In-hospital cardiac arrest and preceding National Early Warning Score (NEWS): A retrospective case-control study

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We aimed to describe and evaluate the National Early Warning Score (NEWS) in the 24 hours preceding an in-hospital cardiac arrest among general somatic ward patients.

The 24 hours preceding the in-hospital cardiac arrest were divided into four timespans and analysed by a medical record review of 127:254 matched case-control patients. The median NEWS ranged from 3 (2–6) to 6 (3–9) points for cases vs 1 (0–3) to 1 (0–3) point for controls. The proportion of cases ranged from 23–45% at high risk vs 3–6% for controls. The NEWS high-risk category was associated with an increase of 3.17 (95% confidence interval (CI) 1.66–6.04) to 4.43 (95% CI 2.56–7.67) in odds of in-hospital cardiac arrest compared to the low-risk category.

NEWS, with its intuitive and for healthcare staff easy to interpret risk classification, is suitable for discriminating deteriorating patients with major deviating vital signs scoring high risk on NEWS.

KEYWORDS: National Early Warning Score, in-hospital cardiac arrest, critical care outreach, medical emergency team, early warning scores

Introduction

A majority (50–57%) of the in-hospital cardiac arrests (IHCA) occur on hospital wards.^{1,2} The survival rate is low, and approximately 83% die within 30-days and, in comparison, if IHCA occur in a cardiac catheterisation laboratory, the 30-day mortality rate is 37%.² The research and guidelines for IHCA have predominantly focused on resuscitation and treatment when the event has already occurred and, despite these efforts, the survival after IHCA is low.² To address this, the latest European Resuscitation Council (ERC) guidelines emphasised the need for preventing IHCA and, in order to take preventive steps, patients at risk of IHCA need to be identified early.³

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Deviating vital signs have been known for decades to precede IHCA, and the National Early Warning Score (NEWS) is a tool designed to identify patients at risk of IHCA, unexpected death and of intensive care unit (ICU) admission within 24 hours.^{4–9} NEWS has been shown to be superior to other early warning score instruments and is a recognised tool widely adopted in hospital settings across Europe.^{10–15} NEWS classifies the clinical risk for critical illness into low, medium and high risk, providing a clinically useful way to discriminate patients at risk of suffering an IHCA. In a clinical setting it might be difficult for the healthcare staff to relate the total score to the risk of serious adverse events like IHCA whereas the NEWS risk classification offers a more intuitive clinical risk stratification. However, previous studies have focused on the total score and shown that IHCA, compared to unexpected death and ICU admission, appears to be the most complicated adverse event for NEWS to discriminate. When using the total score measured some time during the 24 preceding hours, the commonly used area under the curve (AUC) ranged from 0.72–0.78 for IHCA compared to 0.86–0.91 for unexpected death and 0.86–0.86 for ICU admission.^{9,10,12}

Further evaluation of NEWS in this area is needed even though this previous research indicates that NEWS is a promising tool for the detection of IHCA. Knowledge about NEWS when using the clinical risk classification groups (low, medium and high) might contribute to the prevention of IHCA, providing opportunities to intervene and prevent unnecessary suffering.

Moreover, the degree and timing of physiological instability in the 24 hours preceding IHCA have been shown to differ between studies.^{4,5} Instability for as long as 8–24 hours before the IHCA has been reported but none of these studies reflect the dynamics of NEWS.^{4,5}

The aim of the study was to describe NEWS in different timespans in the 24 hours preceding IHCA and to evaluate the discriminative ability of NEWS among general somatic ward patients, using the clinical risk classification.

Materials and methods

Study design and setting

This is a retrospective multicentre medical record review study, using a 1:2 matched case-control design. Three emergency hospitals in Sweden, comprising one university hospital with 997 adult beds and two regional hospitals with 304 and 246 adult beds participated (catchment area population of 1.3 million citizens).

Patients

All patients, \geq 18 years of age, admitted for at least 24 hours, suffering an IHCA on a general somatic hospital ward from 01 January 2016 to 31 December 2017 were reviewed for eligibility. Patients suffering an IHCA in the ICU, cardiac high-dependency unit, cardiac catheterisation laboratory, operating theatre, postoperative recovery unit or in the emergency department were not considered for inclusion. Further, patients with chronic obstructive pulmonary disease (COPD) were excluded because their oxygen saturation should be judged individually depending on their habitual state.⁸ Patients without any NEWS measurements during the studied period were also excluded. The included patients with IHCA (cases) were matched with controls without IHCA in a 1:2 ratio by the same admission year, hospital, ward, sex, age ±5 years, primary admission diagnosis or admission diagnosis chapter according to the International Classification of Diseases 10th revision (ICD-10).¹⁶

Definitions

NEWS is calculated from measures of respiratory rate, oxygen saturations, body temperature, systolic blood pressure, heart rate and level of consciousness which are rated from 0–3, correlating with their divergence from the expected normal values, and summed. Supplemental oxygen increases the score by 2 points.⁸

According to guidelines, the NEWS clinical risk scale was calculated as follows; low risk = 0-4 points, medium risk = 5-6 points or 3 points in one parameter and high risk = ≥ 7 points.⁸

Comorbidity was assessed by the Charlson comorbidity index (CCI) and the age-adjusted Charlson comorbidity index (ACCI).¹⁷ Further, ACCI was categorised into minimal, low, moderate or severe 'burden of age-combined comorbidities' if the ACCI was 0–2 points, 3–5 points, 6–7 points or 8 points and higher, respectively.¹⁸

The hospitals in the study participate in the Swedish Cardiac Arrest Registry and their definition of IHCA was used, ie a patient who is unresponsive with apnoea or agonal, gasping respiration where cardiopulmonary resuscitation and/or defibrillation was initiated.¹⁹

Data collection

Cases were identified in the hospitals' documentation systems and cardiac arrest records. The following data were collected by the researchers and stored in an electronic database: hospital, ward, date of admission, date of IHCA, age, sex, primary diagnosis according to the International Statistical Classification of Diseases and Related Health Problems 10th revision (ICD-10), comorbidity, vital signs, NEWS-parameters and hospital mortality. After inclusion, the hospitals' electronic medical records were searched for matching controls. When the data of both cases and controls were collected, the electronic database was searched both automated and manually for illogical values by one of the authors. For calculation of NEWS, at least 4 of the 7 parameters needed to be registered at the same time and the missing parameters had to be documented in another NEWS measurement during the 24 hours, otherwise the NEWS was categorised as missing. The last measurement was carried forward manually to replace the missing value.

Ethics

This study was approved by the regional Research Ethical Review Board in Lund, Sweden which waived the need for informed consent (Dnr 2016/940). The study is reported in accordance with the strengthening the reporting of observational studies in epidemiology (STROBE) statement.²⁰

Statistical analysis

An a priori sample size calculation showed that 100 cases and 200 controls would generate a power of >80% to detect an odds ratio of 2.0 with an α -level of 0.05. Categorical and nonparametric data are presented with median scores (25–75 percentiles). The Mann–Whitney U-test and χ^2 test were used to test for differences between cases and excluded. We chose to divide the data into four different 6-hour timespans (24–18 hours, 18–12 hours, 12–6 hours and 6–0 hours) preceding the IHCA with inspiration from a report of the National Confidential Enquiry into Patient Outcome and Death.⁵ In case of multiple NEWS measurements within each timespan, the highest NEWS value was chosen. For control patients, the highest NEWS value during the 24 studied hours was chosen as their study period was chosen arbitrarily ie without a fixed time of event. The Friedman test was used to test for differences between cases and controls. The Wilcoxon signed rank test was used to test for differences between cases in different timespans.

Conditional logistic regression analysis was used with high, medium and low risk as independent variables for prediction of IHCA and presented as odds ratio (OR) with 95% confidence interval (CI). The CCI, ACCI, categorised ACCI, sex, medical affiliation and the metric variable age were tested as covariates.

The ability of the NEWS risk classification to discriminate IHCA was performed by AUC. Statistical significance was set at p<0.05. All analyses were performed with IBM SPSS, v25.

Results

Baseline characteristics

A total of 127 patients suffering an IHCA (cases) was included (Fig 1). Median age of the cases was 73 (62–80) years, 76 (60%) were male and 80 (63%) were medical patients (Table 1). When including the 254 control patients there was a total of 970 NEWS measurements and missing data occurred in 203 (21%) of these. The most common missing NEWS parameter was temperature, in 178 (18%) NEWS measurements, followed by supplemental oxygen, in 10 (1%) NEWS measurements. Twenty-six of the 970



Fig 1. Flow diagram of general ward patients included. COPD = chronic obstructive pulmonary disease; IHCA = in-hospital cardiac arrest; NEWS = National Early Warning Score.

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Severe ≥8 points, n (%) 20 (16) 31 (12) n/α	Moderate 6–7 points, n (%)	28 (22)	60 (24)	n/a				
	Severe ≥8 points, n (%)	20 (16)	31 (12)	n/a				

IHCA = in-hospital cardiac arrest; n/a = not applicable.

NEWS measurements were upgraded to medium risk due to a score of 3 in a single parameter. Of the NEWS measurements, 226 were excluded due to multiple NEWS measurements within its timespan, leaving 744 for further analysis.

NEWS in different timespans

In the timespan 24–18 hours before IHCA, 56 cases had a NEWS assessment and the median NEWS was 3(2-6) points vs 1(0-3)point for controls (p<0.001). Among cases, 23% were at high risk and 16% at medium risk vs 3% and 7%, respectively, among the controls (p<0.001; Table 2). Medium or high risk on NEWS was associated with an increase in the odds of 2.47 (95% CI 1.18-5.17, p=0.016) and 3.17 (95% CI 1.66-6.4, p<0.001) for IHCA, respectively, compared to low risk. AUC for the NEWS risk classification in discriminating IHCA was 0.58 (95% CI 0.49-0.67, p=0.087; Table 3).

In the timespan 18–12 hours before IHCA, 63 cases had a NEWS assessment and the median NEWS was 4 (2-6) points vs 1 (0-3)

point for controls (p<0.001). Among cases, 18% were at high risk and 30% at medium risk vs the controls, 3% and 12%, respectively (p<0.001; Table 2). Medium or high risk on NEWS was associated with an increase in the odds of 2.33 (95% CI 1.32-4.11, p=0.003) and 3.57 (95% CI 1.79–7.10, p<0.001) for IHCA, respectively, compared to low risk. AUC for the NEWS risk classification in discriminating IHCA was 0.61 (95% CI 0.52–0.69, p=0.018; Table 3).

In the timespan 12–6 hours before IHCA, 67 cases had a NEWS assessment and the median NEWS was 4 (2–6) points vs 1 (1–3) point for controls (p<0.001). Among cases, 24% were at high risk and 22% at medium risk vs the controls 3% and 16%, respectively (p<0.001; Table 2). Medium or high risk on the NEWS was associated with an increase in the odds of 1.59 (95% CI 0.87-2.92, p=0.131) and 3.69 (CI 2.04-6.67, p<0.001) for IHCA, respectively, compared to low risk. AUC for the NEWS risk classification in discriminating IHCA was 0.59 (95% CI 0.51-0.67, p=0.041; Table 3).

In the timespan 6–0 hours before IHCA, 62 cases had a NEWS assessment and the median NEWS was 6 (3-9) points for cases

Table 2. The NEWS risk classification in the different timespans							
Timespans	Patients with IHCA (cases)	Patients without IHCA (controls)	Cases vs controls, p-value				
NEWS risk classification 24–18 hours before IHCA:	n=56	n=112	<0.001				
Low, n (%)	34 (61)	101 (90)					
Medium, n (%)	9 (16)	8 (7)					
High, n (%)	13 (23)	3 (3)					
NEWS risk classification 18–12 hours before IHCA:	n=63	n=126	<0.001				
Low, n (%)	33 (52)	107 (85)					
Medium, n (%)	19 (30)	15 (12)					
High, n (%)	11 (18)	4 (3)					
p-value between timespan 24–18 vs 18–12 hours	0.819	n/a					
NEWS risk classification 12–6 hours before IHCA:	n=67	n=134	<0.001				
Low, n (%)	36 (54)	109 (81)					
Medium, n (%)	15 (22)	21 (16)					
High, n (%)	16 (24)	4 (3)					
p-value between timespan 18–12 vs 12–6 hours	0.658	n/a					
NEWS risk classification 6–0 hours before IHCA:	n=62	n=124	<0.001				
Low, n (%)	24 (39)	100 (81)					
Medium, n (%)	10 (16)	16 (13)					
High, n (%)	28 (45)	8 (6)					
p-value between timespan 12–6 vs 6–0 hours	0.048	n/a					

IHCA = in-hospital cardiac arrest; n/a = not applicable; NEWS = National Early Warning Score.

and 1 (0–3) point for controls (p<0.001). Among cases, 45% were at high risk and 16% at medium risk vs the controls 6% and 13%, respectively, (p<0.001; Table 2). Medium or high risk on the NEWS was associated with an increase in the odds of 1.63 (95% CI 0.78–3.42, p=0.195) and 4.43 (95% CI 2.56–7.67, p<0.001) for IHCA, respectively, compared to low risk. AUC for the NEWS risk classification in discriminating IHCA was 0.64 (95% CI 0.56–0.72, p=0.002; Table 3).

The CCI, ACCI, categorised ACCI, sex, medical affiliation and the metric variable age were tested as covariates in the different timespans but not found to be significant.

When testing the distribution of the NEWS risk categories among cases in different timespans, a difference was found between 0-6 hours and 6-12 hours before IHCA (p=0.04; Table 2).

Discussion

The results in our study suggest a process of clinical deterioration in patients suffering an IHCA, with the timespan 6–0 hours being the most favourable for NEWS to identify patients at risk. In all timespans, 18–24% of cases were classified as high risk whereas in the timespan 6–0 hours the percentage almost doubled. The corresponding proportion among controls was 3–6% during all timespans. Further, there was a more than threefold increase in odds of IHCA in the high-risk group compared to the low-risk group during all timespans, indicating that a large proportion of patients suffering an IHCA can be detected up to 24 hours prior to the incident.

Medium risk seems to be the most challenging group to differentiate against since the difference in proportion of patients

Table 3. Conditional logistic regression analysis for IHCA on the NEWS risk classification								
NEWS risk classification compared to low risk	24–18 hours before	18–12 hours before	12–6 hours before	6–0 hours before				
	IHCA	IHCA	IHCA	IHCA				
Medium, OR (95% CI,	2.47	2.33	1.59	1.63				
p-value)	(1.18–5.17, p=0.016)	(1.32–4.11, p=0.003)	(0.87–2.92, p=0.131)	(0.78–3.42, p=0.195)				
High, OR (95% CI,	3.17	3.57	3.69	4.43				
p-value)	(1.66–6.04, p<0.001)	(1.79–7.10, p<0.001)	(2.04–6.67, p<0.001)	(2.56–7.67, p<0.001)				
AUC (95 % CI, p-value)	0.58	0.61	0.59	0.64				
	(0.49–0.67, p=0.087)	(0.52–0.69, p=0.018)	(0.51–0.67, p=0.041)	(0.56–0.72, p=0.002)				

AUC = area under the curve; CI = confidence interval; IHCA = in-hospital cardiac arrest; NEWS = National Early Warning Score; OR = crude odds ratio.

suffering an IHCA compared to others was not particularly large, and it might be difficult for a ward-based physician not skilled in the assessment of acutely ill patients to assess these patients. In the revised NEWS2 outline clinical response scale, a clinician or team with competence in the assessment and treatment of acutely ill patients is recommended at this level.²¹ It seems that this might be a crucial step to find patients truly at risk of IHCA in this risk category.

The overall discriminative ability of NEWS as tested by the AUC was poor. The greatest discriminative ability was seen in the timespan 6–0 hours before IHCA but it was still considered low (0.64), indicating that many patients might be missed. Our study showed that a large proportion of patients suffering an IHCA show minor deviating vital signs in the preceding 24–6 hours, thus making it more difficult for NEWS to discriminate in these timespans. Previous studies showed greater AUC values for unexpected death and ICU-admission than for IHCA and support these findings.^{9,10,12}

In a study by Nolan *et al*, IHCA occurred in a median of 48 hours after admittance to the hospital and, in our study, IHCA occurred in a median of 72 hours after admittance among patients being admitted for more than 24 hours to the hospital, signalling that there might be a window of opportunity to detect deterioration in many patients.¹ Survival after IHCA has previously been shown to be associated with comorbidity as shown in the study by Roberts *et al.*¹⁸ However, as in the study by Tirkkonen *et al*, where patients had been reviewed by the rapid response team prior to IHCA, the CCI was not found to be a significant confounder associated with IHCA in our study.²² It seems that comorbidity is not associated with the incidence of an IHCA. However, survival after IHCA seems to be associated with comorbidity as shown in the study by Roberts *et al.*¹⁸

Approximately 39% of patients suffering an IHCA were classified as low risk in the timespan 6–0 hours. However, none of the patients suffering an IHCA had a NEWS of 0 points, which might warrant a new risk category of 'Low-low' or 'Minimal' where those with a NEWS of 0 points are placed. This might increase the discriminative ability of patients at risk and increase hospital staff's awareness of these patients. Further, our results raise the question whether intermittent evaluation of a patient's vital signs is appropriate or if continuous vital signs monitoring should be used on all patients with deviating vital signs.

Limitations and strengths

Missing recordings of vital signs is a well-known problem in healthcare settings.^{5,22–26} In our study, missing data occurred, mostly concerning temperature and, in some cases, supplemental oxygen. We tried mitigating the effects of missing variables by inputting the last recorded value in the parameter and we do not suspect this has introduced any significant bias. Further, temperature has previously been shown not to be a predictor of IHCA and there was just 1% missing in supplemental oxygen, which is deemed non-significant to the results.²⁷

Another limitation was the exclusion of patients; those with COPD which were done because their oxygen saturation should be judged individually depending on their habitual state and those suffering an IHCA without having a documented NEWS in the preceding 24 hours. No major differences were found comparing patient characteristics between excluded and included patients, but a tendency towards a difference in main reasons for admission as categorised by the ICD-10, which was probably due to us deciding to exclude all patients with COPD.

We chose to use the highest NEWS in the different timespans, if multiple NEWS were available, this might be a limitation if it is not the closest one to the IHCA. Since the timespan 6–0 hours before IHCA was the most important for detecting deterioration in our study we considered performing a subgroup analysis. However, there were 20 patients with multiple measurements 0–6 hours preceding IHCA. Of these, 18 patients had the highest NEWS closest to the IHCA and since only two patients did not, we did not perform a subgroup analysis.

Furthermore, the observational retrospective study design only allowed associations to be drawn and not causality, and we thus tried to clarify our results by adjusting for possible confounders in age, sex, comorbidity and medical affiliation.

A strength in our study is the multicentre approach where both a large university hospital and smaller community hospitals were included as this might increase the generalisability.

Conclusion

The proportion of patients classified as high risk almost doubled between 12–6 and 6–0 hours before the IHCA, indicating a dynamic process of deterioration.

NEWS high risk was associated with a more than threefold odds of IHCA compared to low risk during the preceding 24 hours.

NEWS, with its intuitive and for healthcare staff easy to interpret risk classification, is thus suitable for discriminating deteriorating patients with major deviating vital signs scoring high risk on NEWS.

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