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Research article

Variation in nurses' compliance with an Early Warning Score protocol: A retrospective cohort study

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ABSTRACT

Introduction: Early Warning Score (EWS) protocols are based on intermittent vital sign measurements, and aim to detect clinical deterioration in a timely manner. Despite its predictive value, its effectiveness remains suboptimal. An important limitation appears to be poor compliance with the EWS protocol and its variation between general wards. The current research does not yet provide an understanding of EWS compliance and variation in different nursing wards.
Aim: To explore the variation in nurses' compliance with the EWS protocol among patients with and without complications and between different nursing wards.
Methods: In a retrospective single-center cohort study, all patient files from three nursing wards of a tertiary teaching hospital in the Netherlands were reviewed over a 1-month period. Compliance was divided into three categories:1) calculation accuracy, 2) monitoring frequency end 3) clinical response.
Results: The cohort of 210 patients contained 5864 measurements, of which 4125 (70.6 %) included EWS. Significant differences in the measured vital signs within incomplete measurements were found among nursing wards. Compliance to monitoring frequency was higher within EWSs of 0–1 (78.4 %) than within EWSs of ≥2 (26.1 %). The proportion of correct follow-up was significantly higher in patients with complications, as was the correct clinical response to an EWS of ≥3 (84.8 % vs. 55.0; p = .011).
Conclusion: Our results suggest suboptimal compliance with the EWS protocol, with large variations between patients with and without complications and between different general care wards. Nurses tended to be more compliant with the EWS protocol for patients with complications.

1. Introduction

Most adverse events occurring in hospital wards are preceded by a considerable period of changes in vital signs, which are important indicators of clinical deterioration [1]. Therefore, Early Warning Scores (EWS) are widely used in daily clinical practice to facilitate the early identification of deteriorating patients [2,3]. EWS includes objective parameters, such as vital signs and level of consciousness, and a subjective parameter, named nurses' worry indicator. These parameters are measured at predetermined intervals. Cut-off points lead to an aggregated risk score. Based on this score, registered nurses can trigger responses according to protocol [4,5].

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Abbreviations

EWS	Early Warning Score
FFHET	Fisher-Freeman-Halton Exact Test
IM	Internal Medicine
RN	Registered Nurse
RRT	Rapid Response Team

These responses include increasing the monitoring frequency or requesting assistance from physicians or Rapid Response Teams (RRTs).

Previous studies demonstrated that EWS can predict adverse patient outcomes, such as unexpected deaths or cardiopulmonary arrests requiring unplanned intensive care unit (ICU) admission [3,6–9]. In addition, EWSs are user-friendly and provide a common language for healthcare providers across different specialties [7]. Despite these strengths of EWS, research has demonstrated that the identification of clinical deterioration is often late or entirely missed [10–12]. This might be a result of several limitations of the EWS. First, EWSs are limited by its intermittent nature [13]. Predefined intervals make it possible to miss the patient's deterioration between those intermittent measurements [14]. Second, EWSs are generic tools, and disease and population differences may influence its efficacy [13,15]. Thirdly, poor compliance to EWS protocols has been mentioned as a limitation in several studies [4,16–20].

The protocol compliance, consisting of the quality and frequency of vital sign measurements and subsequent protocol-driven measures initiated by nurses, are the most important factors in the identification of clinical deterioration [21,22]. Therefore, hospitals have implemented various strategies to educate nurses and physicians on the EWS, emphasizing when, how and why to use it [23]. Education initiatives often include comprehensive training programs, regular workshops, and integration of EWS protocols into daily clinical routines [24,25]. These programs are designed to ensure that healthcare professionals understand the significance of the EWS in identifying patient deterioration early and the subsequent steps required for timely intervention.

Nevertheless, compliance remains an issue. A previous study divided poor compliance in three themes: 1) 'calculation accuracy' defined as an uncompleted measurements to calculate an EWS, 2) 'monitoring frequency' defined as the EWS is not according the follow-up measurement frequency, and 3) 'clinical response' defined as consultation of a physician of RRT when mandated by protocol [17]. Reasons mentioned for non-compliance are time constraints, understaffing, nurses' confidence in their ability to cope with deteriorating patients, and the large number of patients with elevated EWSs [17,26,27].

However, most studies are limited to assessing EWS compliance in patients only with adverse events, which contrarily have a low incidence in nursing wards [28]. Although poor compliance is also suggested with and without signs of clinical deterioration, current research does not yet provide a complete understanding of EWS compliance and variation on nursing wards. Examining compliance in both patients with and without complications provides a comprehensive understanding of how the EWS is utilized in everyday practice, not just in critical situations. This broader perspective can reveal underlying issues that might otherwise go unnoticed, ensuring that the EWS system functions effectively as a preventive measure rather than solely a reactive tool. Moreover, given the generic nature of EWS, there may be variation in compliance across specialties. Understanding these variations is essential for developing targeted interventions for specific nursing wards to improve compliance and ensure the benefits of the EWS system in diverse clinical settings. Therefore, this study aimed to explore the variation in nurses' adherence to the EWS protocol in patients with and without complications and between different nursing wards.

2. Methods

2.1. Study design

A retrospective, single-centre cohort study was performed, with a review of all patient files for a 1-month period (January 2021) in three nursing wards in a 1245-bed teaching hospital in the Netherlands. Patient files were reviewed throughout the entire admission period up to 30 days after discharge. The study has been reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist (Appendix 1) [29].

2.2. Study population

The study population included all patients admitted to one of the participating nursing wards (internal medicine (IM), surgery, and pulmonary disease) in January 2021 who were 18 years or older and had a minimum length of stay (LOS) of 48 h. Patients who were excluded from the standardised EWS protocol (Appendix 2), such as terminal patients or patients with COVID-19, were also excluded in this study.

2.3. Data collection

The software CTcue (*CTcue, Amsterdam, Netherlands*), powered by artificial intelligence (AI), was used. CTcue can extract data from an electronic health record (EHR) based on preformulated queries. First, the patient cohort was identified based on population and

exclusion criteria. This was followed by creating sufficient queries for each variable. Subsequently, these established queries were validated on content, and all variables were pseudonymously filtered from the patient records. All patient- and baseline-characteristics and measurements of vital signs and EWSs (including date and time) were collected. The data collection process was performed by an executive researcher (#1) in collaboration with a data manager. The validation, structuring and organising of all extracted data was performed by executive researcher (#2) and a statistician and crosschecked by an coordinating researcher (#2). Data on clinical response, including the presence of a description in physician or nurses' reports of consulting a physician or RRT, were collected manually from the patient files by the executive researcher (#1) and crosschecked by the coordinating researcher (#2).

2.4. Outcomes

The mandatory parameters were measured once per day by a registered nurse (RN). An EWS 0–1 is followed within 24 h and an EWS $\geq$2 should be followed every 8 h over the next 24 h. Lastly, an EWS $\geq$3 should be followed by consulting a physician or RRT. Appendix 2 demonstrates the EWS protocol, and its cut-off points applied on the participating nursing wards. Regarding the training received by RNs on the EWS system, there is a standardized training module provided during onboarding to the ward. Additionally, RNs undergo yearly e-learning sessions that include simulation training to reinforce their understanding and application of the EWS protocol.

The primary endpoint was compliance to the EWS protocol divided in three categories: 1) EWS calculation accuracy, 2) monitoring frequency and 3) clinical response [17].

2.5. Calculation accuracy

Calculation accuracy was determined by evaluating the completeness of all mandatory vital signs required for the calculation of an EWS at all measurement moments. A measurement moment was defined as a specific date and time, including all measurements. Registration of all required measurements performed manual by the RN resulted automatically in an EWS calculation and registration in the EHR. Omitting any individual parameter results in the inability to calculate an EWS automatically. Therefore, we defined an incomplete measurement moment as one where no EWS was calculated, and will therefore contain missing parameters for its calculation. First, all measurement moments were evaluated on wheatear an EWS was calculated based on all vital signs. Second, the proportion of measured vital signs were determined for the incomplete measurement moments without an EWS.

2.6. Monitoring frequency

Monitoring frequency was evaluated by calculating proportions correctly followed by EWSs within the mandated timeframes. Follow-up of EWSs 0–1 was considered correct if the next EWS was calculated within 24 h. The follow-up of EWSs $\geq$2 were considered correct if the EWS was calculated within 8 h, 8–16 h and 16–24 h. With one missing part of this follow-up, it was considered incorrect. We also evaluated the proportion of follow-up per timeframe (8 h, 8–16 h and 16–24 h). The last EWS on admission (before discharge) was not included in this analysis because there was no follow-up after discharge.

2.7. Clinical response

If an EWS is $\geq$ 3, the protocol mandates that a physician is consulted within 30 min, with evaluation and medical policy to be determined within 1 h. It was not possible to retrospectively trace whether the clinical response actions had been conducted within the specified timeframes. Therefore, the first EWS of $\geq$ 3 per patient was evaluated for clinical response. The first EWS of $\geq$3 was chosen because it provided the first indication of possible clinical deterioration. The first EWS $\geq$3 was evaluated on presence of a description in physician or nurses' reports of consulting a physician or RRT.

2.8. Other study parameters

For stratification of patients with and without complications, complication status was described as yes/no depending on absence or presence of complications according to the list of Hospital Complications [30] based on the assessment report of the physician together with the discharge letter in the EHR which were independently reviewed by both authors (Appendix 4) [30]. Other demographics and patient characteristics, such as the nursing ward, sex, age, medical history, and clinical outcomes (length of stay, readmission <30days and mortality <30 days) were also obtained to describe the study population.

2.9. Data analysis

All data were analysed using descriptive statistics and presented for the entire cohort, each nursing ward, and for patients with and without complications. Continuous variables were presented as mean and standard deviation (SD) considering the skewness of the data. Skewness was determined by plotting a histogram for visual inspection and the Shapiro-Wilk test. Categorical variables are presented as frequencies and percentages. Primary endpoints are presented for the entire cohort, complications versus non-complications, and each nursing ward (including a distinction between patients with and without complications). Fishers' exact test was applied to test for differences between primary endpoints in patients with and without complications (two groups). A Fisher-

Freeman-Halton Exact Test (FFHET) was used to test for differences between the three nursing wards. Post-hoc analyses were performed using Fishers' exact test with a Bonferroni correction for multiple testing. A two-tailed significance level of <.05 (5 %) was applied in all the tests. In a post-hoc analysis with Bonferroni correction, a significance level of .017 (α/k, .05/3) was applied. All statistical analyses were performed with IBM SPSS Statistics 27.0 (*Armonk, NY, IBM Corp.*).

2.10. Sample size

Due to the explorative nature of this study and the limited available evidence on this specific topic, no formal sample size calculation was conducted [31]. Most importantly, all subgroups (complications vs. no complications and different nursing wards) had to be large enough to accurately describe variations in compliance. The ratio of complications to non-complications across the population base was unclear. Data on surgical complications were most available: postoperative complications occurred in up to 33 % of patients undergoing colorectal procedures [32]. The registration of patients on the nursing wards of interest, showed approximately 200 patients per month and approximately 25 % of the patient with complications. Considered the above, this study focussed on a 1-month cohort, January 2021.

2.11. Ethical considerations

The Medical Ethics Review Committee of Isala reviewed the study protocol (protocol 20211219) and stated this study did not involve Dutch Medical Research Involving Human Subjects Acts (non-WMO) and received waiver for obtain informed consent. The study was conducted in accordance with the Declaration of Helsinki and Data Protection Regulation (GDPR).

Table 1
Patient characteristics.

	Total	Nursing ward			Complications	
Variable	(n = 210)	Internal medicine (n = 60)	Surgical (n = 98)	Pulmonary (n = 52)	Complications (n = 51)	No complications (n = 159)
Demographics						
Gender (male), n (%)	112 (53.3)	33 (55.0)	54 (55.1)	25 (48.1)	31 (60.8)	81 (50.9)
Age (years), mean (sd*)	68.7 (13.8)	67.9 (15.5)	68.8 (13.7)	69.6 (11.9)	69.5 (14.8)	68.5 (13.5)
Medical History						
COPD†, n (%)	66 (31.4)	11 (18.3)	21 (21.4)	34 (65.4)	16 (31.4)	50 (31.4)
CHF‡, n (%)	28 (13.3)	6 (10.0)	13 (13.3)	9 (17.3)	4 (7.8)	24 (15.1)
Diabetes mellitus, n (%)	57 (27.1)	12 (20.0)	34 (34.7)	11 (21.2)	16 (31.4)	41 (25.8)
Hypertension, n (%)	112 (53.3)	31 (51.7)	56 (57.1)	25 (48.1)	28 (54.9)	84 (52.8)
Peripheral Vascular Disease, n (%)	46 (21.9)	4 (6.7)	33 (33.7)	9 (17.3)	10 (19.6)	36 (22.6)
Renal disease (eGFR§ <30), n (%)	21 (10.0)	6 (10.0)	12 (12.2)	3 (5.8)	7 (13.7)	14 (8.8)
CVD¶, n (%)	53 (25.2)	13 (21.7)	22 (22.4)	18 (34.6)	15 (29.4)	38 (23.9)
Dementia, n (%)	3 (1.4)	0 (.0)	2 (2.0)	1 (1.9)	1 (2.0)	2 (1.3)
Connective tissue disease (RA/SLE#)) n (%)	17 (8.1)	2 (3.3)	7 (7.1)	8 (15.4)	6 (11.8)	11 (6.9)
Peptic ulcer disease, n (%)	9 (4.3)	6 (10.0)	1 (1.0)	2 (3.8)	1 (2.0)	8 (5.0)
Liver disease, n (%)	17 (8.1)	13 (21.7)	2 (2.0)	2 (3.8)	1 (2.0)	16 (10.1)
Hemiplegia, n (%)	2 (1.0)	0 (.0)	1 (1.0)	1 (1.9)	1 (2.0)	1 (.6)
Leukemia, n (%)	3 (1.4)	0 (.0)	3 (3.1)	0 (.0)	0 (.0)	3 (1.9)
Lymphoma, n (%)	5 (2.4)	1 (1.7)	2 (2.0)	2 (3.8)	0 (.0)	5 (3.1)
AIDS+, n (%)	0 (.0)	0 (.0)	0 (.0)	0 (.0)	0 (.0)	0 (.0)
Myocardial infarction, n (%)	30 (14.3)	6 (10.0)	20 (20.4)	3 (5.8)	6 (11.8)	24 (15.1)
Clinical Outcomes						
Length of Stay, mean (sd*)	11.7 (11.1)	11.2 (9.0)	13.1 (13.8)	9.6 (6.7)	19.2 (16.6)	9.3 (7.3)
Mortality <30 days	14 (6.7)	6 (10.0)	1 (1.0)	7 (13.5)	10 (19.6)	4 (2.5)
Readmission <30 days	46 (21.9)	19 (31.7)	17 (17.3)	10 (19.2)	9 (17.6)	37 (23.3)
Complication rate, n (%)	51 (24.8)	13 (21.7)	23 (23.5)	15 (28.9)	n/a	n/a

List of abbreviations.
*Standard Deviation.
†Chronic Obstructive Pulmonary Disease.
‡ Congestive Heart failure.
§ Estimated glomerular filtration rate.
¶ Cerebro Vascular Accident.
# Rheumatoid Arthritis/Systemic Lupus Erythematosus.
+ Acquired immunodeficiency syndrome n/a: not applicable

3. Results

3.1. Study characteristics

After exclusion, the cohort consisted of 210 patients (Appendix 3. Of these, 60 (28.6 %) patients were admitted to the IM ward, 98 (46.7 %) to the surgical ward, and 52 (24.8 %) to the pulmonary ward (Table 1). The mean LOS was 11.7 (SD 11.1) days, complication rate was 24.3 % (n = 51), and mortality rate was 6.7 % (n = 14) (Table 1; Appendix 4). A total of 5864 EWS measurements were included in the analysis.

4. Main outcomes

4.1. Calculation accuracy

Of all included measurement moments (n = 5846), 70.6 % contained an EWS and were considered complete (Table 2). Of the 29.4 % incomplete measurement moments, oxygen saturation (60.5 %) and heart rate (53.7 %) were the most frequently measured and respiratory frequency the least frequently measured (22.8 %) (Table 2).

In general, patients with complications had a significantly higher proportion of completed EWSs (75.3 %) than those without complications (67.1 %, p < .001). However, within all incomplete measurement periods, more individual parameters were measured in patients without complications (Table 3). Likewise, when stratified by ward, the internal and surgical wards showed a higher proportion of completed EWSs in patients with complications (p < .001) (Table 4). In contrast, no significant differences were found in the pulmonary ward (p = .337).

When evaluating variation among nursing wards, we found a significantly lower proportion of completed EWSs in the pulmonary ward (64.4 %) than in the internal (72.8 %) and surgical wards (72.5 %) (p < .001) (Table 2). While focusing on the measured parameters within the incomplete measurements, we found variations among the different nursing wards. The pulmonary ward measured oxygen saturation (78.9 %) and respiratory rate (29.9 %) significantly more often than the other nursing wards (p < .001) (Appendix 5). The internal medicine (IM) ward measured blood pressure (66.0 %) and heart rate (62.5 %) more frequently than other nursing wards (p < .001). Additionally, the surgical ward measured temperature significantly more often compared to the other nursing wards (57.4 %) (p < .001). These differences are detailed in Table 2 and Appendix 5.

4.2. Monitoring frequency

Of the 3915 included EWSs for analysis of this endpoint, 67.7 % of EWSs scored 0–1 and 32.3 % EWSs scored ≥2 (Table 2). Of all EWSs 0–1, 78.4 % were correctly followed within 24 h. Of EWSs ≥2, 26.1 % were correctly followed. EWSs ≥2 was most frequently followed within 8–16 h (70.3 %) (Table 2).

The proportion of correct follow-up of EWSs 0–1 was significant higher in patients with complications than in patients without

Table 2
Early Warning Score (EWS) compliance per nursing ward.

Endpoint	Total	Nursing ward			P value
		Internal medicine (n = 60)	Surgical (n = 98)	Pulmonary (n = 52)	
Calculation accurac					
Number of measurement moments, n	5846	1552	2802	1492	
Proportion completed EWSs[†], n (%)	4125 (70.6)	1125 (72.5)	2039 (72.8)	961 (64.4)	<.001*
Number of incomplete measurement moments, n	1721	427	763	531	
Proportion measured parameters within incomplete sets					
Blood pressure, n (%)	858 (49.9)	286 (67.0)	378 (49.5)	194 (36.5)	<.001*
Heartrate, n (%)	9224 (53.7)	267 (62.5)	402 (52.7)	255 (48.0)	<.001*
Temperature, n (%)	794 (46.1)	177 (41.5)	438 (57.4)	179 (33.7)	<.001*
Oxygen saturation, n (%)	1042 (60.5)	231 (54.1)	371 (48.6)	419 (78.9)	<.001*
Respiratory frequency, n (%)	393 (22.8)	69 (16.2)	165 (21.6)	204 (29.9)	<.001*
Monitoring frequency					
Total number of EWS[†] 0–1, n	2650	731	1421	500	
Proportion EWS[†] 0–1 correct followed, n (%)	2080 (78.4)	567 (77.6)	1085 (76.4)	428 (85.6)	<.001*
Total number of EWS[†] ≥2	1265	335	521	409	
Proportion EWS[†] ≥2 correct followed, n (%)	331 (26.1)	71 (21.2)	163 (31.3)	97 (23.7)	.002*
<8u, n (%)	708 (56.0)	184 (54.9)	306 (58.7)	218 (53.3)	.229
8-16u, n (%)	889 (70.3)	233 (69.6)	384 (73.7)	272 (66.5)	.055
16-24u, n (%)	817 (64.6)	203 (60.6)	339 (65.1)	275 (67.2)	.164
Clinical response					
Number of clinical responses (N)	73	23	22	28	
Clinical response correct n (%)	50 (68.5)	17 (73.9)	17 (77.3)	16 (57.1)	.304

List of abbreviations.
*Statistically significant difference with a two-tailed significance level of p < .05, [†] Early Warning Score.

Table 3
Early Warning Score (EWS) compliance in patients stratified by complications.

Endpoint	Complications		P value
	Complications (n = 51)	No complications (n = 159)	
Calculation accuracy			
Number of measurement moments,	2485	3361	
Proportion completed EWSs†, n (%)	1871 (75.3)	2254 (67.1)	<.001*
Number of incomplete measurement moments, n	614	1107	
Proportion measured parameters within incomplete sets			
Blood pressure, n (%)	271 (44.1)	587 (53.0)	<.001*
Heartrate, n (%)	297 (48.4)	527 (56.6)	.001*
Temperature, n (%)	308 (50.2)	486 (43.9)	.013*
Saturation, n (%)	351 (57.2)	691 (62.4)	.035
Respiratory frequency, n (%)	123 (20.0)	270 (24.4)	.042*
Monitoring frequency			
Number of EWS† 0–1, n	1107	1545	
Proportion EWS† 0-1correct followed, n (%)	905 (78.8)	1175 (69.8)	<.001*
Number of EWS† ≥2	713	522	
Proportion EWS† ≥2 correct followed, n (%)	206 (28.9)	125 (22.6)	.014*
<8u, n/N (%)	400 (55.4)	308 (55.8)	.954
8-16u, n/N (%)	531 (73.5)	358 (64.9)	<.001*
16-24u, n/N (%)	465 (64.4)	352 (63.8)	.594
Clinical respons			
Number of clinical responses (N)	33	40	
Clinical response correct n (%)	28 (84.8)	22 (55.0)	.011*

List of abbreviations.
*Statistically significant difference with a two-tailed significance level of <.05 (5 %), † Early Warning Score.

complications (78.8 % vs. 69.8 %, p < .001) (Table 2). Likewise, the proportion of correct follow-up of EWSs ≥2 was higher in patients with complications (28.9 % vs. 22.6 %, p = .014). Both groups showed the best follow-up to an EWS ≥2 within 8–16 h (Table 3). At the surgical ward, correct follow-up of EWS 0–1 (83.0 % vs. 70.6 %; p = .001) and EWS ≥2 between 8 and 16 h (76.8 % vs. 62.0 %; p = .003) were higher in patients with complications. There were no further significant differences between patients with and without complications stratified by the ward (Table 4).

Among the different nursing wards, the proportion EWS 0–1 correct followed was significantly higher in the pulmonary ward (85.6 %) than in the internal and surgical wards (77.6 % and 76.4 %, respectively, p < .001) (Table 3). In contrast, the surgical ward showed a significant higher proportion correct followed EWSs ≥2 (31.3 %, p = .002).

4.3. Clinical response

Seventy-three patients had an EWS of ≥3 during admission. Of these, 50 (68.5 %) clinical responses included a nurses' or physicians report stating a physician was consulted as response to this EWS and were therefore considered correct (Table 2). The proportion correct clinical responses was significantly better in patients with complications (84.8 %) compared to patients without complications (55.0 %, p = .011) (Table 3). The proportion of correct clinical responses on the IM and surgical wards were 73.9 % and 77.3 %, respectively. This was a higher proportion compared to the pulmonary ward (57.1 %). However, this was not statistically significant (p = .304) (Table 2).

5. Discussion

The aim of this study was to describe variation in compliance of the EWS protocol in patients who did and did not experience complications and differences between general nursing wards. To our knowledge this is the first study to provide an more in-depth analysis of current practice of EWS compliance on nursing wards, including its differences among nursing wards and a broader range of complications. This study showed significant variations among all categories of EWS compliance, calculation accuracy, monitoring frequency and clinical response. The compliance to the EWS protocol appeared significantly better in patient with complications. But also, across the different nursing ward we found significant variations on the measured vital signs within incomplete measurement moments.

In our study, approximately 71 % of all measurement moments were completed. In comparison with previous studies, this result varied between 76 and 90 % [17,18,33–35]. The implementation of automated EWS calculation systems appears to improve completed EWS assessments over time [36,37]. In this study, the hospital also implemented an automated EWS calculation system. However, it is suggested that the improvement in calculation accuracy did not translate into an improvement in patient outcomes [37]. Compliance with escalation protocols when scores are elevated is more problematic. Therefore, it remains to be debated whether improving overall compliance to this part of the protocol will significantly improve the detection of clinical deterioration. Especially because nurses rely heavily on EWS scores but also perform holistic physical assessments to detect patient deterioration earlier [38,39]. Overreliance on scores alone may compromise patient safety [40–42]. There were also some differences in the vital signs collected between the general

Table 4
Early Waning Score (EWS) Compliance on each nursing ward divided by complication vs no complications.

Endpoint	Internal Medicine			Surgical			Pulmonary		
	Complications (n = 13)	No complications (n = 47)	P-value	Complications (n = 23)	No complications (n = 75)	P-value	Complications (n = 15)	No complications (n = 37)	P-value
Calculation accurac									
Number of measurement moments, n	619	933		1417	1385		449	1043	
Proportion completed EWSs†, n (%)	480 (77.5)	645 (69.1)	<.001*	1094 (77.2)	945 (68.2)	<.001*	297 (66.1)	664 (63.7)	.337
Number of incomplete measurement moments, n	139	288		323	440		152	379	
Proportion measured parameters within incomplete sets									
Blood pressure, n (%)	69 (48.9)	211 (75.7)	<.001*	155 (48.0)	223 (50.7)	.465	48 (31.6)	146 (38.5)	.136
Heartrate, n (%)	64 (46.0)	203 (70.5)	<.001*	164 (50.8)	238 (54.1)	.379	69 (45.4)	186 (49.1)	.501
Temperature, n (%)	64 (46.0)	113 (39.2)	.208	177 (54.8)	261 (59.3)	.236	67 (44.1)	112 (29.6)	.002*
Saturation, n (%)	62 (44.6)	169 (58.7)	.007*	170 (52.6)	222 (50.5)	.558	119 (78.3)	300 (79.2)	.815
Respiratory frequency, n (%)	14 (10.1)	66 (22.9)	.017*	70 (21.7)	95 (21.6)	1	39 (25.7)	120 (31.7)	.208
Monitoring frequenc									
Number of EWS† 0–1, n	287	444		658	763		162	338	
Proportion EWS† 0–1 correct followed, n (%)	216 (75.3)	351 (79.1)	.239	546 (83.0)	539 (70.6)	<.001*	143 (83.6)	285 (78.3)	.277
Number of EWS† ≥2,	180	155		413	108		120	289	
Proportion EWS† ≥2 correct followed, n (%)	42 (23.3)	29 (18.7)	.349	133 (32.2)	30 (27.8)	.416	31 (26.8)	66 (22.8)	.525
<8u, n (%)	98 (54.4)	86 (55.5)	.912	238 (57.6)	68 (63.0)	.326	64 (53.3)	154 (53.3)	1
8-16u, n (%)	129 (71.7)	104 (67.1)	.405	317 (76.8)	67 (62.0)	.003*	85 (70.8)	187 (64.7)	.251
16-24u, n (%)	114 (63.3)	89 (57.4)	.313	273 (66.1)	66 (61.1)	.365	78 (65.0)	197 (68.2)	.564
Clinical Respons									
Number of clinical responses,	9	14		12	10		12	16	
Correct clinical response, n (%)	8/(88.9)	9 (64.3)	.340	11 (91.7)	6 (60.0)	.135	9 (75.0)	7 (43.8)	.136

List of abbreviations.
*Statistically significant difference with a two-tailed significance level of <.05 (5 %), † Early Warning Score.

wards. Heart rate and blood pressure were the most commonly recorded vital signs, and it is unclear why these rates were high. One possible explanation is that a cuff blood pressure measurement automatically generates a heart rate measurement. This is consistent with other findings from a study of EWS compliance in hospitals [43]. In contrast to heart rate and blood pressure measurements, the frequency of measured respiratory rate was low (22.4 %). This has also been found in previous studies [18,44] and may be explained by a lack of understanding of its physiology and time constraints in performing measurements according to protocol; respiratory frequency is known to be an undervalued vital sign by nurses, resulting in poor recording [45]. Given the early detection of clinical deterioration, the low proportion of measured respiratory frequency is encouraging improvement on all wards.

There were also significant differences in the measured vital signs between the different nursing units. Nurses on the pulmonary ward are likely to focus more on oxygen saturation and respiratory rate measurements, whereas the surgical ward focuses considerably more on temperature and the IM ward on blood pressure and heart rate. These differences may mean that each specialty has its own relevant observations in relation to common diseases or complications within these specialties. The generic aspect of the EWS, as previously discussed by Downey et al. [7], therefore provides less opportunity for a tailored approach. In addition, there is evidence that generic EWSs have lower predictive value than specialty-specific scores, and that their sensitivity can be increased by adding variables [46]. Nevertheless, it should be noted there is considerable evidence for respiratory rate as a sensitive parameter for detection of clinical deterioration in a wide range of settings [47].

We also found a large difference in compliance with monitoring frequency within EWSs of 0–1 (78.4 %) and EWSs of $\geq$2 (26.1 %). We found significantly higher compliance in patients with complications compared to those without (29 % and 23 %, respectively). Although this was statistically significant higher, the compliance remains inadequate. A higher score indicates an increased risk of deterioration. It is therefore alarming that it is precisely the higher EWSs that are poorly adhered to in terms of monitoring frequency. Especially as the intermittent nature of the EWS is already a known limitation [7]. In addition to these findings, we also found that for all subgroups of EWSs, follow-up was best adhered to within 8–16 h $\geq$ 2. However, as the EWS is a tool for 'early' detection of clinical deterioration, we expected follow-up to be best adhered to within 8 h. When compared to other studies, they also found that higher EWSs were significantly associated with a lower likelihood of being monitored according to protocol [18,48]. Time constraints, heavy workloads and understaffing were mentioned by nurses as reasons for non-compliance [17,26,38,49]. On the other hand, nurses with shorter work experience found EWS particularly helpful in prioritizing care [50].

Notably, regardless of the severity of complications, we found better compliance with the EWS protocol in patients with complications. It is known that it is difficult for nurses to comply with EWS protocols due to heavy workloads, previous experiences and challenges in obtaining medical assistance [51]. Although this study did not focus on differences in compliance before and after the manifestation of the complication, better compliance was observed throughout the admission of patients with complications. In particular, we found a large difference in compliance with the clinical response (55 % versus 85 %). The interview study by Petersen et al. which focused on barriers to informing physicians, concluded that nurses considered themselves competent to manage patients without assistance [20,48]. This may explain why nurses had low compliance with the clinical response in patients without complications. Given these findings, it highlights the role of nurses in allocating attention to patients who are about to deteriorate and those who are not considered at risk, regardless of the EWS, as the majority of nurses manipulated or inaccurately documented vital signs to achieve a desired EWS score and would almost override the protocol if it did not agree with their clinical judgement [38,41]. It emphasizes the autonomy of nurses to make clinical decisions based on their clinical judgement.

6. Limitations

The retrospective nature of this study provides an accurate description of current practice, but there are several limitations when considering the results of our study. First, the generalisability of the results is limited due to the single-centre study design. Studying variations in EWS compliance across different centers or over time could be relevant for a first step for future research. Second, although this study included almost 6000 measurements, the subgroups of patients with and without complications stratified by ward resulted in a relatively small sample. Although we found statistical significant differences, this may have compromised the achievement of statistical significance. Third, the distribution of patients within the nursing wards was uneven. Almost 50 % of the included patients were admitted to the surgical ward. Although the statistical power is based on the smallest sample, this did not affect the ability to detect significant variations between the different nursing wards. Fourth, this study focused on completed EWSs and 'incomplete measurements' without an EWS. Clinical decisions to deviate from the protocol were not taken into account and may have resulted in a narrower understanding of current protocol compliance. Fifth, the study was conducted during the COVID-19 pandemic which may affected on the compliance rates in the pulmonary ward.

7. Recommendations for future research

The findings of this study indicate that the current standards for the identification of clinical deterioration is suboptimal and require enhancement. The introduction of the EWS may have been an overly simplistic solution for the complex issue of clinical deterioration [38]. For future improvements of the identification of clinical deterioration, it is crucial to understand the reasons behind low protocol compliance. Significant variations in protocol compliance should be analysed, and improvement strategies should be tailored to specific groups and contexts [42]. Furthermore, individual factors (e.g. age, sex, medical condition) and contextual factors (day/night shifts, nurse-to-patient ratios) that may influence compliance should be further explored in depth. Nursing wards may also benefit from the application of new strategies to detect complex and dynamic clinical situations. We recommend further research into the thorough development of new strategies to detect clinical deterioration using new innovative technologies. Previous studies have already

suggested application of continuous vital signs monitoring increases the accuracy of detecting clinical deterioration in nursing wards [52–55]. Furthermore, trend analysis of intermittent (or continuous) vital signs measurements, enhanced by artificial intelligence and machine learning technologies, may enable the development of more sophisticated and personalised EWSs by combining vital signs with other variables such as patient characteristics [56,57]. Besides a proper algorithm, successful implementation of EWS systems relies heavily on other key factors, including education [42], inter-professional collaboration [58], interoperability with IT systems , and managerial appreciation [59]. These elements collectively contribute to the effective integration and utilization of EWS systems in clinical practice.

8. Conclusion

In conclusion, the results of this study suggest suboptimal compliance with the EWS protocol with a large amount of variation in relation to patients with and without complications and between different general wards. Nurses tended to be more compliant with the EWS protocol in patients with complications. In addition, nursing wards appear to focus on the most important vital signs in relation to the speciality of the ward. It is essential to integrate EWS with nurses' clinical assessments to enhance early detection of deterioration.

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Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Jobbe PL. Leenen: Writing – review & editing, Writing – original draft, Validation, Supervision, Investigation, Data curation, Conceptualization. **Chantal L. Mondria:** Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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