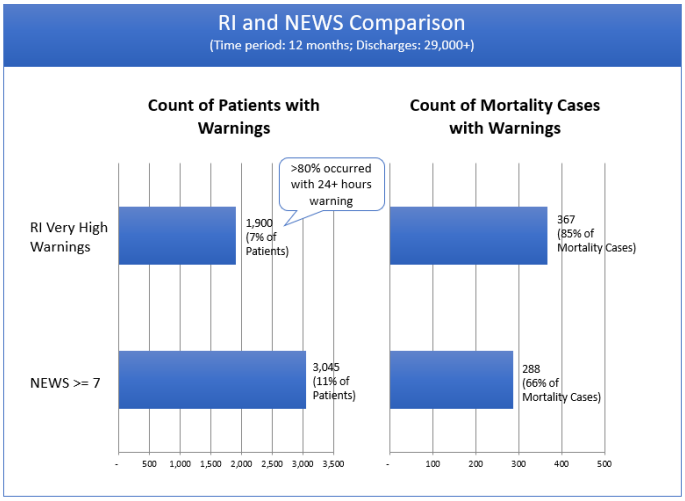


Figure 2

Spacelabs' solutions provide a clear, timely, and holistic representation of the patient's clinical condition, offering significant advancement over vital sign monitoring tools. The Rothman Index clinical surveillance platform can be incorporated into clinical workflow in a manner that minimizes burden on nurses and physicians in order to provide powerful, clinically actionable insights for patients throughout the hospital.

REFERENCES

1 J. S. Murray, L. A. Williams, S. Pignataro, and D. Volpe, “An Integrative Review of Pediatric Early Warning System Scores,” Pediatr. Nurs., vol. 41, no. 4, pp. 165–174, Aug. 2015.

2 Royal College of Physicians. National Early Warning Score (NEWS): Standardisingthe assessment of acute- illness severity in the NHS. Report of a working party. London: RCP, 2012.

3 GB Smith, D.R. Prytherch, P. Meredith, P.E. Schmidt, P.I. Featherstone, “The ability of the National Early Warning Score to discriminate patients at risk of early cardiac arrest, unanticipated intensive care unit admission, and death,” Resuscitation, 84 p.p. 465-470, 2013.

4 M. J. Rothman, A. B. Solinger, S. I. Rothman, and G. D. Finlay, “Clinical implications and validity of nursing assessments: a longitudinal measure of patient condition from analysis of the Electronic Medical Record,” BMJ Open, vol. 2, no. 4, 2012.

5 G. Douw, L. Schoonhoven, T. Holwerda, G.H. Waal, A.R.H. van Zanten, T. van Achterberg, and J.G. van der Hoeven, “Nurses’ worry or concern and early recognition of deteriorating patients on general wards in acute care hospitals: a systematic review,” Crit. Care, vol. 19, no. 2 2015.

6 G. D. Finlay, M. J. Rothman, and R. A. Smith, “Measuring the modified early warning score and the Rothman index: advantages of utilizing the electronic medical record in an early warning system,” J. Hosp. Med., vol. 9, no. 2, pp. 116–119, Feb. 2014.

www.spacelabshealthcare.com

35301 SE Center Street, Snoqualmie, WA 98065 | T: +1 425 396 3300 | F: +1 425 396 3301

SPACELABS HEALTHCARE

An OSI Systems Company