SPECIAL ARTICLE

# Evaluation of the threshold value for the Early Warning Score on general wards

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## ABSTRACT

Introduction: The Early Warning Score (EWS) is used for early detection of deteriorating vital parameters and has been correlated with adverse outcomes. Unfortunately, neither its value on general wards nor the optimal cut-off value have been investigated. We aimed to find the optimal cut-off value for EWS on general wards, and investigated the possibility to raise this value from EWS ≥ 3 without compromising sensitivity too much.

Methods: From May 2010 until May 2011, EWS was calculated from vital parameters in all patients in medical and surgical wards in the Medical Centre Alkmaar. Cut-off value was defined as EWS ≥ 3, unless otherwise specified. Six responses were defined and categorised as interventions (infusion prescription, medication changes, ICU consultation) and other actions (no action, change EWS cut-off value, oxygen supplementation), and it was registered whenever the threshold was exceeded.

Results: 71,911 EWS values were obtained, 31,728 (44%) on medical wards and 40,183 (56%) on surgical wards. On medical wards, the cut-off value was exceeded 3734 times, and response was registered in 29% of the cases with 141 (12%) interventions. On surgical wards, the cut-off value was exceeded 3279 times, and response was registered in 19% of the cases with 633 (36%) interventions.

Sensitivity and specificity for EWS ≥ 3 could not be calculated. For a calculated cut-off at EWS ≥ 4, sensitivity decreased to 74%.

Conclusion: Raising the EWS threshold to 4 on general wards in the hospital would lead to an unacceptable decrease in sensitivity. Therefore, we recommend that the pre-defined cut-off should remain 3, with the possibility to personalise the threshold.

## KEYWORDS

Early warning score, general ward, threshold value, vital signs

## INTRODUCTION

Physiological deterioration is recognised rather late on general wards.[1] This is one of the reasons that patients arriving at an intensive care unit (ICU) from general wards have lower survival rates than patients admitted from operation theatres or emergency rooms.[2] Early recognition of critically ill patients can improve patient safety and may even lower hospital mortality.[3] In order to identify the critically ill, many scoring systems have been developed.[4,5] Most of these scores use periodic observation of physical signs, including vital signs, carried out by nursing staff. These parameters are used to calculate a score, and a response is required if the predefined threshold is exceeded. Different scores, thresholds and responses have been evaluated for emergency and high care units, but none of these systems have been validated for use on general wards. Nonetheless, many hospitals have embraced these scores for their wards, especially when introducing an ICU outreach team or medical emergency team. Previously, a high Early Warning Score (EWS) was correlated with adverse outcomes, although results from different studies are inconsistent.[6] In addition, research was focused on newly admitted patients. We intended to relate EWS on hospital wards to mortality. The threshold value used for EWS is usually 3. It is unclear whether this cut-off value is applicable for general wards, since high sensitivity is accompanied by many false-positive phone calls to the physician.

We aimed to find the optimal threshold value for EWS on a general ward, and investigated whether it was possible to raise this value from 3 without compromising sensitivity too badly.

## METHODS

We investigated the possibility to raise the standard cut-off value for the EWS score from 3 to 4 or 5. Required sensitivity was defined at 90%. This implies that 90% of all interventions would take place at EWS values equal to or exceeding the predefined cut-off. A power analysis revealed that at least 140 registered interventions were needed in order to confirm 90% sensitivity with a 95% confidence interval of 10% (85-95%).

From 1 May 2010 to 20 May 2011, nursing staff recorded vital parameters at least twice a day in all patients on three medical and two surgical wards in the Medical Centre Alkmaar. Medical Centre Alkmaar is a teaching hospital with about 700 beds (Jaardocument Stichting Medisch Centrum Alkmaar 2010) and 14 ICU beds. EWS values were calculated automatically from these parameters once the vital signs were entered into an electronic patient record (McKesson Horizon version 2.08.08.01) (*table 1*).

If the calculated EWS value exceeded the cut-off value, usually 3, the program rendered a signal to contact the physician. In addition, a two-point raise in EWS between two consecutive observations, possibly indicating deterioration of a patient's condition, was reported by the computer program. In these cases a physician was always contacted. Based on previous EWS scores and after physical examination, an individual cut-off value could be set in order to lower the number of phone calls to the physician.

Whenever a physician was contacted, the relevant following action (response) was registered. We defined six different responses: no action, change EWS cut-off, oxygen supplementation, infusion prescription, change in medication, and ICU consultation. These responses were grouped into interventions (infusion prescription, change in medication and ICU consultation) and other responses.

Sensitivity for a cut-off EWS=X was calculated by the following formula:

(*interventions* for EWS ≥ X/total interventions)*100%

This was repeated for the different EWS values, to calculate sensitivity for possible cut-off values.

Specificity was calculated by the formula:

(*other responses* for EWS < X/total other responses)*100%

This was also repeated for the different EWS values.

In addition, we compared in-hospital mortality for all patients admitted to the forenamed wards in the study period for their maximum EWS values ($EWS_{max}$). We did the same for one-year overall mortality and one-year overall mortality with exclusion of hospital mortality. The hospital database depends on people in the community, for example family members and general practitioners, to report the deaths outside the hospital. Therefore, these data are probably incomplete.

## RESULTS

In a period of almost 13 months (May 2010-May 2011), 71,911 EWS values were registered on the participating wards in the Medical Centre Alkmaar. A little more than half (56%, 40,183) were registered on surgical wards, 44% (31,728) on medical wards. All patients admitted in the aforementioned period were included and EWS was calculated at least twice daily.

EWS values were distributed differently on the two wards. Mean EWS values are higher on medical wards (1.4) than they are on surgical wards (1.2) (*figure 1*). The cut-off value was reached in 12% (3734) of EWS values registered on medical wards, as opposed to 8% (3279) of all cases on surgical wards.

The pre-defined cut-off value to contact the physician was EWS ≥ 3, or an increase of more than two points between two consecutive measurements. EWS cut-off could also be set otherwise by the physician. Whenever an EWS value higher than the cut-off value was registered, a response was recorded. The six different responses defined were no action, change EWS cut-off, oxygen supplementation, infusion prescription, change in medication, and ICU consultation.

Responses were registered on medical wards in 29% of the cases with EWS exceeding threshold. Interventions, predefined as the responses infusion prescription, change in medication and ICU consultation, were observed 141 times (12%). On surgical wards, 19% (633) of all responses were registered. The percentage of interventions was 36 (225), much higher than on medical wards. In addition,

**Table 1.** *Early Warning Score scoring system*

| EWS | 3 | 2 | 1 | 0 | 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|
| Pulse rate | | | | 51-100 | 101-110 | 111-130 | >130 |
| BP (systolic) | <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 | | |
| Consciousness | | | | A | V | P | U |

**EWS = Early Warning Score; BP = blood pressure; A= alert; V=responsive to voice; P=responsive to pain; U=unresponsive. 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.**

**Figure 1.** *Distribution of EWS with or without exceeding threshold on different wards on: A) Medical wards; B) Surgical wards*

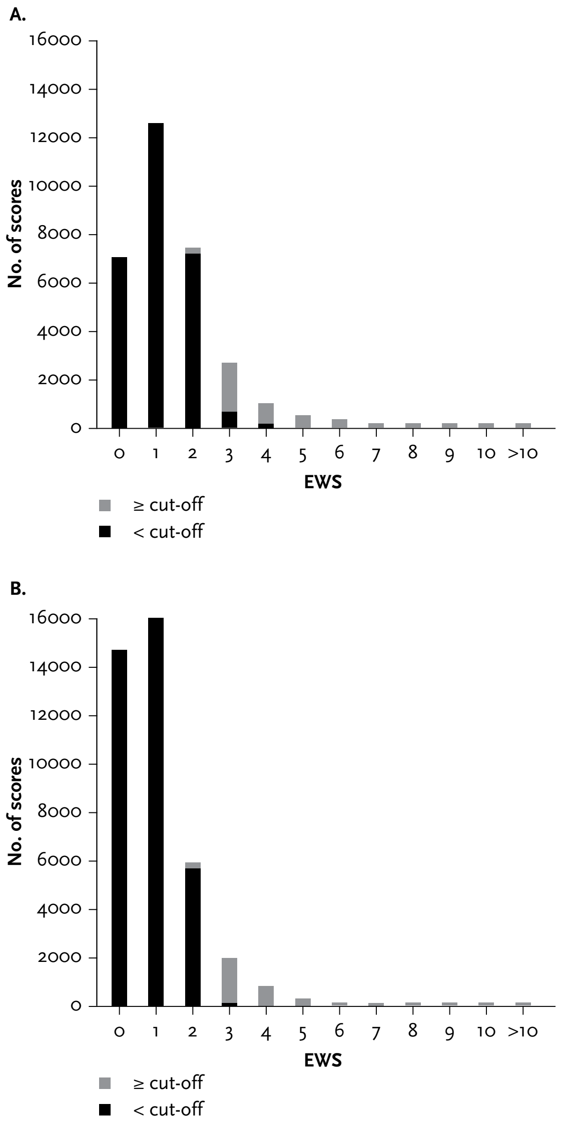
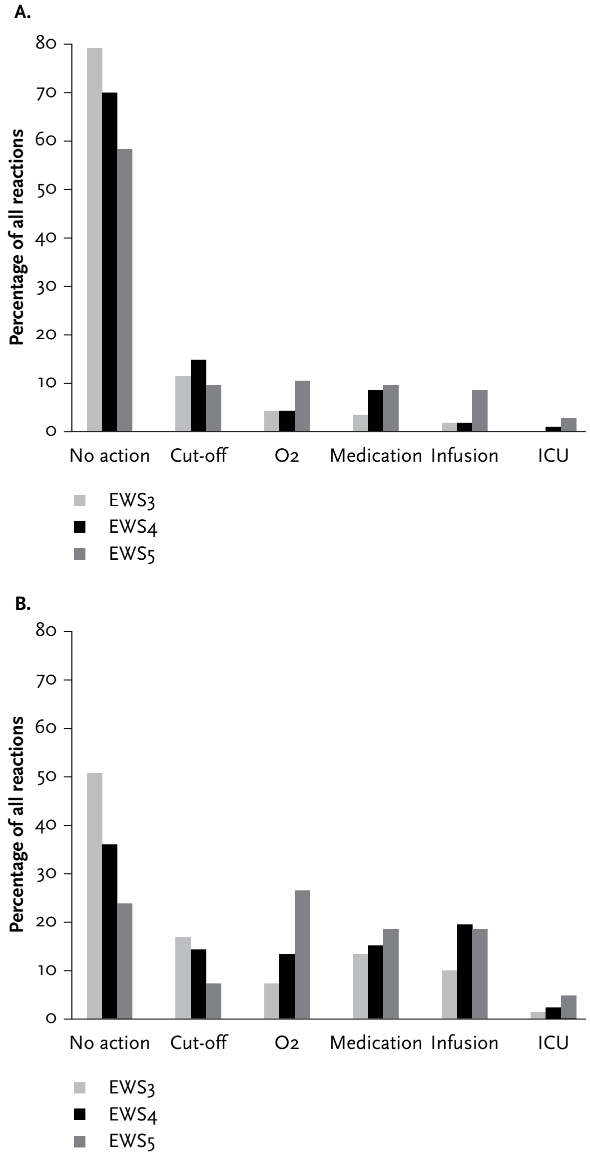



**Figure 2.** *Reactions registered for different EWS values on: A) Medical wards; B) Surgical wards*




the other responses were also distributed differently on the different ward types (*figure 2*). For example at EWS 3, the response no action was found in 51% on surgical wards, as opposed to 79% on medical wards. Overall, the higher the EWS, the more changes in oxygen, medication and infusion regime as well as ICU consultations were seen. The number of no action and change EWS responses decreased with increasing EWS. This effect was seen on all wards.

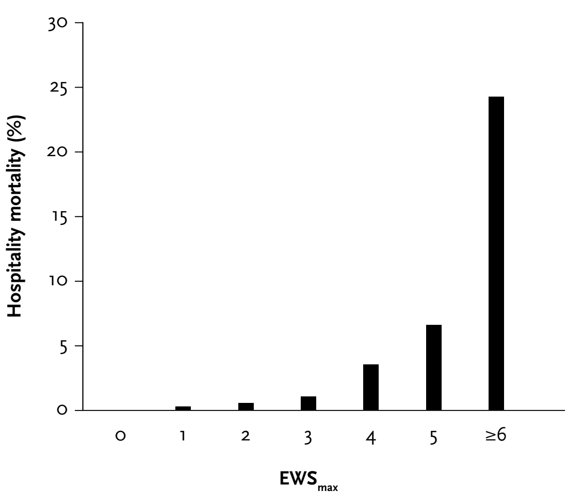
Sensitivity was calculated from the total number of responses and the number of interventions. We required 90% sensitivity with a 95% confidence interval of 10%. By dividing the number of interventions for EWS ≥ X by the total number of interventions, sensitivity was calculated for cut-off EWS=X. The EWS system was introduced in our hospital with the cut-off X=3. Therefore, all registered responses, thus all interventions, were found at EWS ≥ 3. As a result, it was not possible to calculate sensitivity and specificity for cut-off EWS ≥ 3 correctly, since sensitivity would be 100% and specificity 0%. Raising the cut-off value (X) decreased sensitivity and increased specificity. Both sensitivity and specificity found for any X was higher on medical than on surgical wards as can be seen in *table 2*. For cut-off at EWS ≥ 4 (X=4), sensitivity was 79% on medical wards and 71% on surgical wards. Specificity was 51% on medical and 49% on surgical wards. Overall, sensitivity was 74% and specificity 51% for X=4.

**Table 2.** *Sensitivity and specificity for different Early Warning Score values*

| | EWS | 3 | 4 | 5 |
|---|---|---|---|---|
| Sensitivity | Medical | x | 79% | 60% |
| | Surgical | x | 71% | 46% |
| | Total | x | 74% | 52% |
| Specificity | Medical | x | 51% | 74% |
| | Surgical | x | 49% | 72% |
| | Total | x | 51% | 73% |

When X=5 was used, overall sensitivity was 52%, 60% on medical and 46% on surgical wards. Specificity was 73%, with hardly any difference between medical and surgical wards (74% *vs* 72%). Overall, 74% of all interventions took place at EWS ≥ 4, which is less than the 90% we aimed for. To analyse mortality, the deaths for $EWS_{max}$ 6 and higher values were clustered to give a reliable number, due to a relatively small number of values for $EWS_{max}$ ≥ 6. Hospital mortality was 0% for $EWS_{max}$=0 and increased almost logarithmically to 1% for EWS=3 and 24% for $EWS_{max}$ ≥ 6 (*figure 3*). One-year overall mortality and one-year mortality excluding hospital mortality also increased for higher $EWS_{max}$ values, although differences were somewhat less. One-year overall mortality was 3%, 12% and 40% for $EWS_{max}$=0, $EWS_{max}$=3 and $EWS_{max}$ ≥ 6 respectively; when hospital mortality was excluded this was 3%, 11% and 16% for the respective EWS values.

**Figure 3.** *Hospital mortality versus maximum EWS during hospital stay*




## DISCUSSION

Although high EWS has been correlated with adverse outcomes, an optimal threshold value for EWS on general wards has not been established previously.[5] The system was introduced in our hospital using 3 as a cut-off value, since this cut-off is usually applied in other settings. Thus, it was not possible to calculate sensitivity or specificity for a threshold at 3, while 3 was the independent variable. For a cut-off value raised to EWS ≥ 4, the calculated sensitivity was 74%, far below the predefined 90%. Sensitivity decreased even further to 52% if EWS ≥ 5 was used. Thus, raising EWS cut-off for all patients would lead to an unacceptable decrease in sensitivity. Since sensitivity for EWS ≥ 3 could not be calculated and sensitivity for EWS ≥ 4 was inadequate, we presume that 3 is the optimal cut-off value.

By ensuring high sensitivity, specificity is often compromised. A lower threshold results in increased workload, at the risk of making staff less cautious.[5] In particular on medical wards, where mean EWS is higher, an unadjusted cut-off at 3 means 12 phone calls to the physician a day. Although several of these patients may benefit from the attention generated by this extra trigger, most certainly not all these patients are critically ill. Therefore, we included the option to change the EWS cut-off point, based on previous recordings and actual physical state. This will increase both the sensitivity and specificity of the EWS system. However, the majority of patients will not have a personalised threshold and a general cut-off must be used for their EWS values. Another exception to the standard threshold is an increase of two points or more between two consecutive measurements, which could mean rapid deterioration and should always prompt action.

Our results show that EWS is a good predictor for mortality, in-hospital mortality as well as one-year mortality. We could therefore conclude that EWS adequately identifies critically ill patients.
Since the system for registering out-of-hospital mortality depends on others to report death, this registration is probably incomplete. Since reporting is probably approximately equal for all $EWS_{max}$ groups, it is unlikely that this affects the distribution between the different $EWS_{max}$ values.
In previous studies, EWS and similar systems have been used on emergency wards, and for new admissions, but no trigger system has been validated for general wards.[6] However, the emergence of ICU outreach teams has prompted the implementation of these systems to identify patients at risk.[7] Reviews describing the use of many track and trigger systems in various countries state that many

systems have an unacceptably low sensitivity, and that none of the systems identifies the critically ill very well.[4,8] In addition, differences in discriminatory power between the systems may be accounted for by differing thresholds.[5] Nurses trained in EWS performed a little better in identifying a deteriorating patient, although, oddly enough, they hardly ever used EWS.[9] A systematic review found inconclusive evidence regarding the effectiveness of EWS and intensive care outreach teams.[10] Moreover, when compared with an ICU outreach team, a team composed of the patients usual care providers achieved similar results in reducing unexpected mortality, but not overall mortality.[12,13] Despite all these uncertainties, the introduction of early warning systems in the United Kingdom coincided with a decrease in mortality and cardiac arrest rate.[11] Currently, a multicentre study in the Netherlands is evaluating the effectiveness and the cost-effectiveness of rapid response teams (COMET study).

The strength of this study is its large number of patients and EWS values. By including three medical and two surgical units a representative case-mix for general wards was created, and differences between these types of wards could be observed. In general, patients on medical wards were found to have higher EWS values than patients on surgical wards. In addition, results suggest that the same EWS value on different wards does not appear to have the same predictive value. A change in therapy at EWS=3 was recorded on surgical wards in 32% of cases, as opposed to 10% on medical wards.

This could be explained by the fact that the average patient on a surgical ward is younger, has less extensive comorbidity and faces different problems. It was suggested earlier that different triggers could be appropriate for medical and surgical patients.[14] The individual adjusted EWS takes care of some, but not all of these problems.

Although it was a single-centre study, results can probably be generalised for similar hospitals, due to the large number of patients, the different wards and the time course. However, hospitals with different patient categories, such as university hospitals, would need to be studied separately.

A limitation of this study is that only a minority of the relevant following actions are registered. In almost three-quarters of all EWS scores exceeding threshold, no response was reported. Medical wards did a little better than surgical wards, with 29% *vs* 19%. This difference may be another explanation for the different responses for EWS=3. We do not know whether one category or all categories of responses where underreported. Underreporting of ICU consultations was made unlikely by comparing ICU admissions in one month to the EWS data (data not shown).

It is very well possible that many no action situations have gone by without listing. Since it is reasonable to assume that no action responses would have been registered mostly for lower EWS values, more registration would increase specificity. We presume that better registration of no action responses as well as more frequent use of personalised thresholds adds to a higher sensitivity and specificity on medical wards, compared with surgical wards. Sensitivity is not influenced by underreporting of a no action response.

In addition, due to the way our data were collected, we could only analyse EWS values per ward, rather than per patient. Therefore, it is very well possible that EWS values were more frequently registered in the most severely ill patients, causing a relative overestimation of high EWS values. An explanation for the low number of interventions we found could be that many registrations led to only one intervention. However, this would only influence specificity, not sensitivity. It would be interesting to analyse the frequency of EWS registrations, because an increase in frequency without an increase in the number of interventions could also imply that it is useless to measure the EWS more often.

## CONCLUSION

Raising the EWS threshold to 4 on general wards in the hospital would lead to an unacceptable decrease in sensitivity. Therefore, we recommend that the pre-defined cut-off should remain at 3, with the possibility to personalise the threshold.

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