

Research, Audit and Clinical Practice

The value of the Modified Early Warning Score and biochemical parameters as predictors of patient outcome in acute medical admissions: a prospective study

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Key Points

- The Modified Early Warning Score (MEWS), helps to recognize patients with established/impending critical illness.
- MEWS is a simple bedside tool that can be used by nursing staff in a busy clinical area.
- The study evaluates effectiveness of MEWS and biochemical parameters in a acute medical setting
- Those with a higher MEWS had a higher chance of reaching adverse end points
- MEWS was not predictive of length of hospital stay
- Biochemical parameters were better than physiological parameters in predicting length of hospital stay and the probability of reaching adverse outcomes
- Incorporating a score for biochemical parameters improved the sensitivity of the model for prediction of adverse outcomes.

Abstract

We evaluated the effectiveness of MEWS and biochemical parameters in predicting outcomes for acute medical admissions. Data from consecutive admissions to the Acute Medical Unit (AMU) of National Hospital of Sri Lanka were collected. C-reactive protein (CRP), albumin, white cell count, platelet count and haemoglobin values were collected. Adverse endpoints were HDU/ICU admission, cardio-respiratory emergency/resuscitation and death.

A MEWS score of ≥ 5 together with increasing age, pulse rate, respiratory rate, AVPU score, CRP, CRP/Albumin ratio and reduced platelet and albumin level all increased the odds of reaching 'adverse endpoints'. Adding a score for biochemical parameters increased the area under the ROC curve for reaching 'adverse endpoints'. Biochemical parameters better predicted length of hospital-stay and adverse outcomes. A combined scoring system improved the sensitivity of prediction.

Keywords

MEWS; Biochemical parameters; Acute Medical Admissions; Prediction of outcomes.

Background

Patients admitted to hospitals are liable to sudden deterioration in their clinical condition, which sometimes results in unexpected morbidity and mortality.^{1,2} Catastrophic deterioration of patients in hospital is frequently preceded by documented deterioration of physiological parameters.³⁻⁵ Clinicians have developed scoring systems to facilitate detection of potentially serious patients in a

ward setting. The Acute Physiology and Chronic Health Evaluation (APACHE) II Score,⁶ Mortality Probability Model (MPM)⁷ and The Simplified Acute Physiology Score (SAPS)⁸ were thus developed with the aim of predicting such deteriorations. However most of these scoring systems were developed and validated on subgroups involving mainly surgical patients, limiting their utility as bedside assessment tools in general acute medical admissions.⁹

The Modified Early Warning Score (MEWS) is a track and trigger scoring system based on simple routine bedside physiological observations.¹⁰⁻¹² MEWS was originally developed with the aim of facilitating timely recognition of patients with established or impending critical illness and to empower nurses and junior medical staff to secure experienced help through the operation of a trigger threshold which, if reached, requires mandatory attendance by a more senior member of staff.¹¹

However, there are conflicting data on the applicability of MEWS to undifferentiated medical patients admitted to an AMU setting. One study demonstrated no relationship between MEWS score and in-hospital deaths, while another has reported correlations with mortality and length of stay.^{12,13} Studies have also looked at the possibility of using markers of acute and chronic disease to assess prognosis in comparison with the use of MEWS to see if either offers benefits to clinical practice.¹⁴⁻¹⁷ A raised CRP generally suggests an acute infective or inflammatory process, while a low albumin is most

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often associated with chronic disease in addition to being a marker of the acute phase response.^{18,19} Thus these biochemical parameters could have a predictive value individually and when considered together. In addition these investigations are readily available, and are often performed automatically as part of an admission profile in many acute care settings worldwide.

The aims of the present study are to:

1. Evaluate the use of MEWS in predicting outcomes of 'unselected' acute medical admission to a tertiary care hospital in Sri Lanka.
2. Understand the predictive strength of haematological and biochemical parameters (white cell count, platelet count, haemoglobin, serum CRP, serum albumin, CRP/albumin ratio) in this group of patients.
3. Compare effectiveness of biochemical vs. physiological parameters on prediction of outcomes.
4. Evaluate the sensitivity of a scoring system involving both physiological and biochemical parameters for acute 'unselected' medical admissions.

Methods

Sampling

This prospective follow-up study was conducted at the National Hospital of Sri Lanka (NHSL). Data from 250 consecutive medical emergency admissions to the Medical Admissions Unit of the NHSL were collected during a period of one month in June 2009. Situated in Colombo, the NHSL is a tertiary care unit with approximately 3000 beds.²⁰ Patients admitted directly to Coronary Care Unit, Medical High Dependency Unit (HDU), Intensive Care Unit (ICU) and patients re-admitted during the observation period were not included in this study. Patients who declined participation were also excluded from the study (6 patients). Informed written consent was obtained from all study participants or relatives when patients were not fit to give informed consent. Ethical approval for the study was obtained from the Ethics Review Committee, Faculty of Medicine, University of Colombo.

Data Collection

The data were collected from consenting patients using identical methodology by the authors at the time of

admission. Patients were consecutive and unselected. Initial information recorded included age, gender, date and time of admission, past illnesses, reason(s) for admission and their baseline MEWS score at time of admission using verified criteria (Table 1). Blood pressure was measured manually using Accoson Dekamet mercury sphygmomanometers (AC Cossor & Son (Surgical) Ltd, London, UK) to the nearest two mmHg. Oral temperature was recorded using oral mercury thermometers to the nearest 0.1°C. The respiratory and pulse rates were counted over a full minute. AVPU scores were recorded as the best response at the time of other measurements.

Blood was drawn at the time of admission for estimation of C-reactive protein (CRP), albumin, white blood cell count, platelet count and haemoglobin values. Serum CRP levels were measured using a highly sensitive CRP assay (Latex-Enhanced high sensitivity reagent, BioSystems S.A. Barcelona, Spain). The sensitivity of the assay ranged from 0.06–15.0 mg/l. Serum albumin was measured by Albumin Bromocresol Green method (BioSystems S.A. Barcelona, Spain). All biochemical analysis was performed at a laboratory with ISO 9000:2000 certification.

Recruited patients were followed up to evaluate for primary endpoints which were medical HDU/ICU admission, cardio-respiratory emergency/resuscitation, death and hospital discharge (Length of hospital stay). For analytical purposes the adverse individual endpoints were combined into one group called 'Combined adverse outcomes'. The relationship between measured parameters and 'Combined adverse outcomes' were then analyzed. HDU and ICU admission were at the discretion of the attending physicians, who were unaware of the MEWS of the patient.

Statistical Analysis

Statistics were generated using SPSS version 14.0 (SPSS Inc., Chicago, IL, USA). The data were analysed to show the distribution of all patients' MEWS scores at admission and correlation with primary end points. MEWS scores and primary end points were also compared against acute (CRP), chronic (albumin) markers of disease, CRP/albumin ratio, white cell count, platelet count and haemoglobin levels to assess potential correlation.

A linear regression analysis was performed with 'Length of hospital stay' as the continuous dependent variable and age, gender, systolic blood pressure, pulse rate, respiratory rate, temperature, AVPU Score, MEWS, white

	3	2	1	0	1	2	3
Systolic blood pressure (mmHg)	≤70	71-80	81-100	101-199		≥200	
Heart rate (bpm)		<40	41-50	51-100	101-110	111-129	≥130
Respiratory rate (bpm)		≤ 8		9-14	15-20	21-29	≥30
Temperature (°C)		<35		35-38.4		≥38.5	
AVPU				A	V	P	U

Table 1. Modified Early Warning Score..

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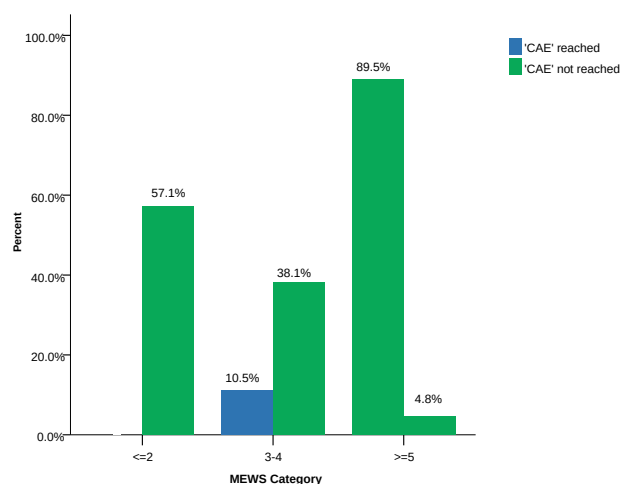


Figure 1. 'Combined Adverse Endpoints' (CAE) reached and not reached in different categories of MEWS.

cell count, platelet count, albumin level, CRP level, CRP/albumin ratio and haemoglobin level as the independent variables (co-variants). A binary logistic regression analysis was performed using the dichotomous variable 'Combined adverse outcomes' as the dependant factor and above mentioned independent variables. In all statistical analyses p values < 0.05 were considered significant.

Results

During the observation period, data were collected from 250 admissions. Patients with incomplete epidemiological or discharge data were excluded. Complete sets of data were available for 242 admissions, which were analysed further. The mean age of patients was 49.4 years (SD $\pm$ 18.7, range 15–99) and 48.3% (n=117) of patients were males.

A wide range of diagnoses were represented across the spectrum of acute admissions with the most common categories being sepsis (25.4%), acute chest pain (18.4%), exacerbation of airways disease (12.3%), renal failure (6.1%), elevated blood pressure (4.4%) and acute cerebrovascular disease (4.4%). During follow-up, twelve patients were admitted to ICU/HDU, none were successfully resuscitated by the cardiopulmonary arrest team and six patients died. All other patients were discharged either directly from the AMU or from the respective medical wards. The length of hospital stay in those patients ranged from 1–21 days (median 2 days).

Mean values of measured physiological parameters on admission were as follows: systolic blood pressure 124 mmHg (SD $\pm$ 24 mmHg), pulse rate 86 bpm (SD $\pm$ 20 bpm), respiratory rate 24 bpm (SD $\pm$ 7 bpm), temperature 36.8 °C (SD $\pm$ 0.9 °C). The median AVPU score was 1 (Alert). Admission MEWS scores ranged from 0 to 8 (median of 2). The mean white cell count, platelet count and haemoglobin level was 10.3 $\times$ 10⁹/l (SD $\pm$ 6.4 $\times$ 10⁹), 274 $\times$ 10⁹/l (SD $\pm$ 121 $\times$ 10⁹) and 12.2 g/dl (SD $\pm$ 2.4) respectively. The mean CRP and albumin level was 12.55 mg/l (SD $\pm$ 19.20) and 39.0 g/l (SD $\pm$ 7.6) respectively. The mean value of the CRP/albumin ratio was 0.37 (range 0.00–2.89).

Incidence of reaching 'Combined Adverse Endpoints' increased with rising MEWS scores, from 0% in patients with scores of 0 to 2, to 61.5% for those with scores of 5 or more. Out of all patients reaching 'Combined Adverse Endpoints' 89.5% were in the MEWS category of $\geq$ 5 (Figure 1).

Patients who reached combined adverse endpoints were significantly older and on admission had higher pulse rate and a higher respiratory rate. They also had a higher CRP level, lower albumin level and lower platelet count. The mean CRP/albumin ratio of patients reaching

	Combined adverse endpoint		<i>p</i>
	Not reached ($\pm$ SD)	Reached ($\pm$ SD)	
<i>n</i>	224	18	41-50
Age (years)	48 ($\pm$ 18.6)	64 ($\pm$ 13.1)	<0.01
Systolic blood pressure (mmHg)	124 ($\pm$ 24)	127 ($\pm$ 26)	NS
Pulse rate (bpm)	85 ($\pm$ 18)	104 ($\pm$ 30)	<0.01
Respiratory rate (min ⁻¹)	24 ($\pm$ 6)	30 ($\pm$ 6)	<0.01
Temperature (°C)	36.8 ($\pm$ 1)	37.2 ($\pm$ 1)	NS
Albumin	39.7 ($\pm$ 7.3)	31.7 ($\pm$ 8.6)	<0.01
CRP	11.6 ($\pm$ 19.1)	23.1 ($\pm$ 18.9)	<0.05
CRP/Albumin ratio	0.33 ($\pm$ 0.56)	0.79 ($\pm$ 0.63)	<0.05
White cell count	10.3 ($\pm$ 6.5)	10.3 ($\pm$ 4.8)	NS
Platelet count	283.88 ($\pm$ 118.07)	164.67 ($\pm$ 107.40)	<0.01
Haemoglobin	12.2 ($\pm$ 2.5)	11.7 ($\pm$ 1.9)	NS

Table 2. Comparison of measured parameters of patients reaching/not reaching endpoints.

NS = not significant

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	Standardized β -coefficient (Standard error)	p value
Gender		
Female	0	
Male	0.053 (0.677)	0.625
Age	0.314 (0.021)	<0.05
Systolic blood pressure	0.258 (0.015)	<0.05
Pulse rate	0.210 (0.021)	<0.05
Respiratory rate	0.202 (0.064)	<0.05
Temperature	0.214 (0.395)	<0.05
AVPU Score		
Alert	0	
Voice	0.191 (0.294)	<0.05
Pain	0.187 (0.278)	<0.05
MEWS		
MEWS <5	0	
MEWS $\geq$ 5	0.148 (0.402)	0.377
Albumin	-0.560 (0.069)	<0.05
CRP level	0.487 (0.101)	<0.05
CRP/albumin ratio	0.436 (0.065)	<0.05
White cell count	0.408 (0.056)	<0.05
Platelet count	-0.385 (0.003)	<0.05
Haemoglobin	0.319 (0.065)	<0.05

Table 3. Linear regression analyses of length of hospital stay and measured parameters.

‘Combined adverse endpoints’ and not reaching ‘Combined adverse endpoints’ were 0.79 (SD $\pm$ 0.63) and 0.33 (SD $\pm$ 0.56) respectively, which was statistically significant ($p < 0.05$) (Table 2).

There was a significant correlation between MEWS and individual values of CRP ($r = 0.19$, $p < 0.05$), albumin ($r = -0.25$, $p < 0.01$) and CRP/albumin ratio ($r = 0.22$, $p < 0.05$). The correlation between MEWS and length of hospital stay was poor with an insignificant correlation coefficient of 0.04. The overall correlation of the length of hospital stay with individual values of CRP ($r = 0.22$), albumin ($r = -0.29$) and CRP/albumin ratio ($r = 0.20$) was significant ($p < 0.05$).

The linear regression model explained 20.4% of the variance in length of hospital stay ($R^2 = 0.204$). The analysis of variance revealed that the final model was significant ($F_{14,90} = 1.58$, $p < 0.05$). In all patients, albumin level was the strongest predictor of duration of hospital stay ($\beta = -0.560$, $p < 0.05$), followed by CRP level, CRP/albumin ratio, white cell count, platelet count, haemoglobin level, age, systolic blood pressure, temperature, pulse rate, respiratory rate and AVPU Score. MEWS and gender were not significant predictors of length of hospital stay (Table 3).

A binary logistic regression using the same independent variables as above was used to predict the likelihood of patients reaching ‘Combined adverse endpoints’. Except gender, systolic blood pressure, temperature, white cell count and haemoglobin, all other

independent variables were significant predictors of patients reaching ‘Combined adverse endpoints’ (Table 4). A MEWS of ≥ 5 together with increasing age, pulse rate, respiratory rate, AVPU score, CRP level and CRP/Albumin ratio all significantly increased the odds of reaching ‘combined adverse end points’. An increasing platelet count and albumin level reduced the odds of reaching ‘combined adverse end points’.

The effects of adding a score for biochemical parameters to MEWS was analysed by using Receiver Operator Characteristic curves. Albumin level, CRP level and CRP/Albumin ratio were classified into 4 equal categories and each category were given a score (Table 5). By adding a score for biochemical parameters, the area under the ROC curve increased from 0.68 ± 0.06 to 0.87 ± 0.02 ($P = 0.0097$) for reaching combined adverse endpoints (Figure 1).

Discussion

The National Institute for Health and Clinical Excellence recommends the use of a track and trigger tool for the triage of acutely ill patients admitted to hospital.²¹ We have demonstrated that raised MEWS scores (MEWS ≥ 5) was associated with increased probability of reaching an adverse outcome in a group of unselected medical emergency admissions. However, there were clear limitations in the predictive value of MEWS in comparison to biochemical parameters, which has not previously been reported.

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	Wald statistic	Exp (β)	p value
Gender			
Female (reference category)			
Male	0.016	1.001	>0.05
Age	16.401	1.751	<0.05
Systolic blood pressure	0.065	0.902	>0.05
Pulse rate	8.658	1.587	<0.05
Respiratory rate	3.765	1.539	<0.05
Temperature	1.141	0.717	>0.05
AVPU Score			
Alert (reference category)			
Voice	3.120	1.720	<0.05
Pain	2.156	1.534	<0.05
MEWS			
MEWS <5 (reference category)			
MEWS ≥5	5.214	1.857	<0.05
Albumin	6.137	0.587	<0.05
CRP	4.212	1.949	<0.05
CRP/albumin ratio	5.356	1.548	<0.05
White cell count	1.213	0.932	>0.05
Platelet count	3.756	0.610	<0.05
Haemoglobin	0.390	0.820	>0.05

Table 4. Logistic regression analyses of reaching 'Combined adverse end points' & measured parameters.

	Category	Score	Frequency (%)
Albumin (g/l)	> = 44.2	0	61 (25.2%)
	40 - 44.1	1	61 (25.2%)
	35.4 - 39.9	2	60 (24.7%)
	≤ 35.3	3	60 (24.7%)
CRP (mg/l)	≤ 0.82	0	60 (24.7%)
	0.83 - 2.88	1	61 (25.2%)
	2.89 - 14.82	2	60 (24.7%)
	≥ 14.83	3	61 (25.2%)
CRP/Albumin ratio	≤ 0.02	0	60 (24.7%)
	0.03 - 0.08	1	61 (25.2%)
	0.09 - 0.42	2	61 (25.2%)
	≥ 0.43	3	60 (24.7%)

Table 5. Scoring categories of biochemical parameters and the respective scores.

A raised CRP generally suggests an acute inflammatory process,¹⁸ while a low albumin is most often associated with chronic disease, often linked with nutritional deficiency. Although these investigations are readily available in developed countries and are often performed automatically as part of the admission profile, their availability is limited in developing countries such as Sri Lanka. Both CRP and albumin showed strong individual correlations with MEWS scores, and the ratio of CRP/albumin also correlated well with MEWS. We also demonstrate the association of the

platelet count with adverse outcomes of acute medical admissions. Previous studies have demonstrated a relationship between thrombocytopenia and adverse outcome in acute coronary syndrome.²² Unlike the other biochemical parameters it is freely available even in developing countries thus increasing its values as a predictor of patients' outcome. However, its usefulness may be related to the relative contribution of conditions characterized by thrombocytopenia, such as dengue fever, and may vary with geographic location.

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MEWS did not correlate well with the length of hospital stay. However, the measured biochemical parameters such as CRP, albumin, CRP/Albumin ratio, white cell count, platelet count and haemoglobin all correlated strongly with the length of hospital stay. Incorporating a score for the 3 biochemical parameters with the strongest prediction capability (CRP, albumin and CRP/albumin ratio) significantly improved the predictive value and sensitivity of the model for prediction of adverse outcomes. However MEWS can be used as a monitoring tool more frequently and this advantage is not present with biochemical parameters.

While the MEWS used in this study did identify some of the patients at increased risk, alterations in the scoring table (e.g. different blood pressure values, respiratory rate) might improve the fit of the score to clinical outcomes. Case mix may be one important factor, and the score may be more predictive if different banding criteria are used for broad ranges of conditions e.g. respiratory disease, cardiac disease. However, MEWS is based on simple routine bedside physiological observations and the integration of the diagnosis into a scoring system might diminish its usefulness by making it too complex.

To prioritize scarce ICU/HDU resources, and promote patient safety it would be valuable to identify patients who would benefit from admission to these units, as well as those whose admission could be prevented by changes in management in the ward. As patients with critical scores ≥ 5 in this study were at increased risk of catastrophic deterioration, MEWS is a helpful screening tool to triage patients for intensified treatment on the ward or in ICU/HDU. Incorporating biochemical parameters

further enhances the predictive value of the model. These simple low-cost investigations should be readily made available for all patients or at least to patients having a higher MEWS on admission.

Our study was limited by several factors. It is a single-centre study on a limited number of patients in a specific local setting. Due to financial constraints and technical reasons we were unable to collect data from a larger population of patients. However, the study findings can serve as cornerstones for further multi-centered studies involving a larger number of patients. In addition further studies are required to see whether identification of critically ill patients, selection of a higher level of care and consecutive changes in management affect outcome in this patient group. The importance of biochemical parameters such as white cell count, platelet count and haemoglobin in predicting patient outcome is another area which requires further study in order to determine whether there are cut-off values which should trigger senior assessment and/or ICU/HDU management.

Competing Interests

The authors declare that they have no competing interests

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