Identification of deteriorating patients on general wards; measurement of vital parameters and potential effectiveness of the Modified Early Warning Score ☆

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Abstract
Background and Purpose: Clear and detectable signs of deterioration have been shown to be present in many patients multiple hours before undergoing a serious life-threatening event. To date, few studies are available describing normal practice and the possible effectiveness of structured tools regarding recognition of deteriorating patients. The aim of this study was to describe the current practice in measurement and documentation of vital signs and the possible usefulness of the Modified Early Warning Score (MEWS) to identify deteriorating patients on hospital wards.
Methods: A retrospective observational study of medical and surgical patients from 2007 with a severe adverse event including cardiopulmonary arrest, unplanned intensive care unit admission, emergency surgery, or unexpected death was performed. We studied all vital parameters that were collected and documented in the 48 hours before these events, and the MEWS was retrospectively calculated.
Results: Two hundred four patients were included. In the 48 hours before the event, a total of 2688 measurements of one or more vital signs were taken. Overall, 81% of the patients had an MEWS value of 3 or more at least once during the 48 hours before their event. Recordings of vital signs were mostly incomplete. Even when the MEWS was 3 or more, respiratory rate, diuresis, and oxygen saturation were documented in only 30% to 66% of assessments.
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1. Introduction

Most critically ill patients who are admitted to the intensive care unit (ICU) or have a cardiopulmonary arrest show clear and detectable signs of deteriorating in the hours preceding these events. More than 80% of these patients

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could be identified in the 24 hours before these severe adverse events (AEs) [1–4]. In 1 study, the quality of care in the hours preceding these AEs has been deemed substandard because of a lack of knowledge and skills, inadequate appreciation of clinical urgency, and failure to seek advice [5].

Current clinical practice regarding the systematic measurement of vital signs in patients on general hospital wards is largely unknown, although data exist that completeness of general observations after major surgery in the first 3 postoperative days was only 17% [6]. The ability to recognize a deteriorating patient is the paramount feature of rapid response systems that aim at the reduction of severe AEs [7]. To aid in this detection of deteriorating patients on the general wards, track and trigger (TT) systems have been developed. These systems rely on the measurement of readily available vital signs. Two types are in use: single-parameter systems are based on the deviation of a single parameter from normality, whereas the multiple TTs rely on the calculation of a score based on a multitude of parameters [8]. Diagnostic performance of TTs varies widely [9,10]. Although TTs, including the Modified Early Warning Score (MEWS), have been widely adopted throughout the world [11,12], the workings of these systems in clinical practice have not been fully elucidated. Predictive capabilities vary between different studies [8,9], and little is known regarding common practice concerning measurement of vital signs on nursing wards [13,14].

The primary aim of this study was to describe the current practice of nurses in a university hospital in the Netherlands regarding the measurement of vital signs. Secondarily, we analyzed the possible usefulness of the MEWS in the early recognition of medical and surgical patients who subsequently died or experienced serious AEs.

2. Methods

2.1. Hospital setting

This study was conducted in the Academic Medical Center in Amsterdam, the Netherlands, which is a 1000-bed teaching university hospital. For this research, all medical and surgical wards participated including 8 medium care beds equally divided between specialties.

2.2. Study design and definitions

This was a retrospective study on all admitted patients in 2007 who endured one of the following AEs: (1) cardiopulmonary arrest, (2) unplanned ICU admission, (3) unexpected death, or (4) emergency surgery. The first 3 AEs were identified according to Cretikos et al [15]. Emergency surgery was added as another important and potentially avoidable AE. An example of this would be emergency laparotomy for ischemic bowel due to circulatory failure or the need for relaparotomy due to abdominal abscesses.

In these patients, all measured vital parameters in the 48 hours preceding the AEs were registered from the medical and nursing charts. Modified Early Warning Score values were calculated retrospectively based on the measurements taken by the nurses for each time point at which one or more vital signs were recorded. Missing parameters were considered "normal." Calculations were based on the system by Subbe et al [16] and are shown in Fig. 1. Within this system, upon reaching a score of 3 or more, the (attending) physician should be notified.

MEWS score	3	2	1	0	1	2	3
Heart rate		<40	40-50	51-100	101-110	111-130	>130
Systolic blood pressure	<70	70-80	81-100	101-200		>200	
Respiratory rate		<9		9-14	15-20	21-30	>30
Temperature		<35.1	35.1-36.5	36.6-37.5	>37.5		
AVPU score				A (**A**lert)	V (response to **V**oice)	P (reacting to **P**ain)	U (**U**nresponsive)
Worried about patient's condition: 1 point							
Urine production below 75 ml during previous 4 hours: 1 point							
Saturation below 90% despite adequate oxygen therapy: 3 points							

Upon reaching 3 or more points → call resident in charge

Fig. 1   Modified Early Warning Score. The MEWS score was implemented as a tool that ward staff can use to identify the patient at risk for deterioration. The described method was adapted from Subbe et al [16].

The AEs were defined as follows: *cardiopulmonary arrest* was defined as an event in which respiratory and/or cardiopulmonary activity was absent for which the cardiac arrest team initiated cardiopulmonary resuscitation including chemical, fluid, or mechanical resuscitation. An *unplanned ICU admission* was defined according to the definitions of the Dutch National Intensive Care Evaluation [17]. *Emergency surgery* was defined as requiring surgery within 1 hour after establishment of this decision. *Unexpected death* was defined as death without the presence of any form of a "Do Not Attempt Resuscitation" order. Patients were identified from the hospital administration system or the National Intensive Care Evaluation registry. Patients with more than 1 AE (eg, cardiopulmonary arrest followed by an unplanned ICU admission) were only included for the first event.

Measured vital parameters included heart rate (beats per minute), systolic blood pressure (millimeters of mercury), respiratory rate (breaths per minute), temperature (degrees Celsius), state of consciousness (normal/abnormal), written worries by a nurse about the condition of the patient (yes/no), oliguria (urine production <75 mL/4 h), and transcutaneous oxygen saturation (percentage).

2.3. Data analysis and statistics

All data were anonymously entered into an Access (Microsoft, Redmond, WA) database. Subsequent analysis was performed in SPSS (Chicago, IL) version 19.0. Continuous data are represented as medians with interquartile range (IQR). Categorical data are presented in percentages.

2.4. Ethics

The research protocol was not subjected to the local medical ethics board because the study was observational and retrospective in nature and was, therefore, redeemed from ethical approval.

3. Results

3.1. Demographics

In Table 1, the demographics of the 204 included patients are shown. Twenty-seven (13%) had a cardiopulmonary arrest, 29 (14%) underwent emergency surgery, 50 (25%) died unexpectedly, and 98 (48%) underwent an unplanned ICU admission. One hundred twelve patients came from the medical wards (55%), and 88 (43%) came from the surgical wards. Emergency surgeries were predominantly performed on surgical patients, whereas unexpected deaths, cardiopulmonary arrests, and unplanned ICU admissions were more common in medical patients. The median age was 67 years (IQR, 57-76), and 124 patients (61%) were male.

3.2. Demographics of measurements and MEWS

Of the 204 included patients, a total of 2688 measurements were taken in the 48 hours before the event. A median MEWS of 2 (IQR, 1-3) and a median of 3 parameters (IQR, 2-4) were taken per measurement. In 1 patient, no vital signs were recorded before the event.

Table 1 Demographics

		Total	Arrests	Unplanned ICU admissions	Emergency surgeries	Unexpected mortality
Events, n (%)		204	27 (13.2)	98 (48.0)	29 (14.2)	50 (24.5)
Age (y), median (IQR)		66.5 (57.0-76.0)	72.0 (65.0-75.0)	60.5 (50.5-73.0)	57.0 (43.5-68.0)	78.0 (68.8-84.0)
Male patients, n (%)		124 (60.8)	20 (74.1)	59 (60.2)	16 (55.2)	29 (58.0)
Specialty of admission, n (%)						
	Medical	112 (54.9)	13 (48.1)	54 (55.1)	6 (20.7)	39 (78.0)
	Surgical	88 (43.1)	14 (51.9)	40 (40.8)	23 (79.3)	11 (22.0)
	Other	4 (2.0)	0	4 (4.1)	0	0
Department on admission, n (%)						
	Nursing ward	171 (83.8)	26 (96.3)	79 (80.6)	26 (89.7)	40 (80.0)
	Medium care	5 (2.5)	0	4 (4.1)	0	1 (2.0)
	ICU	17 (8.3)	1 (3.7)	11 (11.2)	1 (3.4)	4 (8.0)
	Other	11 (5.1)	0	4 (4.1)	2 (6.9)	5 (10.0)
Department at time of event, n (%)						
	Nursing ward	183 (89.7)	26 (96.3)	88 (89.8)	22 (75.9)	47 (94.0)
	Medium care	21 (10.3)	1 (3.7)	10 (10.2)	7 (24.1)	3 (6.0)

In total, 29 patients were excluded from analysis because one of the required medical or nursing charts was absent.

Table 2 MEWS points allocation and measurement of vital parameters

	Pulse		Systolic BP		Respiratory rate		Temperature	
	Total	MEWS ≥3	Total	MEWS ≥3	Total	MEWS ≥3	Total	MEWS ≥3
0	39.9	27.6	54.1	57.9	1.2	1.2	9.6	4.6
1	10.6	13.1	13.5	20.3	5.6	6.3	36.8	49.4
2	14.7	33.1	4.0	8.8	9.1	19.4	2.0	3.5
3	6.4	17.5	1.5	4.1	7.5	20.4	NA	NA
Not measured	28.3	8.7	26.9	8.8	76.6	52.6	51.5	42.5
	Consciousness		Worried		Diuresis		Peripheral saturation	
	Total	MEWS ≥3	Total	MEWS ≥3	Total	MEWS ≥3	Total	MEWS ≥3
0	NA	NA	NA	NA	5.7	8.7	36.2	48.8
1	6.5	9.0	12.2	9.3	10.9	21.1	NA	NA
2	NA	NA	NA	NA	NA	NA	NA	NA
3	NA	NA	NA	NA	NA	NA	6.5	17.7
Not measured	93.5	91.0	87.8	90.7	83.4	70.2	57.3	33.5

The table shows the measured vital signs and the MEWS points based on all measurements (total, N = 2688) and the measurements with a MEWS of 3 or more (n = 988). Vital parameters that were not measured are shown as "Not measured." BP indicates blood pressure; NA, not applicable.

Measured vital signs and the specific MEWS points per parameter contributing to the complete MEWS value are shown in Table 2. Pulse rate and systolic blood pressure were measured in 72% and 73% of cases, respectively. In measurements with a positive MEWS (reaching ≥3), these both increased to 91%. Respiratory rate was measured in 23%; state of consciousness, 6.5%; urine production, 16.6%; temperature, 48.5%; and peripheral oxygen saturation, 43.7% of all measurements. Worries about the condition of the patient were expressed by the nurse at the time of 12.2% of the vital sign measurements.

In Fig. 2, all combinations of vital signs measured are shown. Combinations with a presence of at least 4% were included. Sole measurement of the pulse rate was present in 10% of all measurements. The combination of pulse, blood pressure, and temperature was present in approximately 35% of all measurements. As expected, more complete sets of vital signs were recorded in cases with an MEWS being 3 or more.

The relationship between calculated MEWS values and the time that they were recorded before the event is shown in Fig. 3. For measurements with an MEWS value being 3 or more (n = 988, 37%), the median time before the event was 13.0 hours (IQR, 4.8-27.1). The percentage of MEWS being 3 or more increased when MEWSs were recorded closer to the event, increasing to 56% of MEWSs in the hour before the event. In 166 (81%) of the patients, a positive MEWS was present at least once in the 48 hours before their event. In the last hour before the event, vital signs were measured in 50 patients, 47 (93%) of whom had an MEWS of 3 or more. The median time between the first positive MEWS value and the event was 25.3 hours (IQR, 10.1-38.0).
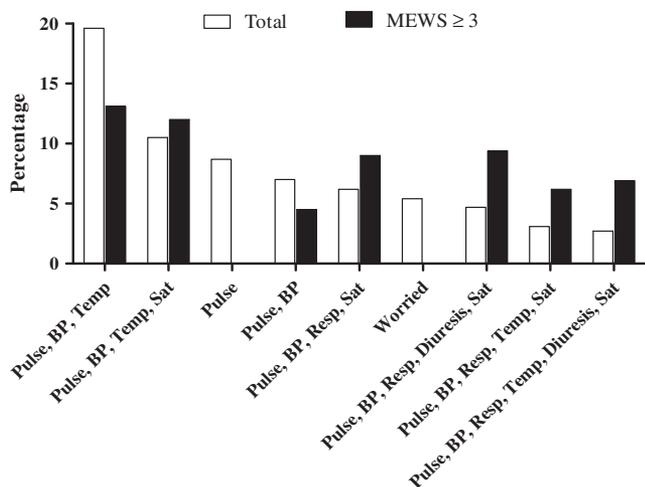

Fig. 2 Content of measurements. The combination (in white) of all measurements taken (N = 2688) is shown compared with the measurements with a positive MEWS (≥3 points) in black (n = 988). All possible combinations were analyzed, and those with a prevalence of 4% or more were included. BP indicates systolic blood pressure; Resp, respiratory rate; Temp, temperature; Sat, peripheral saturation with supplementary oxygen therapy.

4. Discussion

The results of this study show an important lack of measurement and documentation of vital signs in patients in the 48 hours preceding severe life-threatening AEs. Pulse rate and blood pressure were recorded most often, whereas urine production and level of consciousness were seldom recorded. Respiratory rate was documented in only 23% of the cases. As expected, the number of vital sign
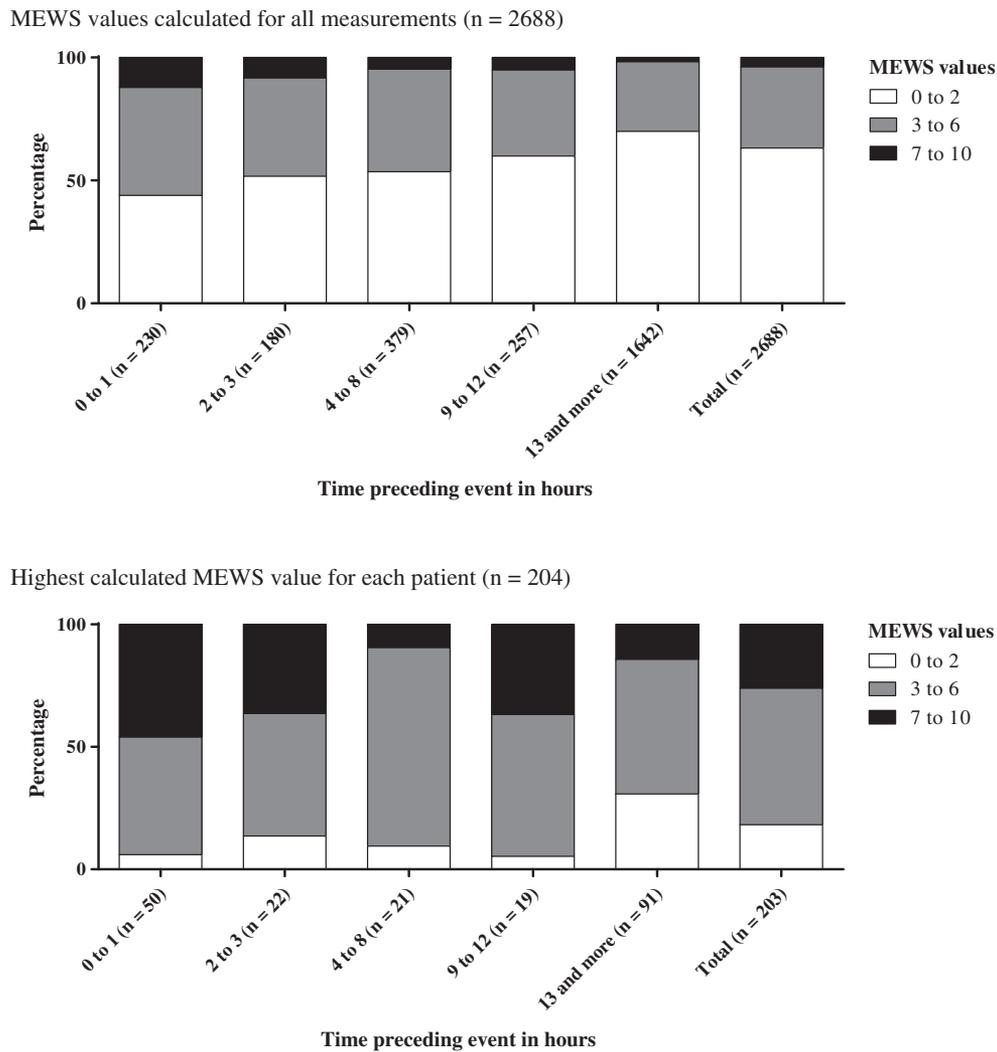
MEWS values calculated for all measurements (n = 2688)

Time preceding event in hours

Highest calculated MEWS value for each patient (n = 204)

Time preceding event in hours

Fig. 3 Modified Early Warning Score value in the hours preceding the event in relation to time. The difference in time between the measurements taken and the moment of the event is analyzed in categories of hours preceding the event. The MEWS value is categorized in 3 categories (0-2, 3-6, and 7-10) and depicted as percentage on the y-axis. The last 2 categories represent direct action according to the MEWS protocol that is required to be undertaken. The top figure shows all calculated MEWS values of all measurements taken (N = 2688), whereas the bottom figure depicts the highest MEWS value per patient (n = 204).

measurements increased when an MEWS of 3 or more was present, but even then, respiratory rate was not documented in most patients. Furthermore, we show that 81% of the patients who died unexpectedly or underwent another AE could be identified early on using the MEWS methodology. Half of these patients showed clear signs of deterioration, with an MEWS value of 3 or more already 25 hours before the event.

We found that, in current practice, the collection of vital signs was incomplete in most cases. The incompleteness of recorded vital signs is in accordance with previous studies. Trinkle and Flabouris [18] showed that afferent limb failure was present in 23% of patients facing a cardiac arrest, requiring unplanned ICU admission, or requiring medical emergency team calls. This was primarily due to absence of

systolic blood pressure measurements (43%) and pulse rate (26%). In our cohort of patients enduring severe AEs and registering all vital parameters in the 48 hours before the event, these parameters were present more often. In our study, respiratory rate was only present in 23% vs 15% in a cohort of postsurgical patients [6]. Leuvan and Mitchell [19] found that the combination of pulse rate, blood pressure, and temperature was most frequently documented but that respiratory rate was only measured in a small percentage of recordings. As respiratory rate is seldom documented as a vital sign, it has been termed *the neglected sign* [20].

We cannot exclude that vital signs were not reported in the charts because there was no need to measure them (eg, documentation of level of consciousness in patients who are

clearly awake and well oriented). However, it may also be that nurses failed to record some important vital signs.

Clearly, the lack of documentation of vital signs may hamper the ability to recognize patients at risk for deterioration. In our study, despite the incomplete measurement of vital signs, 81% of deteriorating patients could still be identified using the MEWS. This is comparable with a large study performed by Smith et al [9] in the United Kingdom. Studies analyzing the predictive capabilities of routinely measured single vital parameters indicated that routine temperature or blood pressure measurements as a sole instrument had low predictive capabilities on AEs [13,14]. However, using combinations of vital sign measurements may largely increase predictive capabilities [21].

Track and trigger systems are generally seen as part (afferent limb) of a rapid response system, with an outreach team as efferent limb. However, it may well be that implementation of MEWS or another TT will lead to more timely recognition and treatment of deteriorating patients, even without implementation of an outreach team. Recently, implementation of MEWS as the only intervention was associated with an improvement of outcome [22,23], and failure of the afferent limb was associated with increased mortality [18]. However, prospective well-controlled studies on the influence on outcome of using a TT for early recognition of deteriorating patients have not yet been performed.

Studies analyzing clinical judgment have shown that the subjective criterion "worried concerning a patient condition" is the most frequent parameter resulting in the activation of the Rapid Response Team [24,25]. Clinical judgment may identify deteriorating patients even without using formal TT systems. In our study, "worries" were expressed in only a minority of cases. This may be a reflection of a lack of clinical judgment. However, it also may be that clinical judgment was appropriate but that nurses failed to document these worries in their clinical notes.

A limitation of this study is the observational design and the fact that MEWS values were retrospectively calculated. In comparison with other studies, emergency surgery was added as an end point. It may be argued that this event is less avoidable than other complications such as cardiac arrest or ICU admission. Nevertheless, in patients who need unplanned surgery as a complication during their hospital stay, vital signs clearly should have been collected and recorded. Secondly, because a cohort consisting of only patients with AEs was used, the false-positive rate could not be ascertained, and formal diagnostic testing was impossible. The data do show, however, that more than 80% of patients with a serious AE could have been detected earlier using the MEWS.

In conclusion, this study clearly shows a lack of documentation of vital signs in the hours preceding life-threatening AEs in hospitalized patients, although effects on outcome have not been proven. Complete and timely measurement and documentation of vital signs are important.

Future research should focus on methods to improve the measurement and documentation of vital signs in patients at risk for deterioration [26,27], for example, by providing guidelines and implementation of TT systems. The results of our single-center study may not be directly extrapolated to other institutions. Instead, hospitals should investigate their own practices regarding measurement of vital signs in these patients. Furthermore, our findings may implicate that TT systems should rely not only on quantitative data but also on (more) qualitative data such as clinical judgment of nurses, physicians, and perhaps even relatives to identify the patient at risk [28,29].

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