Abstract

Background: Early warning scores detect patients at risk of deterioration in hospital. Our objective was to first, demonstrate that the admission Hamilton Early Warning Score (HEWS) predicts critical events and second, estimate the workload required to identify critical events during hospitalization.

Methods: We prospectively identified a consecutive cohort of medical/surgical patients for retrospective review. Critical events were defined as a composite of inpatient death, cardio-pulmonary arrest or ICU transfer. Likelihood of a critical event during hospitalization and the number needed to evaluate to detect a critical event was based on highest admission HEWS.

Results: We found 506 critical events occurred in 7130 cases. HEWS identified graduated levels of risk at admission. We found 2.6 and 1.8 patients needed to be evaluated in the 'high-risk' and very 'high-risk' subgroups to detect a critical event.

Conclusions: HEWS identified patients at risk for critical events during hospitalization at ward admission. Few patients with high HEWS required evaluation to detect a critical event.

Résumé

Contexte : Les scores d'alerte précoce permettent de dépister les patients à risque de détérioration à l'hôpital. Notre objectif était de démontrer, d'une part, que le Hamilton Early Warning Score (HEWS) permet de prédire les épisodes critiques et, d'autre part, évalue la charge de travail nécessaire pour reconnaître les épisodes critiques au cours d'une hospitalisation.

Méthode : Nous avons déterminé de manière prospective une cohorte de patients en vue d’un examen rétrospectif. Les épisodes critiques ont été définis comme étant soit le décès du patient hospitalisé, un arrêt cardio-respiratoire ou un transfert au service de soins intensifs. La probabilité qu'un épisode critique survienne durant l'hospitalisation et le chiffre nécessaire pour prévoir un épisode critique ont été basés sur les scores HEWS les plus élevés à l'admission.

Résultats : Nous avons recensé 506 épisodes critiques survenus pour 7130 cas suivis. Le HEWS a permis de déterminer les niveaux de risque à l'admission. Nous avons fait ressortir que les patients ayant un score de 2,6 et de 1,8 devaient être classés dans les sous-groupes respectifs à « risque élevé » et à « risque très élevé » en ce qui a trait à la probabilité d’un épisode critique.

Conclusions : Le HEWS permet de cibler dès leur admission les patients à risque d'épisodes critiques durant l'hospitalisation. Peu de patients ayant un HEWS élevé ont fait l'objet d'une évaluation pour un épisode critique.
In-hospital emergency systems are designed to detect and respond to unexpected clinical deterioration. These systems are composed of an afferent arm and an efferent arm. The role of the afferent arm is to detect patients at risk of decline while the efferent arm delivers critical care assessment and treatment. Early warning scores may improve outcomes by standardizing and automating the detection arm of the system.1

The Hamilton Early Warning Score (HEWS) was created based on all available scores in literature but also incorporated delirium assessment, adjusted blood pressure thresholds and accounted for variable oxygen delivery (see Table 1). Our objective was to first, demonstrate that the admission HEWS predicts critical events during hospitalization and second, estimate the workload required to identify critical events.

**Methods**

**Study Design, Setting, and Patient Description**

We prospectively identified a consecutive cohort for retrospective chart review over 6 consecutive months in 2014. The study included patients admitted to the medical and surgical wards at the 2 academic hospitals affiliated with the Hamilton Health Sciences. HEWS was built into the electronic medical record at both centres. Mandatory electronic vital sign documentation was implemented to facilitate HEWS use. Patients were included into the study if they were admitted to the medical or surgical floor at the study hospitals. We defined 4 points of entry to the ward: the emergency department, post-ICU discharge, post-operating room and other.

**Ethics**

We received ethics approval from the Hamilton Integrated Research Ethics Board (13-724-C).

**HEWS Ramp-Up Protocol**

HEWS was based on a ramp-up response system. For a score of 3 or greater, the bedside nurse increased the frequency of monitoring and alerted the charge nurse. For a score 4 or greater, a junior resident was called to assess, while at a score 5 or greater, a senior resident and/or the rapid response team was called to assess. The most responsible physician was made aware of all scores greater or equal to 6.

**Data Collection**

Demographic data was recorded and pertinent history was reviewed to calculate a Charlson Co-Morbidity Index (CCI). All charts were reviewed for a critical event identified as an inpatient death, inpatient arrest or ICU transfer. Inpatient deaths included all deaths occurring in hospital except patients specifically admitted for palliation. Inpatient arrests included ventricular tachycardia, ventricular fibrillation, pulse-less electrical activity, or respiratory arrests. ICU transfers were specifically unexpected ICU transfers and excluded patients transferred to the ICU for post-operative monitoring. Critical events were mutually exclusive. As such, a patient may have experienced both an inpatient arrest and inpatient death. This counted toward 2 outcomes. The highest, complete HEWS within a 24-hour window was calculated for all patients at time of admission to the ward. Data were documented as missing if the pre-specified vital signs required to calculate HEWS was incomplete.

**Analysis**

The demographic data, CCI and HEWS at time of admission were compared between patients who had a critical event and those who had an event-free hospitalization. Comparison was made across 4 groups of patients, low risk (HEWS 0–2), moderate risk (HEWS 3–5), high risk (HEWS 6–8) and very high risk (HEWS > 9). Likelihood ratios were calculated for any critical event during hospitalization based on admission HEWS. Additionally, a positive predictive value (PPV) and its inverse, which was defined as the number of cases needed to be evaluated (NNE) to detect a critical event was calculated based on admission HEWS.2

<table>
<thead>
<tr>
<th>Table 1. The Hamilton Early Warning Score</th>
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<tbody>
<tr>
<td>3</td>
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<tr>
<td>Heart Rate</td>
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<tr>
<td>Systolic Blood Pressure</td>
</tr>
<tr>
<td>Respiratory Rate</td>
</tr>
<tr>
<td>Temperature</td>
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<tr>
<td>Oxygen Saturation</td>
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<td>Oxygen Delivery</td>
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</table>

Neurologic status based on CAM, Confusion Assessment Method Tool and AVPU assessment with outlines the patient’s responsiveness to stimuli.
Results

Patient Characteristics
We found 506 critical events occurred in 7130 cases over a six-month period (Table 2). We excluded 74 patients due to insufficient data from the HEWS score. The majority of critical events were either death (49.3% of all critical events), or unanticipated ICU transfer (44.0% of all critical events). The inpatient arrest rate was 4.95 arrests/1000 hospital admissions. We found that patients with critical events were more likely to be older, male, and have other co-morbidities.

Characteristics of the Admission HEWS
We used HEWS to stratify risk for critical event during hospitalization based on initial ward presentation (Table 3). We found that the high-risk group and very high-risk group comprised only 4% of patients admitted to the ward (261/7130). High-risk patients were much more likely to have a critical event than low-risk patients. The number needed to evaluate analysis revealed 1 critical event would be detected for every 2.6 cases evaluated in the high-risk group and 1.8 cases evaluated in the very high-risk group. Conversely, a low-risk HEWS and a moderate risk HEWS was associated with a reduced risk of a critical event during hospitalization.

Discussion
We found that HEWS at the time of ward admission predicted the risk of a critical event during hospitalization. Moreover, only 2.6 cases and 1.8 cases needed to be evaluated in the high-risk group and very high-risk group to potentially prevent a critical event. Our work showed that the initial vital signs at the time of ward admission predicted the risk of critical event during hospitalization. Similar work had been demonstrated with the National Early Warning Score and the Abbreviated VitalPac Early Warning Score (ViEWS).3,4 Identifying patients at high risk of deterioration early in hospitalization provides a method for rapid response teams and ward healthcare teams to organize and allocate resources necessary to meet patient acuity.

In order to determine workload, we studied the number of cases that needed to be evaluated to detect a critical event. This is based on the seminal work published by Romero-Brufau et al who outlined a method of using the PPV to evaluate early...
Conclusions

HEWS identified patients at risk for critical events at the time of ward admission. Few patients with elevated HEWS required evaluation to detect a critical event. Number needed to evaluate is a method to anticipate resources required to treat a patient at risk of critical illness.

Acknowledgements

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Conflict of Interest and Funding

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References


<table>
<thead>
<tr>
<th>Admission HEWS</th>
<th>Critical Event</th>
<th>Likelihood Ratio (95% CI)</th>
<th>Positive Predictive Value (95% CI)</th>
<th>Number Needed to Evaluate (95% CI)</th>
</tr>
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<tbody>
<tr>
<td>Low Risk 0–2</td>
<td>Yes</td>
<td>222/506 = 0.437</td>
<td>0.56 (0.50–0.61)</td>
<td>25 (22–27)</td>
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<td></td>
<td>No</td>
<td>5201/6624 = 0.785</td>
<td>4.1 (3.7–4.5)</td>
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<tr>
<td>Moderate Risk 3–5</td>
<td>Yes</td>
<td>177/506 = 0.350</td>
<td>1.82 (1.60–2.08)</td>
<td>12.2 (10.9–13.7)</td>
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<tr>
<td></td>
<td>No</td>
<td>1270/6624 = 0.192</td>
<td>8.3 (7.2–9.2)</td>
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HEWS, Hamilton Early Warning Score