

Nurses' 'worry' as predictor of deteriorating surgical ward patients: A prospective cohort study of the Dutch-Early-Nurse-Worry-Indicator-Score



Gooske Douw^{a,b,*}, Getty Huisman-de Waal^b, Arthur R.H. van Zanten^c, Johannes G. van der Hoeven^d, Lisette Schoonhoven^{e,b}

^a Gelderse Vallei Hospital, Care Division, Willy Brandtlaan 10, 6716 RP Ede, The Netherlands

^b Radboud university medical centre, Radboud Institute for Health Sciences, Scientific Center for Quality of Healthcare (IQ H), Geert Grooteplein 21 (route 114), Nijmegen, The Netherlands

^c Gelderse Vallei Hospital, Willy Brandtlaan 10, 6716 RP Ede, The Netherlands

^d Radboud university medical centre, Geert Grooteplein 10, 6525 GA Nijmegen, The Netherlands

^e University of Southampton, Faculty of Health Sciences, NIHR CLAHRC (Wessex), Level A, (MP11) South Academic Block, Southampton General Hospital, Tremona Road, SO16 6YD, United Kingdom

ARTICLE INFO

Article history:

Received 30 October 2015

Received in revised form 3 April 2016

Accepted 5 April 2016

Keywords:

DENWIS

Deterioration

Early recognition

Hospital Rapid Response Team

Intensive Care Unit

Nurses

Worry

ABSTRACT

Background: Nurses' 'worry' is used as a calling criterion in many Rapid Response Systems, however it is valued inconsistently. Furthermore, barriers to call the Rapid Response Team can cause delay in escalating care. The literature identifies nine indicators which trigger nurses to worry about a patient's condition.

Objectives: The objective of this study is to determine the significance of nurses' 'worry' and/or indicators underlying 'worry' to predict unplanned Intensive-Care/High-Dependency-Unit admission or unexpected mortality among surgical ward patients.

Design: A prospective cohort study.

Settings: A 500-bed tertiary University affiliated teaching hospital.

Participants: Adult, native speaking surgical patients, admitted to three surgical wards (traumatology, vascular- and abdominal/oncological surgery). We excluded patients with a non-ICU policy or with no curative treatment. Mentally incapacitated patients were also excluded.

Methods: We developed a new clinical assessment tool, the Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) based on signs underlying 'worry'. Nurses systematically scored their 'worry' and the DENWIS once per shift or at any moment of 'worry'. DENWIS measurements were linked to routinely measured vital signs. The composite endpoint was unplanned Intensive-Care/High-Dependency-Unit admission or unexpected mortality. The DENWIS-indicators were included in a univariate and multivariate logistic regression analysis, subsequently inserting 'worry' and the Early Warning Score into the model. We calculated the area under the receiver-operating characteristics curve.

Results: In 3522 patients there were 102 (2.9%) patients with unplanned Intensive Care Unit/High Dependency Unit-admissions or unexpected mortality. 'Worry' (0.81) and the DENWIS-model (0.85) had a lower area under the receiver-operating characteristics curve than the Early Warning Score (0.86). Adding 'worry' and the Early Warning Score to the DENWIS-model

* Corresponding author at: Gelderse Vallei Hospital, Willy Brandtlaan 10, 6716 RP Ede, The Netherlands. Tel.: +31 614483964; fax: +31 318 434116.
E-mail addresses: douw@zgv.nl (G. Douw), Getty.Huisman-deWaal@radboudumc.nl (G. Huisman-de Waal), ZantenA@zgv.nl (Arthur R.H. van Zanten), Hans.vanderHoeven@radboudumc.nl (J.G. van der Hoeven), L.Schoonhoven@soton.ac.uk (L. Schoonhoven).

resulted in higher areas under the receiver operating characteristics curves (0.87 and 0.91, respectively) compared with the Early Warning Score only based on vital signs.

Conclusions: In this single-center study we showed that adding the Early Warning Score based on vital signs to the DENWIS-indicators improves prediction of unplanned Intensive-Care/High-Dependency-Unit admission or unexpected mortality.

© 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

What is already known about the topic?

- Some Rapid Response Systems add ‘worry’ or ‘concern’ as subjective calling criterion, but it is valued inconsistently.
- Barriers for ward nurses to call an RRT are: lack of confidence, the need to justify the call, overestimation of own ability, and/or underestimation of clinical signs.
- The indicators ‘changes in breathing’, ‘changes in circulation’, ‘rigors’, ‘changes in mentation’, ‘agitation’, ‘pain’, ‘no clinical progress’, ‘patient indicating not feeling well’, and ‘subjective nurse observations’ were identified as underlying ‘worry’.

What this paper adds

- Development of the Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS).
- DENWIS indicators or ‘worry’ added to an Early Warning System based on vital signs improves prediction of unplanned Intensive Care Unit admission or unexpected mortality.
- DENWIS can be an assessment tool to:
 - structure the reporting of signs and symptoms underlying nurses’ ‘worry’,
 - improve (inter) disciplinary communication,
 - empower nurses and overcome barriers to call the RRT on the ‘worry’ criterion.

1. Introduction

Increasing complexity of patients on general wards warrants a rapid and adequate response in case of imminent deterioration. Rapid Response Systems (RRSs) can fill the gap when knowledge or skills of ward staff in managing deteriorating patients is insufficient. RRSs often provide supplementary knowledge and competencies of Intensive Care Unit (ICU) professionals to general ward patients through Rapid Response Teams (RRTs) (DeVita et al., 2006). As a consequence, treatment on the ward is optimized to prevent further deterioration at an early stage. Rapid Response Teams are activated through calling systems which are mainly based on abnormal vital signs, either as single calling criterion or as an aggregated system with cumulative scoring in an Early Warning System (EWS) (Gao et al., 2007).

In addition to vital signs, nurses’ ‘worry’ can be a calling criterion to activate RRTs, but it is used and valued inconsistently (Gao et al., 2007; Hodgetts et al., 2002; Smith et al., 2013). Furthermore, nurses experience barriers to call an RRT such as a lack of confidence (Jones et al., 2009; Shapiro

et al., 2010), the need to justify a call (Astroth et al., 2013; Braaten, 2015; Mackintosh et al., 2012) or fear of criticism (Bagshaw et al., 2010). Apart from these feelings of uncertainty, also underestimation of the pathophysiology underlying clinical signs (Jones et al., 2006) or a belief that patients should or can be managed on the ward (Shearer et al., 2012) influence nurses’ decisions to call the RRT. These barriers can cause a delay in escalating care.

In order to explore the ‘worry’ criterion, we recently performed a systematic literature review (Douw et al., 2015) and identified underlying signs and symptoms of the ‘worry’ criterion that nurses pick up and subsequently act upon. The signs were categorized into 10 indicator domains. Apart from ‘intuitive knowing’ these indicators included ‘changes in breathing’, ‘changes in circulation’, ‘rigors’, ‘changes in mentation’, ‘agitation’, ‘pain’, ‘no clinical progress’, ‘patient indicating not feeling well’, and ‘subjective nurse observations’.

We hypothesized that nurses’ ‘worry’ and/or the nine indicators underlying ‘worry’, can improve the system for RRT activation and potentially contribute to earlier treatment and better patient outcomes, such as unplanned ICU-admission or unexpected mortality. We designed a prospective observational study to determine the value of nurses’ ‘worry’ and/or the other nine indicators underlying ‘worry’ to predict unplanned ICU/High Dependency Unit (HDU)-admission or unexpected mortality among patients admitted to a surgical ward, either in comparison or in addition to a vital signs based RRT calling system.

2. Methods

This prospective cohort study was performed from March 2013 until April 2014 in a 500-bed tertiary University affiliated teaching hospital in the Netherlands, including a level 3 ICU, capable of providing, complex, multisystem life support, a Medium Care Unit (MCU), and Cardiac Care Unit (CCU).

The hospital introduced an RRS in 2007, with the RRT consisting of an ICU-nurse, an ICU-resident and a consultant intensivist. All are available 24 h a day, seven days a week. Vital signs included in the EWS were: respiratory rate, arterial oxygen saturation, oxygen supply, systolic blood pressure, heart rate, temperature, and consciousness level. These vital signs could be awarded 0–4 points depending on the severity of deterioration, and with a maximum of 21 points. Although urine production and lactate were included in the EWS, they were not included in our present study, since these criteria frequently are not known at the first call. ‘Worry’ was an additional criterion which enabled nurses to consult the RRT-nurse with a low

threshold. At an EWS trigger point of 7 nurses first consulted the attending physician, who should assess the patient within 30 min and consult the RRT. In case of delay nurses were allowed to call the RRT directly.

2.1. Selection criteria

We included adult (>18 years of age), native speaking surgical patients, admitted to three surgical wards (traumatology, vascular and abdominal/oncological surgery). The hospital used different codes for treatment agreements and Do-Not-Resuscitate (DNR)-codes: code 1: active treatment; code 2: no cardiopulmonary resuscitation; code 3: code 2 and additionally no (invasive) ventilation and/or renal support; code 4: code 3 and palliative or end-of-live care. Only patients with the first two codes were included. Mentally incapacitated and non-native speaking patients were excluded.

2.2. Measurements

We developed a clinical assessment tool, the Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) (Table 1), based on previously determined 'worry' signs (Douw et al., 2015).

The DENWIS was added to the electronic nursing files and nurses received notification through thorough oral and written instructions before data collection commenced. Nurses were requested to score the DENWIS once per shift or at any moment of 'worry'. 'Worry' was scored as present or not. Apart from 'worry' we also defined worry when the EWS trigger point to call for assistance was not reached to differentiate between worry with vital signs triggering an RRT call, which might be the cause of 'worry'. We defined it as 'worry with an EWS < 7'.

As routine care, vital signs were measured every eight hour shift, however this frequency could be changed according to the prevailing EWS-protocol: when stable once a day, EWS 5–7 every two hours and EWS > 7 every hour. Based on this protocol we assumed vital signs to be normal if measured once a day. DENWIS-measurements were linked to the vital signs closest to the DENWIS measurement.

If vital signs were missing we used measurements up to a maximum of 8 h before or 4 h after a DENWIS observation. In case single vital signs measurements were still missing, we used measurements up to 24 h before the DENWIS observation. According to the EWS-protocol, vital signs

should have been repeated when abnormal. When a single vital sign was not measured during these 24 h they were considered to be normal and we scored 0 points on the EWS.

The composite endpoint was unplanned ICU/HDU-admission or unexpected in-hospital mortality. Secondary endpoints were: Hospital-Length-of-Stay and 30-day mortality after the day of hospital admission.

2.3. Data-collection

Data from the electronic patient files were extracted from the hospitals' Datawarehouse using SAS Enterprise Guide (SAS Institute, Huizen, the Netherlands).

2.4. Sample size

The nine DENWIS indicators together with the EWS accounted for 10 variables in the prediction model. For reliable predictions we needed to include at least 100 unplanned ICU/HDU-admission or unexpected mortality events to fulfill the rule of a minimum of 10 events per variable in a prediction model (Peduzzi et al., 1996). Based on earlier experience we estimated that approximately 4000 ward admissions should be included, and used a termination criterion to stop inclusion if during data collection a minimum of 100 events was reached.

2.5. Nursing sample

Ninety-six nursing staff worked on the participating wards at the start of the data-collection. Nineteen percent had a bachelors degree, 57% were diploma nurses, and 24% were students. Sixty-one percent of the nurses had five or more years experience, 15% less than 5 years and the remaining 24% were students.

2.6. Data-analysis

Continuous variables are reported as mean \pm SD, nominal variables as frequencies and percentages. Comparisons of data between patients with and without unplanned ICU/HDU-admission or unexpected mortality, were performed using the Fishers Exact Test and Students *t*-test for nominal and continuous data, respectively. For non-normally distributed continuous data, the Mann-Whitney test was used.

The EWS, 'worry', 'worry with an EWS < 7' and the separate DENWIS-indicators were analyzed in a univariate

Table 1
Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) assessment tool.

Indicator	Underlying signs and symptoms
Change in breathing	Noisy breathing and/or short of breath and/or unable to speak full sentences and/or use of accessory muscles
Change in circulation	Color changes and/or clammy and/or coldness and/or impaired perfusion and/or edema
Rigors	Rigors
Change in mentation	Lethargic and/or confused
Agitation	Restless and/or anxious
Pain	New pain and/or increasing pain
No progress	No progress and/or abdominal distension and/or nausea and/or bleeding and/or dizzy/fall
Patient indicates	Not feeling well and/or feeling of impending doom
Subjective nurse observation	Change in behavior and/or doesn't look good and/or look in the eyes

Signs were scored when present.

logistic regression analysis. Next, DENWIS-indicators were included in a multiple logistic regression analysis, forcing all indicators into the model, subsequently adding 'worry' and the EWS to the DENWIS-model. We calculated the area under the receiver-operating characteristics curve (AUROC) (95% Confidence Interval [CI]) to determine the best predictor for unplanned ICU/HDU-admission or unexpected mortality. As each patient had multiple measurements taken per day we used the measurement which occurred first in the 24 h before unplanned ICU/HDU-admission or unexpected mortality as the variable in the logistic regression analyses. This was either 'worry with an EWS < 7' or an EWS \geq 7. If both were not present, the last measurement before an event was used. In the group with no events (control group) we used the first measurement to occur during hospital stay: 'worry with an EWS < 7' or an EWS \geq 7. If both were not present we used a random measurement (Table 2).

All calculations were performed using SPSS version 20 (IBM Corp., 2011). A p -value < 0.05 was considered significant for all tests. The local ethical committee approved the study, and waived the need for informed consent. All data were handled anonymously.

3. Results

We included 3522 patients of whom 102 (2.9%) had an unplanned ICU/HDU-admission (ICU: $n = 70$; Medium Care Unit: $n = 20$; Cardiac Care Unit: $n = 7$) or died unexpectedly ($n = 5$) (flow diagram in Fig. 1).

Demographic data are shown in Table 3.

Patients in the event group more frequently had a DNR-code 2 (22.5% vs. 6.3%; $p < 0.001$). The 30-day mortality after hospital admission was significantly higher in the group of patients with unplanned ICU/HDU admission (11.3% vs. 0.4%; $p < 0.001$). Most patients transferred to the ICU/HDU previously underwent abdominal/oncological surgery (55.9%). Presence of co-morbidities was similar in the event and the control group (38.2% vs. 34.2%; $p = 0.399$).

In the event group 85% of cases had a positive 'worry' and 70% had a positive 'worry with an EWS < 7' versus 23% and 22% in the control group, respectively ($p < 0.001$). We found 29% of the event group had incomplete vital signs sets versus 76% of the control group. Most frequently missing vital signs were: respiratory rate (event: 22.5%, controls: 70.3%), oxygen supply (event: 3.9%, controls: 39.4%); level of consciousness (event: 11.8%, controls: 23.0%). The frequency of the DENWIS-indicators is shown in Fig. 2.

Most frequent DENWIS-indicators in the event group were: change in circulation (57.8%), change in breathing (45.1%) and no clinical progress (42.2%). Most frequent

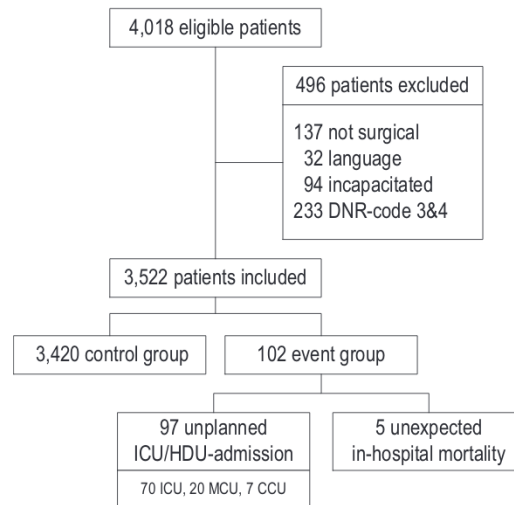


Fig. 1. Study population.

DENWIS-indicators in the control group were: unexpected trajectory (11.3%), change in circulation (9.9%) and new or persistent pain (8.1%).

In the univariate logistic regression analysis all indicators showed a significant association with unplanned ICU/HDU admission or unexpected mortality ($p < 0.001$). Most important indicators with the highest odds ratios (OR) were change in breathing (OR 15.2), subjective nurse observations (OR 14.6) and change in circulation (OR 12.4). This means patients with these positive indicators had respectively 15.2, 14.6 or 12.4 times more change of an event than patients without the indicator (Table 4).

The AUROC (95%CI) for unplanned ICU/HDU-admission or unexpected mortality with the EWS as the predictor variable, was 0.86 (0.82–0.90). 'Worry' and 'worry with EWS < 7' had lower AUROCs: 0.81 (0.77–0.85) and 0.74 (0.69–0.79) respectively. The DENWIS-model, with all indicators in the model, demonstrated an AUROC of 0.85 (0.80–0.89) and 'worry' added to the DENWIS-model showed an AUROC of 0.87 (0.84–0.91). The combination of EWS and the DENWIS showed the highest AUROC: 0.91 (0.88–0.93). Adding 'worry' to this combined model did not show further improvement.

4. Discussion

In this single-center study we showed that adding an EWS based on vital signs to the nine DENWIS-indicators improves the prediction of unplanned ICU/HDU-admission

Table 2
Measurements used in the logistic regression analysis.

	Unplanned ICU/HDU-admission or unexpected mortality	
	No	Yes
1st measurement 'worry' (EWS < 7)	Within hospital stay	Within 24 h before an event
OR 1st measurement EWS \geq 7	Within hospital stay	Within 24 h before an event
OR measurement: no worry	Random during hospital stay	Last measurement an before event

Table 3
Clinical and demographic variables.

	Control n = 3420	Event group n = 102			p-Value (controls–event total)
		Unplanned ICU/HDU- admissions (n = 97)	Unexpected mortality on the ward (n = 5)	Total event group (n = 102)	
Men, n (%)	1576 (46.1%)	60 (61.9%)	2 (40%)	62 (60.8%)	0.003
Age, years (range; SD)	59.3 (18–96; 18.1)	68.1 (20–94; 13.2)	84 (61–97; 13.7)	68.9 (20–97; 13.6)	<0.001
Hospital length of stay, days (range; median)	5.1 (1–171; 3)	30.2 (1–158; 24)	9.8 (3–31; 5)	29.2 (1–158; 24)	<0.001
Co-morbidities, n (%)	1170 (34.2%)	36 (37.1%)	3 (60%)	39 (38.2%)	0.399
Co-morbidity 1	678 (19.8%)	18 (18.6%)	2 (40%)	20 (19.6%)	1.000
Co-morbidity 2	372 (10.9%)	12 (12.4%)	1 (20%)	13 (12.7%)	0.520
Co-morbidity 3	108 (3.2%)	4 (4.1%)	–	4 (3.9%)	–
Co-morbidity 4	12 (0.4%)	2 (2.1%)	–	2 (2%)	–
Indication hospital admission, n (%)					
Abdominal–oncological surgery	1227 (35.8%)	56 (57.7%)	1 (20%)	57 (55.9%)	<0.001
Vascular surgery	477 (13.9%)	11 (11.3%)	4 (80%)	15 (14.7%)	0.773
Traumatology	839 (24.5%)	15 (15.5%)	–	15 (14.7%)	0.025
Other	877 (25.6%)	15 (15.4%)	–	15 (14.7%)	0.011
DNR, code 2, n (%)	214 (6.3%)	20 (20.6%)	3 (60%)	23 (22.5%)	<0.001
30-day mortality, n (%)	14 (0.4%)	11 (11.3%)	–	–	<0.001
Worry (EWS < 7), n (%)	752 (22%)	69 (71.1%)	2 (40%)	71 (69.6%)	<0.001
Worry, n (%)	774 (22.6%)	85 (87.6%)	2 (40%)	87 (85.3%)	<0.001
EWS, mean (range; SD)	1 (0–14; 1.3)	3.9 (0–14; 2.8)	3.6 (2–6; 1.5)	3.9 (0–14; 2.6)	<0.001

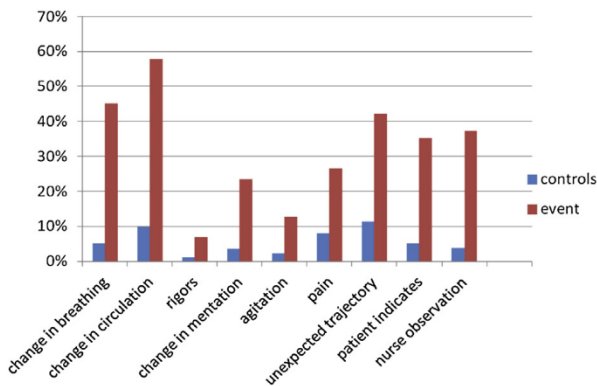


Fig. 2. Frequency of DENWIS indicators in control- and event group. Control group: patients without unplanned Intensive Care Unit/High Dependency Unit admission or unexpected mortality. Event group: patients with unplanned Intensive Care Unit/High Dependency Unit admission or unexpected mortality.

or unexpected mortality. Also a combination of 'worry' and the DENWIS indicators showed a better performance demonstrated by a higher AUROC compared with the EWS alone. 'Worry with an EWS < 7' as single predictor performed less well than the EWS, but still had an AUROC of 74%. These data demonstrate that patients with these indicators were much more likely to have an event than patients without the indicator. Given the fact that the EWS does not yet trigger a call, 'worry' and underlying DENWIS-indicators may be more important and alert in an early stage of deterioration.

These results suggest that not only vital signs play an important role in the process of recognition of deterioration, but that objectifying nurses' 'worry' may contribute to better prediction of unplanned ICU/HDU admission or mortality. Our results are consistent with earlier studies that showed some of the domains we included into the DENWIS, were associated with ICU-admissions and/or mortality (Buist et al., 2002; Hodgetts et al., 2002; Jacques et al., 2006; Santiano et al., 2009). Furthermore, Finlay et al. (2014) show improved

Table 4
Univariate logistic regression DENWIS-indicators.

	B	SE	Wald	p-Value	Odds ratio
Changes in breathing	2.7	0.2	162.6	<0.001	15.2
Changes in circulation	2.5	0.2	146.1	<0.001	12.4
Rigors	1.9	0.4	19.7	<0.001	6.6
Changes in mentation	2.1	0.3	70.3	<0.001	8.2
Agitation	1.8	0.3	33.6	<0.001	6.3
Pain	1.4	0.2	36.3	<0.001	4.1
No progress	1.7	0.2	70.2	<0.001	5.7
Patient indicates	2.3	0.2	107.9	<0.001	9.9
Subjective nurse observation	2.7	0.2	144.3	<0.001	14.6

prediction of deterioration when items from the electronic nursing files were combined with an EWS.

The lower performance of 'worry with an EWS < 7' and 'worry' alone may be explained by the fact that we included a clinically representative sample of nurses with different experience levels. This may have influenced and possibly diluted our results since pattern recognition, the recognition of deviating patterns to specific patient conditions can improve through repeated exposure to these patient conditions (Odell et al., 2009). Furthermore, we compared the nominal level of 'worry' (yes or no) with the EWS on a continuous scale (± 0 –14), which may result in a higher AUROC in favor of the continuous data, favoring the performance of the EWS.

To our knowledge this is the first study that provides systematically collected data on nurses' 'worry'. The indicators underlying 'worry' summarized in the DENWIS, provide an assessment tool that may empower nurses. The DENWIS can help nurses put 'worry' into words and make nurses more confident in making the decision to call for assistance. It can support nurses in developing Situation Awareness (SA), which is an essential skill in effectively managing complex situations (McIlvaine, 2007). SA encompasses three levels linked to decision-making: the perception of current situation, comprehension of current situation and the ability to project what can happen next (Endsley, 1995; Stubbings et al., 2012). Furthermore, the DENWIS provides an overview of all relevant observations and completes the assessment supplementary to vital signs and other measurements like laboratory results and fluid balance. As such it can be used in communication methods like the Situation, Background, Assessment, Recommendation (SBAR) tool. Also, interdisciplinary agreement on the importance of the DENWIS-indicators could potentially result in physicians having higher regard for its role in enabling nurses to better identify and respond to the deteriorating patient.

Our study has several limitations. First, we did not measure reliability and validity of the DENWIS. Although we asked nurses specifically to observe all signs included in the DENWIS, signs may have been missed or wrongfully recorded. We did not measure interrater reliability and validity as this was practically impossible, with about 100 nurses participating in the study and 'worry' occurring at unpredictable moments. A second limitation is the number of missing vital signs. This may have influenced the AUROC of the EWS and the AUROC should therefore be interpreted with caution. Non-adherence to vital signs protocols is a well-known problem and has been described earlier (Cretikos et al., 2008; De Meester et al., 2013; Hands et al., 2013; Hillman et al., 2005; Ludikhuizen et al., 2012); the respiratory rate is the most frequently missing vital sign (Cretikos et al., 2008) with percentages of 30–66% missing reported (De Meester et al., 2013; Ludikhuizen et al., 2012). We did see a higher number of completed EWSs in the event group compared to the control group. A third limitation may be related to the choice of our composite endpoint, unplanned ICU-admission or unexpected mortality. Ideally patients who deteriorate will have been treated at an early stage of deterioration and we assume that nurses called the attending physician when they were worried, thus early treatment preventing patients to reach the composite endpoint. This could explain why our study did not show

that nurses' 'worry' and/or the nine indicators underlying 'worry' alone contributed to better patient outcomes and 'worry with an EWS < 7' had the lowest AUROC. A fourth limitation is that vital sign measurements were not necessarily recorded at the exact same time as the DENWIS-indicators. On the other hand, to stimulate nurses' cooperation we allowed the nurses' own judgment and discretion when to assess the DENWIS-indicators. It remains unknown whether a nurse documented 'worry' first which prompted the collection of vital signs or the reverse order.

5. Conclusions

In this single-center study we showed that DENWIS-indicators were associated with unplanned ICU/HDU-admission or unexpected mortality and improved RRS calling criteria based on vital signs. The indicators can be seen as a way of objectifying the 'worry' criterion and thus potentially may also be of value for nurses with less knowledge and experience in identifying and responding to deteriorating patients. We also noticed that the DENWIS-indicators predict deterioration when the EWS-scores still are below the triggering threshold, facilitating earlier recognition. Potentially, the DENWIS-indicators can be used to educate nurses and doctors and facilitate communication. Our results should be prospectively validated in other hospitals, health care systems, patient categories and wards. We assume that use of the DENWIS improved nurses' confidence in escalating a call due to 'worry'. Further research is needed to confirm this assumption.

Acknowledgements

We would like to thank Mr. Ton de Haan, MSc and Mr. Rogier Donders, PhD for their valuable help with the statistical analysis. We are grateful to all participating nurses for their efforts, commitment and enthusiasm during the year of data collection. We thank our principal nurses Wilma Geuze, Anneke van de Haar and Gerda ter Roller for coaching and stimulating the ward nurses and Mr. Wouter de Graaf, MSc manager of the surgical department. Without their support the study could not have been conducted.

Conflict of interest

None of the authors has any conflict of interest to declare.

Funding

None declared.

Ethical approval

This study was waived by the local ethical committee.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.ijnurstu.2016.04.006>.

References

- Astroth, K.S., Woith, W.M., Stapleton, S.J., Degitz, R.J., Jenkins, S.H., 2013. Qualitative exploration of nurses' decisions to activate rapid response teams. *J. Clin. Nurs.* 22 (19–20), 2876–2882. <http://dx.doi.org/10.1111/jocn.12067>.
- Bagshaw, S.M., Mondor, E.E., Scouten, C., Montgomery, C., Slater-MacLean, L., Jones, D.A., Bellomo, R., Gibney, R.T., Capital Health Medical Emergency Team Investigators, 2010. A survey of nurses' beliefs about the medical emergency team system in a Canadian tertiary hospital. *Am. J. Crit. Care* 19 (1), 74–83. <http://dx.doi.org/10.4037/ajcc2009532>.
- Braaten, J.S., 2015. CE: Original research: hospital system barriers to rapid response team activation: a cognitive work analysis. *Am. J. Nurs.* 115 (2), 22–32. <http://dx.doi.org/10.1097/01.NAJ.0000460672.74447.4a>, test 33; 47.
- Buist, M.D., Moore, G.E., Bernard, S.A., Waxman, B.P., Anderson, J.N., Nguyen, T.V., 2002. Effects of a medical emergency team on reduction of incidence of and mortality from unexpected cardiac arrests in hospital: preliminary study. *BMJ* 324, 1–6.
- Cretikos, M., Bellomo, R., Hillman, K., Chen, J., Finfer, S., Flabouris, A., 2008. Respiratory rate: the neglected vital sign. *Med. J. Aust.* 188, 657–659.
- De Meester, K., Das, T., Hellemans, K., Verbrugge, W., Jorens, P.G., Verpooten, G.A., Van Bogaert, P., 2013. Impact of a standardized nurse observation protocol including MEWS after Intensive Care Unit discharge. *Resuscitation* 84 (2), 184–188.
- DeVita, M.A., Bellomo, R., Hillman, K., Kellum, J., Rotondi, A., Teres, D., Auerbach, A., Chen, W.J., Duncan, K., Kenward, G., Bell, M., Buist, M., Chen, J., Bion, J., Kirby, A., Lighthall, G., Ovreveit, J., Braithwaite, R.S., Gosbee, J., Milbrandt, E., Peberdy, M., Savitz, L., Young, L., Harvey, M., Galhotra, S., 2006. Findings of the first consensus conference on medical emergency teams. *Crit. Care Med.* 34, 2463–2478.
- Douw, G., Schoonhoven, L., Holwerda, T., Huisman-de Waal, G., van Zanten, A.R.H., Achterberg, T., van der Hoeven, J.G., 2015. Nurses' worry or concern and early recognition of deteriorating patients on general wards in acute care hospitals: a systematic review. *Crit. Care*. <http://dx.doi.org/10.1186/s13054-015-0950-5>.
- Endsley, M.R., 1995. Toward a theory of situation awareness in dynamic systems. *Hum. Fact.* 37 (1), 32–64.
- Finlay, G.D., Rothman, M.J., Smith, R.A., 2014. Measuring the Modified Early Warning Score and the Rothman Index: advantages of utilizing the electronic medical record in an Early Warning System. *J. Hosp. Med.* 9 (2), 116–119.
- Gao, H., McDonnell, A., Harrison, D.A., Moore, T., Adam, S., Daly, K., Esmonde, L., Goldhill, D.R., Parry, G.J., Rashidian, A., Subbe, C.P., Harvey, S., 2007. Systematic review and evaluation of physiological track and trigger warning systems for identifying at-risk patients on the ward. *Intens. Care Med.* 33 (4), 667–679.
- Hands, C., Reid, E., Meredith, P., Smith, G.B., Prytherch, D.R., Schmidt, P.E., Featherstone, P.I., 2013. Patterns in the recording of vital signs and early warning scores: the degree of compliance with a clinical escalation protocol. *BMJ Qual. Saf.* 22 (9), 719–726.
- Hillman, K., Chen, J., Cretikos, M., Bellomo, R., Brown, D., Doig, G., Finfer, S., Flabouris, A., 2005. Introduction of the medical emergency team (MET) system: a cluster-randomised controlled trial. *Lancet* 365, 2091–2095.
- Hodgetts, T.J., Kenward, G., Vlachonikolis, I.G., Payne, S., Castle, N., 2002. The identification of risk factors for cardiac arrest and formulation of activation criteria to alert a medical emergency team. *Resuscitation* 54 (2), 125–131.
- IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. IBM Corp., Armonk, NY. <http://www.presidion.com/software/ibm-spss-software-faqs/> (accessed 06.09.15)
- Jacques, T., Harrison, G.A., McLaws, M.L., Kilborn, G., 2006. Signs of critical conditions and emergency responses (SOCCER): a model for predicting adverse events in the inpatient setting. *Resuscitation* 69 (2), 175–183.
- Jones, D., Baldwin, I., McIntyre, T., Story, D., Mercer, I., Miglic, A., Goldsmith, D., Bellomo, R., 2006. Nurses' attitudes to a medical emergency team service in a teaching hospital. *Qual. Saf. Health Care* 15 (6), 427–432.
- Jones, L., King, L., Wilson, C., 2009. A literature review: factors that impact on nurses' effective use of the Medical Emergency Team (MET). *J. Clin. Nurs.* 18 (24), 3379–3390. <http://dx.doi.org/10.1111/j.1365-2702.2009.02944.x>.
- Ludikhuijze, J., Smorenburg, S.M., de Rooij, S.E., de Jonge, E., 2012. Identification of deteriorating patients on general wards; measurement of vital parameters and potential effectiveness of the Modified Early Warning Score. *J. Crit. Care* 27 (4), 424.e7–13.
- Odell, M., Victor, C., Oliver, D., 2009. Nurses' role in detecting deterioration in ward patients: systematic literature review. *J. Adv. Nurs.* 65 (10), 1992–2006.
- Mackintosh, N., Rainey, H., Sandall, J., 2012. Understanding how rapid response systems may improve safety for the acutely ill patient: learning from the frontline. *BMJ Qual. Saf.* 21 (2), 135–144.
- McIlvaine, W., 2007. Situational awareness in the operating room: a primer for the anesthesiologist. *Pediatr. Anaesth.* 26 (3), 167–172.
- Peduzzi, P., Concato, J., Kemper, E., Holford, T.R., Feinstein, A.R., 1996. A simulation study of the number of events per variable in logistic regression analysis. *J. Clin. Epidemiol.* 49 (12), 1373–1379.
- Santiano, N., Young, L., Hillman, K., Parr, M., Jayasinghe, S., Baramy, L.S., Stevenson, J., Heath, T., Chan, C., Claire, M., Hanger, G., 2009. Analysis of medical emergency team calls comparing subjective to objective call criteria. *Resuscitation* 80 (1), 44–49.
- Shapiro, S.E., Donaldson, N.E., Scott, M.B., 2010. Rapid response teams seen through the eyes of the nurse. *Am. J. Nurs.* 110 (6), 28–34.
- Shearer, B., Marshall, S., Buist, M.D., Finnigan, M., Kitto, S., Hore, T., Sturgess, T., Wilson, S., Ramsay, W., 2012. What stops hospital clinical staff from following protocols? An analysis of the incidence and factors behind the failure of bedside clinical staff to activate the rapid response system in a multi-campus Australian metropolitan health-care service. *BMJ Qual. Saf.* 21 (7), 569–575. <http://dx.doi.org/10.1136/bmjqs-2011-000692>.
- Smith, G.B., Prytherch, D.R., Meredith, P., Schmidt, P.E., Featherstone, P.I., 2013. The ability of the National Early Warning Score (NEWS) to discriminate patients at risk of early cardiac arrest, unanticipated intensive care unit admission, and death. *Resuscitation* 84, 465–470.
- Stubbings, L., Chaboyer, W., McMurray, A., 2012. Nurses' use of situation awareness in decision-making: an integrative review. *J. Adv. Nurs.* 68 (7), 1443–1453. <http://dx.doi.org/10.1111/j.1365-2648.2012.05989.x>.