



Clinical paper

Is the Modified Early Warning Score (MEWS) superior to clinician judgement in detecting critical illness in the pre-hospital environment?☆

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ABSTRACT

Aim: Physiological track and trigger scores have an established role in enhancing the detection of critical illness in hospitalized patients. Their potential to identify individuals at risk of clinical deterioration in the pre-hospital environment is unknown. This study compared the predictive accuracy of the Modified Early Warning Score (MEWS) with current clinical practice.

Methods: A retrospective observational cohort study of consecutive adult (≥ 16 yrs) emergency department attendances to a single centre over a two-month period. The outcome of interest was the occurrence or not of an adverse event within 24 h of admission. Hospital pre-alerting was used as a measure of current critical illness detection and its accuracy compared with MEWS scores calculated from pre-hospital observations.

Results: 3504 patients were included in the study. 76 (2.5%) suffered an adverse event within 24 h of admission. Paramedics pre-alerted the hospital in 224 cases (7.3%). Clinical judgement demonstrated a sensitivity of 61.8% (95% CI 51.0–72.8%) with a specificity of 94.1% (95% CI 93.2–94.9%). MEWS was a good predictor of adverse outcomes and hence critical illness detection (AUC 0.799, 95% CI 0.738–0.856). Combination systems of MEWS and clinical judgement may be effective MEWS ≥ 4 + clinical judgement: sensitivity 72.4% (95% CI 62.5–82.7%), specificity 84.8% (95% CI 83.52–86.1%).

Conclusions: Clinical judgement alone has a low sensitivity for critical illness in the pre-hospital environment. The addition of MEWS improves detection at the expense of reduced specificity. The optimal scoring system to be employed in this setting is yet to be elucidated.

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1. Introduction

Ambulance crews and pre-hospital clinicians often represent the first point of contact with medical services. In the pre-hospital environment key decisions regarding commencement of therapy and both priority and destination of patient transfer are often made in the absence of full clinical information, by staff with varying degrees of training and expertise. Such judgements are largely based on subjective processes, clinical experience and are rarely evidence based.^{1–3}

Several studies have raised concern that the severity of a patient's illness, especially those presenting with medical

(non-trauma) pathology, is currently being overlooked by pre-hospital staff.^{1,4,5} Subsequent transfer to hospitals with limited critical care resources and experience, or delayed identification and referral to critical care following arrival may ensue, with associated adverse outcomes.^{6–8} This is in sharp contrast to pathology-specific protocols, such as stroke or myocardial infarction, where diagnoses are often accurately made, appropriate management administered, and patients conveyed to suitable receiving centres with attendant improvements in morbidity and mortality.^{9,10}

'Early warning score' or 'track and trigger systems' aim to aid the timely recognition of patients with potential or established critical illness. They allow the risk of deterioration in heterogeneous groups of patients to be quantified on a numerical scale and, via pre-defined escalation protocols, facilitate objective decision-making to ensure a suitable clinical response.^{11,12} Appropriately derived and validated scores may help to optimise individual patient management through improved risk stratification and prognostication from point of admission: guiding resource allocation and place-of-care whilst simultaneously providing a benchmarking tool for research, audit and standardisation of care across healthcare organisations.⁵

Abbreviations: PTTS, physiological track and trigger system; MEWS, Modified Early Warning Score; ED, emergency department; PRF, patient report form; ICU, intensive care unit.

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The role of physiological track and trigger systems (PTTS) and their implementation in clinical practice has been expanding rapidly under the influence of various political initiatives, healthcare organisations and think-tanks.^{13–16} Their use on both medical and surgical wards is well established^{17–19} if not clearly validated.^{11,12,20} Interest in their role at point of admission is growing, especially in medical patients and those with suspected sepsis, but requires further work to achieve true clinical utility.^{5,21–25} Despite the obvious potential, their role in facilitating more objective evidence-based decision making and triage in the pre-hospital environment has only recently been considered.^{26,27}

1.1. Pre-alerting: a clinical comparison

UK ambulance crews directly or in-directly (via a dispatch centre) pre-alert receiving centres when transporting individuals they determine to be critically unwell or with time-critical pathology.^{28,29} No standardised protocol describing indications for pre-alert to hospitals currently exists and decisions are based on subjective criteria.¹ Ambulance crews' pre-alerting of hospitals thus represents a measure of the current accuracy of clinical detection of critical illness in the pre-hospital environment and offers a paradigm against which alternative methods may be tested.

This study seeks to assess whether one example of an aggregate-weighted PTTS, the Modified Early Warning Score (MEWS),¹⁸ is superior to clinician assessment in detecting critical illness in the pre-hospital environment.

2. Methods

2.1. Design and subjects

A retrospective observational cohort study of consecutive adult attendances (≥ 16 yrs) of all aetiologies to Birmingham Heartlands Hospital between April and June 2010. Heartlands Hospital is an 800 bed inner city NHS hospital in the UK. The Emergency Department (ED) treats approximately 115,000 patients a year. Patients who had clinical observations undertaken and recorded by ambulance staff prior to arrival at hospital were eligible for inclusion. Patients in cardiac arrest (receiving CPR) were excluded, as were those patients that had no clinical observations completed by ambulance staff. The study protocol was reviewed and approved by the Hospital Research Governance Department. They waived the need for Research Ethics Approval given the use of routinely collected data and the non-interventional nature of the study.

2.2. Data collection

Patient records were accessed through the electronic patient management system (MSS Patient First V8.0.1). This contains full patient episode data along with access to individual records and scanned ED and Acute Medical Unit (AMU) documents, including observation charts and ambulance patient report forms (PRF).

2.3. Adverse events and ambulance pre-alerts

Patients pre-alerted to the hospital via ambulance crews were identified via review of the routinely maintained paper alert log in the ED. Alerts issued according to pathology specific protocols (STEMI or FAST-positive) were excluded.

Adverse events were defined as the requirement of immediate operative management, admission to the intensive care unit (ICU), high-dependency unit (HDU) or coronary-care unit (CCU), requirement of a medical emergency team attendance, transfer to tertiary centre for definitive care (clinical emergency, not due to absence of

service provision on-site, e.g. maxillo-facial surgery), cardiac arrest or death.

Correct or accurate pre-alerts were regarded as those where an adverse event subsequently occurred. Incorrect pre-alerts were regarded as those with no subsequent occurrence of an adverse event.

2.4. Modified Early Warning Score (MEWS)

MEWS^{18,30} was selected due to its use of objective routinely collected physiological data and previously demonstrated application in multiple patient populations including the ED. MEWS makes use of the AVPU score (see Table 1) and four physiological readings; systolic blood pressure (mmHg), heart rate (bpm), respiratory rate (RR) and temperature ($^{\circ}\text{C}$). The MEWS score ranges between 0 and 14 and the scoring system employed is shown in Table 1. In this study, scores were calculated from the first set of pre-hospital values taken.

2.5. Statistical analysis

Multiple imputation^{31,32} was used to replace missing values in the pre-hospital observation set. The imputation model was built using a total of 13 variables including the outcome of interest (adverse event). Five imputed datasets were generated and the distributions of the imputed values were checked for plausibility. An assumption of the imputation process is that the data are missing at random (MAR).³² For this dataset, there was evidence that values were more likely to be missing in patients with more serious injuries. However, efforts were made to include a wide range of characteristics in the imputation model in order to make the MAR assumption more reasonable.³²

The primary outcome of interest was whether or not a patient suffered an adverse event within 24 h of admission to the hospital (yes or no). Descriptive statistics, including means (medians) with standard deviations (inter-quartile ranges) and frequencies with percentages, were used to explore the characteristics of the patients in the two outcome groups; 'adverse event' versus 'no adverse event'. The sensitivity and specificity with 95% confidence intervals were calculated for the 'alert' variable to assess the accuracy of using ambulance crew judgement to determine patients at risk of an adverse event.

Individual MEWS scores were calculated for each patient across the five imputed datasets and the overall score for a patient was obtained by taking the mean of the five individual MEWS scores. This amounts to using the method of Rubin for combining estimates after multiple imputation has been used.³¹

The distributions of the MEWS scores in the two outcome groups were visualised using a bar chart. In terms of decision-making, there are multiple potential integer thresholds for determining patients at high risk of an adverse event. Sensitivities and specificities with 95% confidence intervals were calculated for each possible integer cut-point on the MEWS scale and the results were plotted in a receiver operator characteristic (ROC) curve. The area under the curve (AUC) was calculated, with 95% confidence interval, to assess the overall performance of MEWS.

In order to consider the combination of using MEWS with clinical judgement, sensitivities and specificities with 95% confidence intervals were calculated for the situation in which the ambulance crew can override a negative MEWS decision to alert the hospital. This was considered for three separate MEWS cut-points.

All analyses were carried out across the five imputed datasets and both parameter estimates and corresponding standard errors were estimated using the method of Little and Rubin.³¹ Data

Table 1
Modified Early Warning Score (MEWS).

	3	2	1	0	1	2	3
Systolic blood pressure (mmHg)	<70	71–80	81–100	101–199		≥200	
Heart rate (bpm)		<40	40–50	51–100	101–110	111–129	≥130
Respiratory rate (RR)		<9		9–14	15–20	21–29	≥30
Temperature (°C)		<35		35–38.4		≥38.5	
AVPU score				Alert	Reacting to Voice	Reacting to Pain	Unresponsive

cleaning was carried out using SPSS v.18 and analyses were performed in the R statistical software.³³

3. Results

5170 patients were brought to hospital during the study period. 3504 patients had clinical observations undertaken, recorded by ambulance staff and scanned by ED staff making them eligible for study inclusion. Twenty-six (0.7%) patients were excluded due to missing outcome data. Of the 3478 cases remaining, a number of patients had more than one record in the data file due to multiple admissions, as identified by the patient identification numbers. For each patient, only the first record was retained resulting in the exclusion of 421 patient records. This was determined using the date and time of admission. A total of 3057 patient records were therefore included in the analysis. Data were missing (percentage missing) for respiratory rate (2.3%), heart rate (1.9%), temperature (36%), systolic blood pressure (6.0%), oxygen saturation (5.4%) and AVPU (1.2%).

Mean age was 54.9 years (standard deviation 23.8 years), 1545 (50.5%) were female and 1512 male (49.5%). The ambulance crew pre-alerted the hospital of a patient’s arrival in 224 cases (7.3%) and 76 patients (2.5%) suffered an adverse event within 24 h of admission to the hospital. Death was the most frequently observed adverse outcome (21 cases in ED [27.6% of adverse events], 10 [13.2%] on wards), followed by requirement of HDU or ITU (16 [21.1%]). Patient characteristics within the two outcome groups, ‘adverse event’ versus ‘no adverse event’, are shown in Table 2.

Ambulance crews were paramedic-led in 2082 (68.1%) cases and technician-led in 854 (27.9%). Data on this variable was missing in 121 (4.0%) cases. Paramedic-led and technician-led crews pre-alerted 8.3% (172) and 4.9% (42) of their caseload respectively,

Table 2
Patient characteristics and pre-hospital observations by outcome (n = 3057).

Characteristic ^a	Adverse event (n = 76)	No adverse event (n = 2981)
Age (years); mean (SD)	66.3 (19.3)	54.7 (23.8)
Sex; male (n, %)	47 (61.8)	1465 (49.2)
Respiratory rate (RR); mean (SD)	22.4 (11.0)	19.2 (4.9)
Heart rate (bpm); mean (SD)	101.5 (43.5)	88.7 (20.8)
Temperature (°C); mean (SD)	36.5 (1.0)	36.7 (0.8)
Systolic blood pressure (mmHg); mean (SD)	117.8 (36.6)	134.5 (24.7)
Oxygen saturation; median (IQR)	96 (6)	98 (3)
AVPU; N (%):		
Alert	50 (65.8)	2855 (95.8)
Voice	9 (11.8)	103 (3.5)
Pain	8 (10.5)	14 (0.5)
Unresponsive	9 (11.8)	9 (0.3)

^a All observations were taken pre-hospital, SD, standard deviation; IQR, interquartile range.

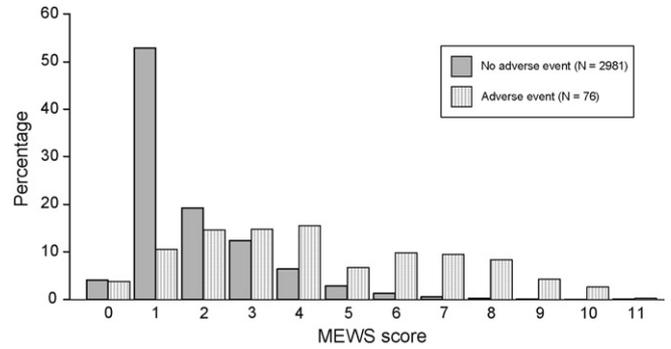


Fig. 1. Distribution of MEWS scores for patients who suffered an adverse event within 24 h of hospital admission (n = 76) and those who did not (n = 2981).

with paramedic transferred patients experiencing a higher rate of adverse events (2.8% [57] vs. 1.5% [13]; 6 unknown).

3.1. MEWS scores

A MEWS score was calculated for each patient and the distributions of the scores for the ‘adverse event’ and ‘no adverse event’ groups are shown alongside each other in Fig. 1. The distribution of scores for patients who did not suffer an adverse event is highly positively skewed with 2271/2981 (76.2%) having a score less than 3. In contrast, the distribution of scores for the patients who suffered an adverse event is much less skewed with only 22/76 (28.9%) having a score less than 3. Sensitivities and specificities with 95% confidence intervals were calculated for each integer cut-point of the MEWS score and plotted as a ROC curve (Fig. 2). A score greater

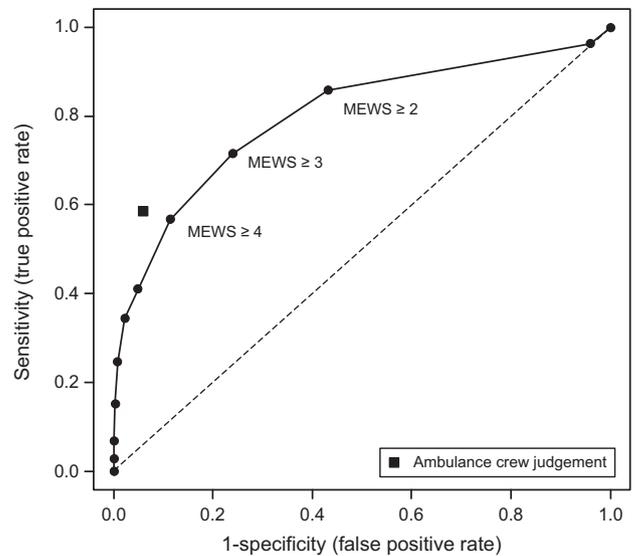


Fig. 2. Receiver operator characteristic (ROC) curve for the MEWS score including a point to indicate the accuracy of ambulance crew judgement in pre-alerting the hospital emergency department. The diagonal dashed line shows the line of no discrimination whereby a completely random guess would yield a point on this line.

Table 3
Sensitivities and specificities with 95% confidence intervals for various decision rules.^a

N = 3057		Adverse event within 24 h		Estimate (95% confidence interval)	
		Yes	No	Sensitivity	Specificity
Pre-hospital alert (clinician judgement)	Yes	47	177	61.8 (51.0, 72.8)	94.1 (93.2, 94.9)
	No	29	2804		
MEWS \geq 2	Yes	65	1287	85.5 (77.8, 93.7)	56.8 (55.0, 58.6)
	No	11	1694		
MEWS \geq 3	Yes	54	710	71.1 (61.1, 81.6)	76.2 (74.6, 77.7)
	No	22	2271		
MEWS \geq 4	Yes	43	342	56.6 (45.3, 67.9)	88.5 (87.4, 89.7)
	No	33	2639		
MEWS \geq 2 + alert	Yes	70	1339	92.1 (86.3, 98.5)	55.1 (53.3, 56.9)
	No	6	1642		
MEWS \geq 3 + alert	Yes	64	795	84.2 (76.2, 92.7)	73.3 (71.7, 74.9)
	No	12	2186		
MEWS \geq 4 + alert	Yes	55	454	72.4 (62.5, 82.7)	84.8 (83.5, 86.1)
	No	21	2527		

^a Reported frequencies and estimates are averaged across the five imputed datasets.

than or equal to the chosen cut-point indicates that the ambulance crew should alert the hospital of the patient's arrival. The area under the ROC curve (AUC) is 0.799 (95% CI 0.738–0.856), which indicates good discrimination between the two groups.

Table 3 shows the sensitivities and specificities with 95% confidence intervals for the ambulance crew 'alert' and for three MEWS cut-points that have a greater sensitivity than ambulance crew judgement. In addition, the table shows results of using a combination of MEWS and clinical judgement to determine which patients require a hospital pre-alert. In the case of a negative MEWS outcome (i.e. a MEWS score less than the stated cut-point), the ambulance crew can still choose to pre-alert the hospital if they judge a patient to be critically ill. Table 4 explores the components of the composite adverse event category separately.

4. Discussion

This study is the first to test an established PTTS against clinical judgement, and attempt to establish its role as a decision-making tool in the detection of critical illness in the pre-hospital environment.

In common with previous studies we have highlighted a failure to predict adverse outcomes by pre-hospital practitioner clinical judgement alone. 76 patients (2.5%) in this study suffered an adverse event within 24 h of hospital admission and paramedics alerted the hospital to a patient's arrival in 224 cases (7.3%). Paramedic clinical judgement had a sensitivity of only 61.8% (95% CI 51.0–72.8%) but a specificity of 94.1% (95% CI 93.2–94.9%). In a comparable population, Brown and Bleetman describe an even lower clinical judgement sensitivity of 44%.⁴ Separately, Brown and

Table 4
Characteristics of patients who suffered adverse events ($n = 76$).

Adverse event	n	Characteristic		
		Age (years); Mean (SD)	Sex; male (n; %)	MEWS score; Median (IQR) ^a
CCU	8	59.8 (17.9)	6 (75.0)	2 (2)
Died in ED	21	69.4 (19.9)	15 (71.4)	6 (3)
Died on ward	10	81.1 (13.6)	7 (70.0)	6 (4)
ITU/HDU	17	70.3 (11.9)	7 (41.2)	5 (4)
Theatre	8	59.5 (27.3)	4 (50.0)	1 (2)
Transfer	12	51.7 (16.8)	8 (66.7)	2 (3)
Total	76	66.3 (19.3)	47 (61.8)	4 (4)

^a MEWS scores have been averaged across imputed datasets IQR, interquartile range; SD, standard deviation.

Warwick have demonstrated that pre-hospital practitioner inability to detect critical illness might reflect a failure of information processing and decision-making.¹ On review of pre-hospital documentation they concluded that 55% of undetected critically unwell patients should have been identified and hence pre-alerted to the hospital. It was noted that abnormal observations were witnessed in 46% of those determined to be critically unwell.

In this study, if a pre-hospital MEWS score greater than or equal to 3 was used as the cut-point defining 'critically unwell', sensitivity increased to 71.1% (95% CI 61.1–81.6%), however specificity fell to 76.2% (95% CI 74.6–77.7%) compared to clinical judgement alone. This may be considered too low for clinical implementation, entailing the pre-alerting of 764 patients (25.0%) in our dataset. Such a high false positive rate would have significant resource implications and runs the risk of reducing the meaning and impact of pre-alerts.

Combination systems were demonstrated to offer one potential solution (see Table 3). If MEWS was assumed to be correct when classifying the patient as critically ill, with clinician judgement over-riding a negative decision, MEWS with a cut-point of 4 resulted in a sensitivity of 72.4% (95% CI 62.5–82.7%) and a specificity of 84.8% (95% CI 83.5–86.1%). This represents a pragmatic compromise. PTTS alone would never be expected to replace pre-hospital clinical judgement or decision-making yet these results, as a trial of concept, highlight the potential to augment it. Sub-group analysis of the separate contributors to the adverse event category supports this view (see Table 4).

The median initial pre-hospital MEWS score of those with the most clinically significant endpoint, death, either in ED or on a ward within 24 h, was 6 (IQR 3). The predominant pathology in this group was medical (respiratory, neurological, sepsis or an antecedent of cardiac arrest). In contrast, surgical (general, neuro, trauma and orthopaedics) and ischaemic cardiac pathology largely fell into different categories with lower median MEWS scores (CCU 2 [IQR 2], theatre 1 [IQR 2] or transfer 2 [IQR 3]). A recognised failing in current practice is pre-hospital practitioner's diminished ability to detect patients at high risk of death presenting with general medical pathology.⁴ Equally, it is known that MEWS may fail to detect serious or time-critical pathology without significant physiological derangement (e.g. myocardial ischaemia, head trauma, spinal injury) likely to be identified by clinical staff. From this data it may be hoped that the two systems would, when used in parallel, function synergistically to address each other's deficits, improving the rate of pre-hospital critical illness detection. It is also likely that with a larger sample size and a unitary end-point (death), the recorded sensitivity and specificity of a pre-hospital MEWS would be higher than seen here.

4.1. A role for early warning scores?

It is well recognised that early identification of critical illness and reduction in time to initiation of definitive treatment is of prime importance if outcomes are to be modified^{25,34}. Consensus has been reached both internationally and in the UK on the requirement for all adult patients in acute hospital settings to be monitored by PTTS^{13,14} and ideally for a unified early warning score to be established (in the UK a 'national or NHS EWS').³⁵ In the face of such apparent clinical need it seems illogical that this proposal is not extended into the pre-hospital environment.

Pre-hospital PTTS, in conjunction with validated action-plans, have the scope not only to improve the detection of critical illness but to reduce clinical uncertainty, regulating, and unifying treatment decisions by affording additional risk stratification.^{1,4,36} Their derivation from routinely obtained observations allows an objective, valid, reliable predictor of clinically important outcomes to be obtained for large numbers of patients.^{5,22} Importantly, this may be achieved without additional workload on staff and at minimal expense, especially with the advent of computerised systems.²⁰ The significance of abnormal readings, especially as they deviate further from normal, is highlighted to junior and less experienced staff^{7,11} improving communication between health-care professionals, hand-over to receiving centres, and potentially transfer and discharge on scene decisions. This will become increasingly relevant if regional critical care networks are established.²⁷ Hospitals accurately made aware of critically ill patients prior to arrival may tailor their response. Prompt attendance by senior physicians and speciality teams will allow limited clinical resources to be focused with attendant clinical benefit.^{7,15,34}

Whilst this study, in-line with previous work,²¹ demonstrates only a modest improvement in critical illness detection and outcome prediction with the addition of MEWS, we believe the potential of PTTS and their secondary benefits are vital. The introduction of PTTS into pre-hospital practice will undoubtedly be challenging and initially have an unknown effect on a complex system, however once fully integrated, may improve clinical practice. Scoring systems specifically designed for the pre-hospital environment, appropriately refined, will likely improve their utility further.

4.2. Limitations

The study has several weaknesses. The data were collected from one ambulance service and one receiving hospital. Both ambulance alerting and the composite outcomes identified as adverse events (e.g. requirement of theatre, ICU admission) are open to bias from local preferences, resources and policy. The study had a limited time frame and, therefore, a low event rate. Some data were missing, as reported above.

Patients who were pre-alerted may have received superior treatment to those not alerted, hence avoiding an adverse outcome. Conversely those not alerted were more likely to experience an adverse event. The selected adverse event window of 24 h may represent too short a period to fully capture the clinical utility of pre-hospital PTTS and warrants further investigation. Patients with pre-existing 'do not resuscitate orders' or those made subsequent to admission could not be identified and thus were not excluded.

Further work is required to support these findings. External validation with a larger population set, prospectively derived from multiple ambulance services and multiple receiving centres, would be advantageous. Scoring systems are becoming increasingly advanced and better validated, whether developed primarily for in-hospital³⁷ or out-of-hospital^{27,38} use. Testing and comparison of these alternatives and/or refinement of existing scores will be necessary. This may take the form of altered early warning score

boundaries, different variables (e.g. age or oxygen saturations) or multiple time-point sampling.³⁹

5. Conclusions

Current rates of critical illness detection and outcome prediction in the pre-hospital environment are low. The addition of MEWS to clinical assessment improves sensitivity, particularly to medical pathology, at the expense of increased clinical resource expenditure. The secondary benefits afforded by PTTS are considerable and come at little expense. The optimal scoring system to be employed in this setting is yet to be elucidated.

Conflict of interest

No conflicting interests to declare. Full control over the primary data is retained by the authors.

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