JUST WORRY

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Nijmegen, 2018

'Niet Pluis Gevoel' is a Dutch expression that refers to a sense of alarm, specifically: knowing that something is not right and being worried about it. Fluffy dandelion seeds often symbolise this *'Niet Pluis Gevoel'*

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JUST WORRY

Exploring triggers used by nurses to identify surgical patients at risk for clinical deterioration

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“Let people who have to observe sickness and death
look back and try to register in their observation
the appearances which have preceded relapse, attack, or death”

Florence Nightingale

Contents

Chapter 1

General Introduction

General Introduction

A couple of years ago, my colleague, who is an experienced nurse, called the attending physician for a deteriorating patient during an evening shift on a gastro-intestinal surgical ward. Despite her experience it took effort to convince the physician, who had a busy shift in the Emergency Department and was responsible for another four surgical wards, to visit her ward and assess the patient. She ended the call stating, 'I am your eyes and your ears on the ward. You really need to listen to me. You need to come and assess this patient'. Situations like these were not unheard of, and improvement strategies like Rapid Response Systems and communication tools such as the SBAR method have since been implemented. In this thesis possibilities for further improvement of the process of early recognition and treatment of deteriorating patients are explored and discussed from the perspective of the general ward nurse.

Patient safety

The publication of 'To Err Is Human: Building a Safer Health System' at the beginning of this century caused a paradigm shift in thinking and dealing with medical 'errors'.[1] A potential 100,000 preventable deaths a year were reported in the United States alone.[1] These figures had never before been published and they shook the hospital world to its foundations. In response, the Institute for Healthcare Improvement launched the '100,000 Lives Campaign' in 2005, based on the safety approach of the aviation and petrochemical industries. All United States hospitals were invited to join. The campaign's ambitious goal was to reduce harm by 75% within three years.[2,3] The initiative was followed worldwide.[4-6] In 2006, the '5,000,000 Lives Campaign' aimed at reducing the number of incidents by 5,000,000 over a period of two years.[7]

In the Netherlands recommendations for improvement were formulated,[8] and the patient safety management system[6] was implemented in 2008-2012 in all Dutch hospitals. This programme aimed to reduce potential preventable events by 50%. Despite increasing complexity of care during this period the patient safety programme resulted in a reduction of potential preventable deaths from 5.5% in 2008 to 2.6% in 2011/2012.[9] However, in the following years, no further reductions were achieved. In 2015/2016, the percentage of potentially preventable deaths reached 3.1.[10] This emphasises the importance and need for ongoing improvement initiatives. Early recognition of deteriorating patients is one of the themes of patient safety programmes[4-7] and Rapid Response Systems (RRSs) aim to

improve the early recognition and treatment of critically ill general wards patients, with an important role for nurses.[11,12]

Rapid Response Systems

Patients on general wards show signs of deterioration in the hours prior to cardiac arrest, unplanned Intensive Care Unit (ICU) admission, and mortality.[13-15] In Australia, the United Kingdom, and the United States, intensive care physicians and nurses began to develop RRSs with the aim of preventing cardiac arrest, unplanned ICU admission and mortality among patients on general wards.[11] This caused a paradigm shift, moving the focus from improving the performance of cardiac arrest teams and cardiopulmonary resuscitation, to emphasising the importance of cardiac arrest prevention.[16]

An RRS is an integrated system with four components. The afferent limb concerns identification of deterioration in patients on the general ward and the formulation of response triggers to escalate care. The efferent limb channels knowledge and equipment from intensive care professionals to general ward staff and patients. This response from ICU staff can be nurse led, with Rapid Response Teams (RRT) or Critical Care Outreach Teams, or physician led, with Medical Emergency Teams (MET), but the names are used interchangeably. Escalation of care can be a one-tier system with general ward nurses calling directly to the ICU team, or a two-tier system in which general ward nurses first call the ward physician, who is responsible for prompt assessment and treatment, and if necessary, subsequently calls the MET. A quality improvement limb and administrative limb, collecting data for accountability and improvement, complete the system.[16]

As the organisation of ICU's, the number of ICU beds, and other resources vary between hospitals, the choise of response trigger system and response team that best suits the local situation is left to the discretion of individual hospitals.[6] In the studies included in this thesis, we refer to the responding team as the 'RRT'. The hospital where the studies were conducted had a two-tier system, but nurses were able to call the ICU nurse based on the worry criterion.

Nurses' role in recognising deteriorating patients

General ward nurses play a crucial role in the afferent limb of the RRS. They are the professionals who observe the patient most frequently and will detect deterioration first. As Florence Nightingale wrote in 1860 in her 'Notes on nursing: What it is and what it is not', 'Let people who have to observe sickness and death look back and try to register in their observation the appearances which have preceded relapse, attack, or death.[17]

In RRSs the emphasis is on monitoring vital signs as a means of detecting deterioration in the early stages. The professional profile of nurses also includes vital signs deviating from normal values as a core patient problem upon which nurses should act.[18] Nevertheless, failure to identify patients at risk of deterioration is often related to deficiencies in vital signs monitoring and interpretation.[19,20] Nurses' compliance with measuring of complete sets of vital signs can be low.[21-24] Respiratory rates are the most frequently missed vital sign,[25-28] despite being proved to be an important - if not the most important - early indicator of deterioration.[14,15,25,29]

In addition to deviating vital signs, nurses also recognise deterioration through more subtle signs by observing the patient.[30] When vital signs do not confirm their judgement of a patient's condition, nurses face barriers to calling for assistance, such as a lack of confidence,[31,32] a feeling that they must justify a call,[33-35] fear of criticism,[36] and difficulty in formulating why they are concerned.[33,35,37] Some 'track and trigger' systems take these aspects into account and add nurses' worry as a calling criterion, either valued within an aggregated system or as a single criterion.[38] When worry is not included, the problems described may become even more pronounced, as there is a tendency to marginalise those risks not assimilated into risk scores.[35,37]

Nurses' worry

Nurses appreciate RRSs because these systems help them to manage deteriorating patients.[36,39,40] In the one-tier system, nurses initiate most of the RRS calls, with 11 - 58% of calls based on the worry criterion.[41-45] Analysis of these calls shows that worry calls are partly due to vital signs deviating from normal values.[43,44] This raises the question of what the signs and symptoms are that underlie a nurse's worry about a patient's condition when vital signs are *not* the cause of worry.

Nurses' clinical judgement and decision-making

In the RRS, nurses' worry is not specifically defined, but it seems clear that for a nurse to be worried, they must suspect a (potential) problem. This encompasses all three levels of situation awareness (SA), which is essential for effective decision-making.[46,47] The three levels of SA are perception of a situation, interpretation of the situation, and foreseeing potential problems. The RRS supports nurses in decision-making with protocols on how to act when vital signs deviate from normal values. When worry is based on subtler signs, and vital signs are either unchanged or only slightly deviated, nurses must make decisions based on their knowledge and/or experience. As well as the conscious process of critical reasoning, there are unconscious processes, such as intuition, gut feeling, and clinical gaze, which are described in nursing research as part of nurses' judgement and decision-making.[30,48-52]

Clinical judgement and decision-making are skills that are mostly thaught and tested in simulated (high fidelity) scenarios.[53-59] How nurses act upon their worry in daily practice, and whether this leads to adequate decisions or overuse of the medical system, has not yet been studied.

Predictive value of track and trigger systems

Various track and trigger systems have been developed in the RRS to improve detection of deterioration and escalation of care. In the so-called one parameter system, care can be escalated based on any deviating vital sign or, if included, on worry. Aggregated systems (early warning systems [EWS]) also exist, with points awarded to each vital sign according to the severity of deviation from normal values, and a total score then is calculated.[38] In both systems, care can be escalated when reaching a predetermined trigger threshold.

Due to different values being given to deviating vital signs, different EWS have been developed. The National Early Warning Score (NEWS) has proven the best at discriminating between those patients at risk of deterioration and those who are not.[60] Respiratory rate, oxygen saturation, need for oxygen supply, heart rate, systolic blood pressure, temperature, and level of consciousness are all incorporated. Worry is not included in the NEWS, although the recommendations[60] for use state that professionals' concerns should always overrule the NEWS score. The value of worry or underlying indicators for identifying patients at risk of unplanned ICU admission or mortality has not been established as such.

Aim of the thesis

The aim of this thesis is to explore nurses' worry and its role in the process of early recognition of deteriorating surgical ward patients, in order to empower nurses to call for assistance at an early stage. The specific goals are as follows:

- ✓ Identify signs and symptoms underlying nurses' worry
- ✓ Explore the occurrence of nurses' worry in clinical practice, how nurses respond to it, and whether this leads to appropriate use of medical assistance
- ✓ Determine whether nurses' worry and underlying signs and symptoms can identify patients at risk of deterioration, both with and without deviating vital signs
- ✓ Determine whether systematic assessment of nurses' worry and underlying signs and symptoms identify patients at risk of ICU admission, resulting in ICU admissions of less severely ill patients and, as a consequence, shorter ICU and/or hospital length of stay

Outline of the thesis

In this thesis, the results described in **part 1** concern an exploration of the triggers for nurses' worry and how nurses act upon this; while in **part 2**, the focus is on worry and the underlying signs and symptoms as predictors of deterioration in surgical ward patients.

Part 1: Exploration of worry

Chapter 2 describes a systematic review of the literature addressing signs and symptoms underlying nurses' worry. The databases PubMed, CINAHL, PsycINFO, and Cochrane Library (Clinical Trials) were searched from the start of the databases up to February 2014. The Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) assessment tool, was developed and implemented in the electronic nursing file of a University-affiliated teaching hospital, based on the results of the systematic review.

In **Chapter 3**, the occurrence of nurses' worry and underlying indicators are described at normal and deviating vital sign levels. Nurses prospectively scored worry and underlying signs and symptoms for each patient in every shift. In retrospect, the electronic nursing and medical files were studied for data on calls for assistance and whether interventions were initiated. The need for calls and interventions at normal vital signs levels were also judged by intensivists not involved in the study, in order to establish appropriate use of medical assistance.

Part 2: Worry and underlying signs and symptoms as predictors of unplanned Intensive Care Unit/High Dependency Unit admission or mortality

In **Chapter 4**, the value of worry and underlying DENWIS indicators for predicting unplanned ICU/High Dependency Unit (HDU) admission or unexpected mortality is determined and compared with the predictive value of the track and trigger system used in the study hospital. The association of underlying indicators with unplanned ICU/HDU admission or mortality is tested for each individual indicator and for the indicators combined, leaving all indicators in the prediction model.

In addition, the focus of **Chapter 5** is on recognition of deterioration at an early stage, when vital signs do not reach the trigger threshold to call the RRT. The predictive value of nurses' worry and underlying indicators is described by the composite endpoint of unplanned ICU/HDU admission or unexpected mortality.

In **Chapter 6**, the assumption is made that utilising judgement of a patient's condition by expressing explicitly whether a nurse is worried or not, as well as assessing patients according to the presence of DENWIS indicators, will improve patient outcomes. The primary outcomes are unplanned ICU admission, the severity of illness at ICU admission, and ICU and hospital length of stay.

In **Chapter 7**, the main findings and implications for clinical practice are discussed, specifically the early stage of deterioration. The implications for medical and nursing education and further research are also explored.

In **Chapters 8 and 9**, the main findings are summarised in English and Dutch.

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Chapter 2

Nurses' worry or concern and early recognition of deteriorating patients on general wards in acute care hospitals: a systematic review

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Abstract

Introduction: Nurses often recognize deterioration in patients through intuition rather than through routine vital signs measurement. Adding the worry sign to the Rapid Response System provides opportunities for nurses to act upon their intuitive feelings. Identifying what triggers nurses to be worried might help to put intuition into words and potentially empower nurses to act upon their intuitive feelings and obtain medical assistance in an early stage of deterioration. The aim of this systematic review is to identify the signs and symptoms that trigger nurses' worry about a patients' condition.

Methods: We searched the databases PubMed, CINAHL, PsycINFO and Cochrane Library (Clinical Trials) using synonyms related to the three concepts: 'nurses', 'worry' and 'deterioration'. We included studies concerning adult patients on general wards in acute care hospitals. The search was performed from start of the databases until February 14, 2014.

Results: The search resulted in 4,006 references, and 18 studies (five quantitative, nine qualitative and four mixed-methods designs) were included in the review. A total of 37 signs and symptoms reflecting the nature of the criterion worry emerged from the data and were summarized in 10 general indicators. The results showed that worry can be present with or without change in vital signs.

Conclusions: The signs and symptoms we found in the literature reflect the nature of nurses' worry and nurses may incorporate these signs in their assessment of the patient and their decision to call for assistance. The fact that it is present before changes in vital signs suggests potential for improving care in an early stage of deterioration.

Introduction

Early recognition and treatment of critically ill patients on general wards is a key aspect of Rapid Response Systems (RRSs). The aim of RRSs is to reduce Intensive Care Unit (ICU) admissions, length of ICU and/or hospital length of stay and mortality.[1]

Nurses often recognize patients in the ward who are deteriorating through intuition rather than through routine measurement of vital signs.[2] Intuition is an ability to understand or know something immediately based on feelings rather than facts.[3] In nursing research, Benner *et al.* (2009) define intuition as 'a judgment without a rationale, a direct apprehension and response without recourse to calculative rationality'. Nurses develop this skill over time, and often anticipate a patient's decline before any objective evidence of deterioration is present.[4]

The activation of an RRS is usually based on the recording of vital signs that deviate from predetermined values.[5,6] Respiratory rate, oxygen saturation, heart rate, blood pressure, temperature and consciousness are often included, but in addition to these objective criteria, the subjective criterion 'nurses' worry or concern' may be important.[7,8] It provides an opportunity for nurses to call assistance when they intuitively feel that something is wrong with a patient, even when vital signs do not (yet) meet RRS calling criteria. However, RRSs value this criterion differently. Worry or concern can be a single calling criterion, in which case the team can be activated based solely on worry or concern.[9] This provides optimal opportunities for nurses to act upon their intuitive feelings and get assistance in an early stage of deterioration. In the combined approach, subjective criteria like worry or concern are added to objective criteria in an aggregated system.[10] This reduces possibilities for nurses to activate an RRS in an early stage, since vital signs must also be deteriorating. In RRSs that do not include the worry or concern criterion, it can be harder for nurses to get assistance when objective evidence is lacking.[11,12]

So far it is unclear whether including worry or concern as a calling criterion results in better patient outcomes. We need a better understanding of its essence. Identifying what triggers nurses' worry or concern might help nurses to put intuition into words, and potentially empower them to act upon their intuitive feelings and obtain medical assistance for the patient in an early stage of deterioration. The aim of this systematic review is to identify the signs and symptoms that trigger nurses' worry or concern about a patient's condition.

Methods

A systematic review of quantitative and qualitative studies was performed using the systematic review guidelines from the 'Centre for Reviews and Dissemination'[13] as guidance to structure the review process.

Selection criteria

We included full-text original studies (all designs and languages), performed on general wards (adult patients, aged 18 years and older) in acute care hospitals, addressing the worry or concern of nurses in the process of recognition of deterioration in patients, or preceding calling for assistance and/or activation of the Rapid Response Team (RRT). We excluded studies that focused solely on specialized wards, such as emergency departments, ICUs, medium care units, obstetrics wards, operating rooms, pediatric wards and psychiatry wards, or studies concerning homecare. We also excluded studies of low methodological quality (see Quality appraisal).

Search strategy

First, we searched the databases PubMed, CINAHL, PsycINFO and Cochrane Library (Clinical Trials) for original studies. We combined three major search terms: 'nurses', 'worry', and 'deterioration'. Synonyms for these search terms were also used, which can be found in the complete PubMed search presented in Additional file 1. We used a two-stage study selection for the database search: an initial screening of titles and abstracts against inclusion criteria and assessment of the full-text articles of potentially eligible studies. The search was performed from the start of the databases until 14 February 2014. Second, experts on the subject were asked for unpublished studies. Third, studies included for full-text reading were used to locate related articles using the 'related citations' link of the databases. Finally, references of included articles were examined for additional studies. Fig. 1 gives a complete overview of the search strategy.

Quality appraisal

We used the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) instrument[14] to assess quantitative study quality. Included items were: design, eligibility criteria, selection procedure, outcomes, risk of bias, study size, number and characteristics of participants, statistical methods, relevant subgroups and results. We valued items as positive, negative or unclear. Studies with between nine and 11 positive scores were considered to be of high methodological quality, those between five and eight positive scores of moderate quality and those with less than five positive scores to be of low methodological quality.

Qualitative and mixed-methods studies were assessed using the National Institute for Health and Clinical Excellence Methodology checklist: qualitative studies[15]. This tool has six sections: theoretical approach, study design, data collection, validity, analysis and ethics. An overall score of quality is not included as not all measurement domains are considered equally important.[16] The assessment was used to gain understanding of relative strengths and weaknesses of eligible studies.

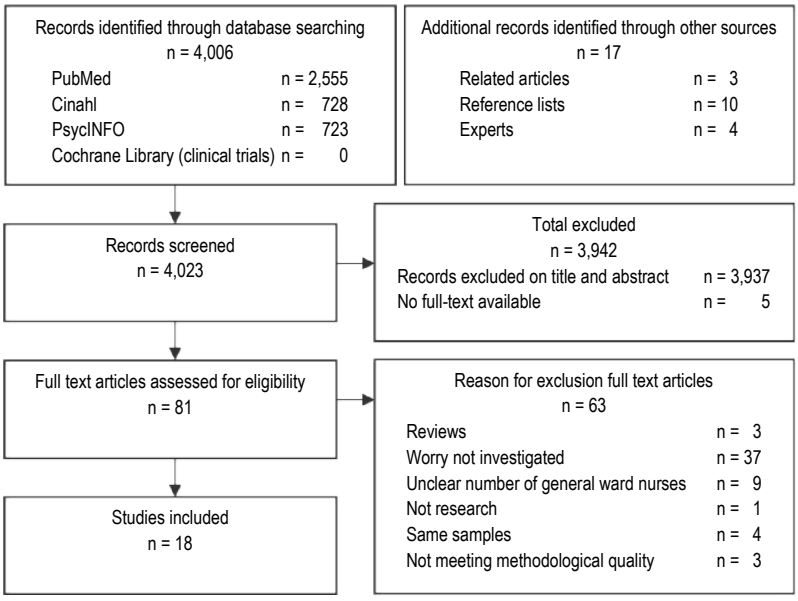

Figure 1. Flow diagram of the selection procedure

Data extraction

We extracted the following data: design, aim, data collection, sample, setting, RRS (calling) system and outcomes. Outcomes extracted were the signs and symptoms underlying worry or concern of nurses.

Review process

The database search (GD and LS), data selection (GD and LS), methodological quality assessment (TvA, GD and TH) and data extraction (GD and LS) were independently performed by two researchers. Disagreement was solved through discussion, and a third researcher (TvA or AvZ) was available in case of doubt.

Synthesis

We included heterogeneous studies and as such, a meta-analysis could not be performed. Since our aim is strictly explorative, analysis of the data from both quantitative and qualitative studies was undertaken. Two researchers (GD and TH) independently analyzed all signs and symptoms that were extracted from the literature and separately suggested the themes that emerged from the data. The indicators were determined through discussion (GD and TH) and presented to three researchers (LS, TvA and AvZ) for agreement. Disagreement was solved through discussion until consensus was reached.

Results

Search outcome

The database search provided 4,006 records. One additional article and three abstracts of congress (poster) presentations were retrieved via experts. Additionally, three articles were retrieved via 'related articles' in the databases, and 10 articles via reference lists of the included studies. In total, 3,937 articles of the database search did not meet the inclusion criteria. Two articles from the reference lists were not available, and there were no articles on the three congress abstracts. The full-text of 81 publications was examined; 56 were excluded as they did not meet the selection criteria and three studies were excluded for low methodological quality.[17-19] Of the remaining 22 publications,[11,20-40] four additional studies were removed because of overlapping results in the same patient samples.[20,23,24,37] This resulted in 18 studies included in the review (Fig. 1).

Quality assessment

Quality assessment of the quantitative studies resulted in one high,[30] four moderate,[21,27-29] and three low quality studies.[17-19] The low-quality studies were excluded. The qualitative studies had several limitations. However, as described in the methods section, they were all included. Detailed information of the quality assessment is presented in Tables 1 and 2.

Characteristics of included studies

We found large heterogeneity in the studies, including in design. Studies were conducted in Australia (n = 8), the US (n = 5), the UK (n = 4) and Brazil (n = 1), with hospital settings varying from peripheral (non) teaching hospitals to university hospitals. Six studies included all wards, four included general wards and four studies were performed on medical wards. Four studies that analyzed RRS calls did not specify wards but were included since the description in the articles suggest that general wards were involved. Studies comprised data

Table 1. Quality assessment of the quantitative studies

First author	Year	Reference	Are objectives clearly stated?	Is the design appropriate?	Are eligibility criteria, sources and methods of selection of participants described?	Are outcomes described?	Sources of data and details about methods of measurements described and appropriate?	Risk of bias is taken into account	Is the study size adequate?	Are characteristics, numbers of participants and reasons for non-participation described?	Is the statistical method adequate?	Are relevant subgroups described in results?	Are results properly described?	Overall study quality
Bertaut	2008	17	-	-	-	-	-	-	?	-	-	?	+	L
Boniatti	2010	21	+	±	+	+	-	±	+	+	+	?	+	M
Hourihan	1995	27	+	+	+	+	+	+	±	+	+	±	+	M
Laurens	2011	28	±	±	±	±	±	+	±	+	+	+	+	M
Offner	2007	18	±	±	±	+	-	-	?	±	+	?	+	L
Parr	2001	29	+	+	+	+	±	?	+	±	+	?	+	M
Santiano	2009	30	+	+	+	+	±	+	+	+	+	+	+	H
Thomas	2007	19	-	?	-	?	-	?	?	+	+	+	?	L

* + = yes; ± = partly; - = no; ? = not assessable; H = high; M = moderate; L = low

Table 2. Quality assessment of the qualitative studies

First author	Reference	Qualitative approach appropriate? Appropriate + /inappropriate - /not sure ±	Aim/ literature/theory Clear +/unclear- / mixed ±	Study design Defensible+ /not defensible - / not sure ±	Data collection methods Appropriate+ /inappropriate - /not sure ±	Validity: Role researcher Clear+ /unclear - / not described ±	Validity: Description context Clear+ /unclear- / not sure ±	Validity: Reliability methods Reliable/unreliable - / not sure ±	Validity: Rigorous+ /not rigorous - /not sure or not reported ±	Analysis: Rich+ /Poor - /Not sure or not reported ±	Analysis: Reliable+ /unreliable - / not sure or not reported ±	Analysis: Finding convincing Convincing+ /not convincing - / not sure ±	Analysis: Findings relevant to aim n of study Relevant+ /irrelevant - / partially relevant ±	Analysis: Conclusion adequate Adequate+ / inadequate - / not sure ±	Ethical considerations Clear+ /unclear - / not sure or not reported ±
Andrews, 2005	11	+	+	±	-	±	±	±	+	+	±	±	+	+	+
Cioffi, 2000	22	+	+	+	+	±	+	±	±	+	+	+	+	±	±
Cioffi, 2009	25	±	+	±	+	±	+	±	±	±	±	+	+	+	+
Cox, 2006	26	+	±	±	±	+	±	-	+	+	±	+	+	+	+
Donaldson, 2009	31	+	+	+	±	±	±	+	+	-	+	±	+	±	-
Endacott, 2007	32	+	±	±	+	±	+	+	±	±	±	+	+	±	+
Gazarion, 2010	33	+	+	+	±	±	+	±	±	+	±	+	+	+	±
Leach, 2010	34	+	±	+	±	±	±	±	+	±	±	-	+	+	-
Massey, 2014	35	+	+	+	+	+	±	+	+	±	±	+	+	±	+
McDonell, 2013	36	+	+	+	+	-	+	±	±	±	±	+	+	±	+
Minick, 2003	38	+	+	+	±	±	+	+	+	+	±	+	+	+	±
Pattison, 2011	39	+	+	+	+	±	±	±	+	+	±	+	+	+	+
Williams, 2011	40	+	+	+	+	+	+	±	+	+	±	+	+	+	+

on nurses (n = 13), of which five studies also included physicians and/or other healthcare workers. Worry or concern was the primary end-point in five studies.[22,25,32,33,39]

Five studies had quantitative designs: one quasi-experimental design[28] and four observational studies.[21,27,29,30] Nine studies had qualitative designs: two grounded theory,[11,34] one phenomenology,[38] one interpretative,[35] and five descriptive studies.[22,25,26,33,40] We retrieved four mixed-methods studies, of which the qualitative part was relevant for the review.[31,32,36,39]

A total of 12 studies reported on RRSs: seven Medical Emergency Teams (all in Australia), with single parameter calling systems, of which six included worry as calling criterion and one study did not specify; three outreach teams (all in de UK) with aggregated calling systems without worry as calling criterion; and two RRTs (in the US), (one nurse-led) made no mention of the type of calling system. A summary of study characteristics is shown as Additional file 2.

Signs and symptoms underlying worry or concern

A total of 170 signs and symptoms were extracted from the included articles that describe worry or concern (Table 3). For synonyms, one major term was chosen, reducing the 170 terms to 37 different signs and symptoms. These 37 signs and symptoms were categorized into 10 general indicators: change in respiration, change in circulation, rigors, change in mentation, agitation, pain, unexpected trajectory, patient indicates they are feeling unwell, subjective nurse observation and nurse convinced that something is wrong without a rationale (Table 4).

Qualitative studies described up to nine different indicators, that is, all except rigors.[20,22,25,26,32-36,38-40] The analysis of the worry calls yielded up to seven different indicators, that is, all except for the three indicators: patient, nurse observation and knowing without a rationale.[21,27-30] Table 5 presents an overview of the different indicators in the studies. Both qualitative and quantitative studies mention deteriorating vital signs, like fall in SaO2, hypertension, arrhythmia, and fever[11,21,22,25,29,30,33,38] as triggers for worry or concern. The majority of these studies report worry or concern based on minor changes in vital signs[21,22,25,33,38] this was also reported in two other studies.[31,34]

Table 3. Summary of signs and symptoms related to worry as indicator of deterioration reported by nurses or as analyzed from Rapid Response calls

10 indicators	Analysis qualitative studies (exploring cues nurses use)	Analysis qualitative studies (process of recognition)	Analysis RRS worry calls
Change in Breathing	Breathless, low SpO2[22], inability to talk in sentences, noisy breathing, gasping, wheezing, using accessory muscles, change in breathing, short of breath, increasing supplemental O2 to maintain SaO2, increase respiratory rate (just more than the day before)[25]	Continued use of oxygen[11], respiratory distress[35], breathing more labored, trouble breathing[38]	fall in SaO2[29], low SpO2[30], dyspnea[21, 27], respiratory distress[29, 30]
Change in Circulation	(Quite) pale, coldness, tachycardia, color drainage changes, dusky, more pale than usual, porcelain pale, just a sort of gray, they sort of lose that pink color to their skin, color draining[22], impaired coetaneous perfusion, new observation, just a bit paler, cold feet[25], clammy[22,39], (new) sweating[22, 25, 39]	Clammy, (quite) pale, pale gray, blue[11], gray[31], ashen gray, sallow, change in skin color, cold feet[38] (new) sweating[11, 21], any change in color from patients' usual one[11, 36]	Arrhythmia[21], rhythm disturbance, hypertension[29]
Temperature			Fever[21], rigors, febrile[29], hypo/hyperthermia[30]
Change in Mentation	Confused, impaired mentation, change in mentation, vaguer, slower[25], sleepy, not making sense, less verbal, sensory change in level of consciousness[33], lethargic[25, 33]	Withdrawn[11] lethargic[31], sensory change in level of consciousness[38], confused[11, 38], drowsy[11, 36]	Sensory change in the level of consciousness (without a decrease in GCS ≥2 points)[21], confused, drowsy[29], (mental) deterioration[30]
Agitation	Not comfortable in or out of bed, sitting on the edge of the seat, unsettled, distressed, anxious, climbing about, wanting tablets, pulling catheters and tubes out, calling out, pressing the buzzer more often[22], agitation, not getting out of bed, uneasy, want to sit in chair instead of bed, can't get right position, restless, not comfortable[25] activity level[32], increase activating the bed alarm[33]	slumped in chair, not getting out of bed[11], panicky[34], not comfortable[38]	Aggression[27], restless[30], agitation[29,30]
Pain	Pain combined with bleeding[22], new or increasing pain, jaw, neck, shoulder chest pain[25]	(Unusual) pain[38]	Headache[21, 30], chest[21, 27-29]
Unexpected trajectory	Bleeding[22], not progressing, not expected trajectory, not following recovery pattern, not responding to treatment, abdominal distension, not eating[25]	Not progressing, abdominal distension, not eating, vomiting[11]	Unstable blood sugars[27], seizures[28], syncope, vomiting collapse, fall[30], nausea[27, 30], bleeding[28, 29], hypoglycemia, dizzy[28-30]
Patient indicates feeling unwell	Feeling of impending doom, scared, I am not like this normally[22], new symptom, feeling different, feeling terrible, knowing something is happening, cannot explain what's wrong, generally unwell[25], feeling not right, feeling unwell[22, 25]		
Subjective nurse observation	Patients look unwell, look in the eyes, like a gaze[22], cannot settle the patient down, new symptom[25] does not look/seem right[22,33], looked terrible[32], can tell it's not his normal face[33], something is not right[39]	Patients look unwell[11], looked really bad[31], sensing[35], just a feeling, somehow looked so ill, difference in behavior, not acting like himself, patient was quieter, did not open eyes, not getting out of bed, reduced motivation, neglect, not themselves, changes in mood[38], sixth sense[39], something does not look right/is a tiny bit worse, can't put a label on it, not as expected[40], just know[11, 26], something is not right[26, 34]	
Knowing without a rationale	Gut feeling, can't put a finger on it, just a feeling[22], knowing something is happening, unconscious something[25], something does not look right[33], intuition, sixth sense[36], knowing something is wrong[22, 25, 39]	knowing something is wrong[36, 40], intuition, gut feeling[11, 38, 40], does not look/seem right[34, 36, 38]	

Table 4. Thirty-seven signs and symptoms underlying worry summarized in 10 indicators

Indicator	Underlying signs and symptoms
Change in breathing	Noisy breathing and/or short of breath and/or no full sentences and/or accessory muscles and/or increasing supplemental O2 to maintain SaO2 and/or increase respiratory rate
Change in circulation	Colour and/or clammy and/or coldness and/or impaired perfusion and/or colour drainage changes and/or hypertension and/or arrhythmia
Temperature	Rigors and/or fever and/or hypothermia
Change in mentation	Lethargic and/or confused and/or sensory change in level of consciousness
Agitation	Restless and/or anxious
Pain	New pain and/or increasing pain
Unexpected trajectory	No progress and/or abdominal distension and/or nausea and/or bleeding and/or dizzy and/or fall and/or hypoglycemia
Patient	Not feeling well and/or feeling of impending doom
Subjective nurse observation	Change in behaviour and/or doesn't look good and/or look in the eyes
Knowing without a rationale	Gut feeling and/or knowing something is wrong

Table 5. Frequency of indicators per study

	First author	Year	Change in breathing	Change in circulation	Temperature	Change in mentation	Agitation	Pain	Unexpected trajectory	Patient indicates feeling unwell	Subjective nurse observation	Knowing without a rationale	Number of indicators
Analysis qualitative studies	Andrews	2005	x	x		x	x		x		x	x	7
	Cioffi	2009	x	x		x	x	x	x	x	x	x	9
	Cioffi	2000, 2001[a, b]	x	x			x	x	x	x	x	x	8
	Cox	2006									x	x	2
	Donaldson, Shapiro	2009, 2010		x		x					x	x	4
	Endacott	2007					x				x		2
	Gazarion	2010				x	x				x	x	4
	Leach	2010					x				x		2
	Massey	2013	x									x	2
	McDonnell	2013		x		x					x	x	4
	Minick	2003	x	x		x	x	x			x	x	7
	Pattison	2011		x							x	x	3
	Williams	2011										x	1
Analysis worry RRS-calls	Boniatti	2010	x	x	x	x		x					5
	Hourihan	1995	x				x	x	x				4
	Laurens	2011						x	x				2
	Parr	2001	x	x	x	x	x	x	x				7
	Santiano	2009	x		x	x	x	x	x				6
	Total number of studies		9	9	3	9	10	8	7	2	11	11	

Discussion

We examined signs and symptoms underlying worry or concern of nurses in relation to early recognition of deteriorating patients on general wards in acute care hospitals. Our most important finding is that 37 different signs and symptoms, summarized in 10 indicators, can alert nurses that a patient may rapidly deteriorate. Seven of the included studies reported the presence of worry before vital signs worsened.

Signs and symptoms underlying worry or concern

Although nurses find it hard to put intuition into words, we extracted objective signs and symptoms underlying worry or intuitive knowing. The indicators change in breathing, change in circulation, rigors and change in mentation can be related or precede deviating vital signs. Others are not related to vital signs: agitation, pain, unexpected trajectory and patient indicates feeling unwell. The indicator subjective nurse observations might partly cover the inability to explain what is wrong (patient does not look good), on the other hand it covers subtle signs such as change in behaviour or the look in the patient's eyes, both appealing to the observation skills of nurses. The indicator knowing without a rationale comprises the intuitive knowing that something is wrong based on possible unconscious observations. Skilled judges are often unaware of the cues that guide them.[41] Still intuition plays an important and excepted role in nurses' decision-making.[42,43] Intuition is believed to develop over time[4], so less experienced nurses might have more problems or even not see or acknowledge the importance of signs. The overview of signs and symptoms can contribute to the awareness of the importance of the mentioned indicators, and either help make the unconscious awareness for expert nurses more objective, or help less experienced nurses to articulate their feelings. This will improve the communication regarding deteriorating patients who do not yet meet the RRS calling criteria.

The significance of some of the signs and symptoms we found as early signs of deterioration has already been demonstrated in other studies. Shortness of breath and chest pain was present before cardiac arrest (CA).[10] Buist *et al.* (2002) found significantly lower rates of CA and mortality after implementation of an RRS with respiratory distress, difficulty speaking, agitation or delirium, uncontrolled pain and failure to respond to treatment included as RRS calling criteria.[44] Another study found a significant association between the following: poor peripheral circulation and mortality and CA; new pain with mortality and ICU admission; alteration in mentation with mortality, CA and ICU admission; uncontrolled pain with CA; and chest pain with CA and ICU admission.[45] The signs and symptoms underlying worry that we found in the literature alert nurses, and as such motivate nurses to take action to verify their

intuitive feelings, which makes them valuable as potential early indicators of deterioration. While the importance of these signs and symptoms has been highlighted in several studies, they are not included as such in most RRSs. The National Early Warning Score (NEWS), based on vital signs, discriminated more patients at risk of unplanned ICU admission or mortality than 33 other Track and Trigger Systems.[46] As the authors discuss, the NEWS must be seen as the minimum in monitoring patients, and should be used alongside other triggers such as worry or concern of nurses and other criteria.

Implications for practice

The 10 indicators identified in our study might help nurses to articulate their worries or their intuition, and contribute to better communication on deterioration. Yet without a medical response, an opportunity would be missed to intervene in an early stage. The medical response indeed prevents patients from further deterioration. This implies that not only nurses should be aware of the importance of the indicators, but also that doctors should acknowledge their importance. RRSs that include worry as calling criterion do give nurses the opportunity to call, but still would benefit if nurses articulate their worries in objective words. The presence of worry or concern of nurses before vital signs deteriorate suggests that the signs underlying the worry or concern of nurses have potential as early indicators of deterioration, and could imply that in RRSs without the worry criterion, the chances for early activation of the RRT are reduced.

Limitations

This systematic literature review has several limitations. First, results from observational and qualitative designs are not considered strong in the hierarchy of evidence. However, due to the nature of research involved - exploratory or evaluating - more rigorous study designs would not have been appropriate. Second, the heterogeneity of studies prevented to conduct another type of analysis other than a content analysis and thematic synthesis, reducing evidence strength; however, we consider these studies valuable to initiate more rigorous research. Third, the majority of included studies did not focus primarily on worry, therefore worry could have been present more often than documented in these studies. Fourth, most studies included had quality weaknesses, but we feel that the recurrence of similar findings in both quantitative and qualitative studies support the observations, especially with regard to our proposed indicators. Last, the instrument for quality assessment of quantitative studies has not been validated, yet the items used for assessment were all relevant for internal validity.

Conclusions

We found 37 signs and symptoms summarized in 10 general indicators reflecting the nature of nurses' worry or concern. Nurses may incorporate these signals in their assessment of patients and the decision to call for assistance. Nurses' subjective feeling of worry or concern is valuable in the process of recognizing deteriorating patients in general wards. Its presence even before vital signs have changed suggests potential for improving care in an early stage of deterioration. However, the number of studies is limited. The evidence found in this review was merely from retrospective research, which might have biased the results. A prospective cohort study is warranted, with nurses recording the indicators and worry or concern systematically, to establish if and how worry can improve the existing calling criteria in RRSs. Potentially, this may lead to earlier recognition and treatment of deteriorating patients and improve patient outcomes.

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Additional file 1

PubMed search n=2555

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Additional file 2

Study characteristics

Author	Design	Aim	Data collection	Sample	Setting	RRS	Outcome measures
Andrews and Waterman, 2005	Grounded theory Theoretical sampling until saturation	Investigate difficulties ward staff experienced in detecting deterioration and how it is resolved	Interviews (open ended questions) Participant and nonparticipant observation	30 Nurses, 7 doctors, 7 healthcare support workers	1 surgical and 1 general medical ward University teaching hospital (UK)	Type RRT: outreach Aggregated scoring system No worry/concern criterion	Signs and symptoms of recognition of deterioration
Boniatti et al. 2010	Observational Cross-sectional	Describe reasons for RRS activation and verify association of calling criteria with 30-day mortality	Review registration of RRS-calls	1051 RRS-calls for 901 patients during January 2007 to June 2008	Type of ward: not specified 794 bed university-affiliated hospital (Brazil)	Type RRT: MET Single-parameter system Criterion worry/concern included	Analysis worry/concern criterion
Cioffi et al. 2009	Exploratory descriptive Purposive and snowball sampling Analysis procedures according to Klein et al.1989	Identify cues of potential early clinical deterioration used to recognise a patient of concern who is not meeting the current objective calling criteria	Interviews; recall of incident, use of probes	17 Nurses	12 medical, 2 surgical, 3 HDP units 2 tertiary referral hospitals and 2 metropolitan hospitals (Australia)	Not reported	Signs and symptoms of recognition of deterioration
Cioffi 2000	Exploratory Descriptive Purposive sample	Explore patient characteristics and process of recognition nurses when worried.	Unstructured interviews, describing an experience	32 Nurses > 5 years' experience, high RRS users	Surgical, renal, gynaecological, CCU, orthopaedics, with high numbers of RRS calls. Teaching hospital and a peripheral hospital (Australia)	Type RRT: MET Single-parameter system Criterion worry/concern included	Signs and symptoms of recognition of deterioration
Cox et al. 2006	Exploratory Descriptive Purposive sample	Explore factors that influence experiences of trained nurses caring for critically ill patients	Semi-structured interviews; recount an incident	7 Nurses Experience: newly qualified to 20 years.	1 medical ward District general hospital	Not reported	Signs and symptoms of recognition of deterioration

	Content analysis				(UK)		
Donaldson et al.2009	Mixed-method qualitative part for review: Descriptive Convenience sample Thematic analysis until saturation	Evaluate impact of RRT (from nurse perspective)	Interviews; open-ended questions	56 Nurses	Acute care units 136 – 412 beds; 9 robust RRT adopter hospitals and 9 delayed RRT adopter hospitals (USA)	Type RRT: nurse led Calling system not reported	Signs and symptoms of recognition of deterioration
Endacott et al. 2007	Mixed-method qualitative part for review: Descriptive Purposive sample Content analysis	Identify cues ward nurses/doctors use to identify patient deterioration Examine assessment and communication of deterioration in patients on acute wards	Semi-structured interviews	14 Doctors and 11 nurses caring for 17 patients 24 hours before unexpected ICU admission	General wards 220 bed regional hospital (Australia)	Not reported	Signs and symptoms of recognition of deterioration
Gazarion et al. 2010	Descriptive Purposive sampling until saturation. Cognitive task	Describe cues and factors employed by nurses to identify and interrupt a potential preventable CPA	Interviews	13 Nurses (10 RN's, 1 Nurse in Charge, 2 staff nurses, unit preceptors) caring for patients who had experienced a prearrest period)	4 medical wards 747 bed academic medical centre (USA)	Not reported	Signs and symptoms of recognition of deterioration
Hourihan et al. 1995	Observational Descriptive prospective cohort	Describe utilisation of RRS after implementation	Registration of RRS-calls	294 RRS-calls from April - October 1994	All wards, 460 bed university teaching hospital (Australia)	Type RRT: MET Single-parameter system Criterion worry/concern included	Analysis of RRS calls
Laurens & Dwyer, 2010	Quasi-experimental, Before and after study	Determine effect RRS implementation on mortality rates, cardiopulmonary arrests, and ICU admissions	Retrospective patient files Prospective RRS registration	105 activations of cardiac arrest team pre-intervention period 296 RRS activations	All wards, 150 bed regional teaching hospital (Australia)	Type RRT: MET Single-parameter system Criterion worry/concern included	Analysis worry/concern criterion

Leach et al. 2010	Grounded theory Purposive sampling Open coding, constant comparison and contrasting	Investigate how RNs rescue patients in hospitals with RRT	Semi-structured interviews	50 Nurses involved with RRT's (14 bedside staff RNs who had called RRTs,16 RRT-staff RNs, 2 respiratory therapists who had responded to RRTs, 8 nurse supervisors who had observed RRTs)	Type of ward: not mentioned 6 acute care hospitals (non-profit community, magnet-designated, public, academic, for-profit community and integrated delivery system) (USA)	Type RRT: RRT Calling system not reported;	Signs and symptoms of recognition of deterioration
Massey et al. 201	Interpretive qualitative approach Transcribed verbatim and thematical analysis	Explore nurses' experiences and perceptions of using and activating a RRS	In-depths semi-structured interviews.	15 Registered ward nurses	General wards. Large public teaching hospital (Australia)	Type RRT: MET Single-parameter system Not specifically mentioned whether 'worry/concern' was calling criterion	Signs and symptoms of recognition of deterioration
McDonnell et al. 2012	Mixed-method qualitative part for review: Descriptive Purposive sampling Thematic framework analysis	Evaluate impact of new T&T and observation charts on the knowledge and confidence of nurses to recognize and manage deteriorating patients	Semi structured interviews	15 Registered nurses	Type of ward: surgical, orthopaedic, acute medicine, Medicine District general hospital > 500 beds (UK)	Type RRT: outreach Aggregated scoring system No worry/concern criterion.	Signs and symptoms of recognition of deterioration
Minick and Harvey 2003	Interpretative Phenomenology Purposive sampling	Describe phenomenon of early problem recognition among medical-surgical nurses	In-depths group interviews, describing an experience	14 Nurses	Orthopaedics, neurology, renal, oncology, cardiac, or pulmonary ward Urban hospital (USA)	Not reported	Signs and symptoms of recognition of deterioration
Parr et al. 2001	Observational Cross-sectional	Describe reasons for, and immediate outcome following RRS activation	Review registration of RRS-calls	713 RRS- calls concerning 559 patients during the year 1998	Wards not specified, ED excluded 580 bed tertiary teaching university affiliated hospital (Australia)	Type RRT: MET Single-parameter system Criterion worry/concern included	Analysis of worry/concern RRS-calls

Pattison & Eastham, 2011	Mixed-method qualitative part for review Explanatory Theoretical sampling Using grounded theory principles	Explore referrals (characteristics) to Critical Care Outreach Team (CCOT)	In-depths interviews, loosely structured	7 nurses and 2 doctors	Patients with cancer referred to CCOT. Specialist hospital over an 8 months period (UK)	Type RRT: outreach Aggregated scoring system Not specifically mentioned whether 'worry/concern' was calling criterion.	Signs and symptoms of recognition of deterioration
Santiano et al. 2009	Observational Cross-sectional	Explore reasons nurses use subjective 'worried' calling criterion. Compare outcomes of worried with calls on objective criteria	Review registration of RRS-calls	3189 RRS calls during 2006	Type of ward: not specified 6 acute care hospitals (tertiary referral centre, major metropolitan, metropolitan and rural) (Australia)	Type RRT: MET Single-parameter system Criterion worry/concern included	Analysis of worry/concern RRS-calls
Williams et al. 2011	Descriptive Convenience sample Content analysis	Clarify nurse perceptions of RRT's	Focus groups, 15 item topic guide	13 nurses	156 bed community hospital General wards (USA)	Not reported	Signs and symptoms of recognition of deterioration

Chapter 3

Surgical ward nurses' responses to worry; an observational descriptive study

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Abstract

Background: Rapid Response Systems (RRSs) aim to improve early recognition and treatment of deteriorating general ward patients. Sole reliance on deviating vital signs to escalate care in RRSs disregards nurses' judgments about a patient's condition based on worry and other indicators of deterioration. To make worry explicit, the Dutch-Early-Nurse-Worry-Indicator-Score was developed, summarising non-quantifiable signs of deterioration in the nine indicators: breathing, circulation, temperature, mentation, agitation, pain, unexpected trajectory, patient indicates not feeling well and nurses' subjective observations. Nurses' worry can be present even when vital signs are largely unchanged, enabling treatment to commence at an early stage. On the other hand, reliance on nurses' worry might lead to unnecessary calls for medical assistance or an overuse of RRSs. The aim of the study was to explore the occurrence of nurses' worry in real time, determine whether acting on worry leads to unnecessary action and determine the indicators present at different levels of deterioration.

Methods: A prospective cohort study was performed on three surgical wards in a tertiary, university affiliated teaching hospital. All nurses participated in the study and adult, surgical, native speaking patients were included. A descriptive analysis is performed on one year of data on surgical ward nurses' experience of worry and its underlying indicators in addition to routinely measured vital signs.

Results: Out of a total of 46,571 measurements, vital signs were normal 18,727 times, with worry expressed 605 times (3%), resulting in 62 calls (10.2%) to the attending physician. More than half of these calls resulted in necessary interventions. Calls for assistance and subsequent intervention after worry was expressed increase in parallel with early warning scores. The breathing indicator showed the highest increase in frequency with increasing deviation in vital signs.

Conclusion: This study suggests that worry has potential as an early indicator of deterioration, alerting nurses and encouraging them to start timely interventions. Overuse of medical assistance could not be determined, The Dutch-Early-Nurse-Worry-Indicator-Score objectifies worry when vital signs do not support its presence and systematic assessment of these indicators is recommended.

Introduction

Nurses play an important role in the recognition of clinical deterioration in general ward patients. They are the first professionals to encounter, judge and interpret the severity of problems and make decisions about calling a physician. Since critically ill patients frequently deteriorated in general wards without notice or action, Rapid Response Systems (RRSs) have been introduced as a systematic approach to improve early recognition and treatment of deteriorating general ward patients.[1,2]

In an RRS response triggers to escalate care are formulated in a track-and-trigger system, and a responding team of intensive care professionals contributes specialist knowledge to general ward staff.[3] Depending on the preference and organization of individual hospitals, these Rapid Response Teams (RRTs) can either be nurse- or physician led, with different escalation protocols. General ward nurses call directly to the RRT, or first to the ward physician.[4] The escalation protocols present clear cut-off points of deviating vital signs to guide decisions to call either on a single criterion or in an aggregated system.[5]

In addition to deviating vital signs, nurses also recognise deterioration through more subtle indicators.[6-9] The RRS provides opportunities for nurses to call assistance even when vital signs do not confirm their judgment of a patient's condition, by adding worry as a calling criterion. A systematic review evaluating track-and-trigger systems reveals that only 28% of such systems use worry as a calling criterion.[5] If worry is not included in track-and-trigger systems, nurses face problems in escalating care, specifically when vital signs do not confirm the judgment, since there is a tendency to marginalise risks not assimilated into risk scores.[10,11] Barriers nurses face in calling for assistance are a lack of confidence,[12,13] a perceived need to justify the call,[11,14,15] fear of criticism,[16] and difficulty formulating their concerns.[10,14]

In the RRS, worry was not specifically conceptualized but recently signs and symptoms used by expert nurses in their clinical judgments and decisions to call for medical assistance were identified as underlying to worry.[8] All non-quantifiable signs are summarised in the Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) assessment tool. Excluding intuitive knowledge, the nine indicators included are changes in breathing (noisy breathing, shortness of breath or inability to speak in full sentences or use accessory muscles), changes in circulation (colour changes, clammy skin, coldness, impaired perfusion or oedema), rigors, changes in mentation (lethargy or confusion), agitation (restlessness or anxiety), pain (new pain, increasing pain), an unexpected trajectory (lack of progress, abdominal distension, nausea, bleeding, dizziness or falling), the patient indicating a feeling

of unwellness or impending doom and subjective nurse observations (changes in behaviour, a perception of the patient as looking unwell or a look in the patient's eyes).[6]

Individually and combined, worry and the underlying DENWIS indicators are good predictors of unplanned admissions to the intensive care unit (ICU) or high dependency unit (HDU) or unexpected mortality, even when vital signs have not or only slightly deviated from normal.[6,7] The presence of worry before vital signs deviate suggests that nurses judge situations and foresee potential problems at an early stage of deterioration. Situation awareness is an important skill preceding adequate clinical judgment and decision making and includes perception, interpretation and foresight into potential problems.[17] Nurses use a variety of reasoning patterns, including intuitive, analytical or both elements.[18] Intuitive decisions are unconscious and quick,[19] and associated with pattern recognition based on past experiences.[9,20,21] This can lead to over- or underestimation of possible risks resulting in incorrect decisions by ignoring other possible signs.[22-24] Analytical, well-structured and deliberate judgement makes the decision process more transparent for others.[25,26] As hospital care becomes more complex due to shorter hospital stays and an aging population with increasing comorbidities, these skills become increasingly important.

Although evidence is growing that RRSs reduce adverse events including cardiopulmonary arrest, unplanned ICU admission, and in-hospital mortality,[27,28] improving care at an earlier stage could prevent patients from deteriorating. Not incorporating worry and/or underlying indicators in RRSs disregards nurses' judgment in an early stage or might lead to unnecessary calls for medical assistance.

To understand if and how nurses' worry, or its underlying indicators should be incorporated into RRSs, we explored the occurrence of nurses' worry in real time. We determined whether acting on worry leads to unnecessary actions and which indicators of worry are present at different levels of deterioration.

Methods

Setting

An observational descriptive study was performed on three surgical wards (abdominal/oncological surgery, vascular surgery, and traumatology) in a 500-bed university-affiliated, tertiary teaching hospital. The study hospital implemented an RRS 2007. In this RRS, when vital signs reach a trigger threshold, ward nurses call the attending

physician, who decides whether or not to consult the ICU-resident. In addition, nurses can call the ICU-nurse directly if worried about a patient, without involving the ward physician. An intensivist is also available 24/7.

We obtained approval for our study from the local ethics committee, who waived the need for informed consent for the use of patient data. All data were handled anonymously.

Participants

All nurses from the three surgical wards studied, agreed to participate in the study**.** At the time of initial data collection, 96 nurses worked in the participating wards. 19% of these nurses held a bachelor's degree, 57% were diploma nurses, and 24% were students. All had various levels of experience.

Inclusion and exclusion criteria for patients

All surgical patients over 18 years of age were included in our study, with the exception of patients who did not or poorly speak Dutch, patients lacking capacity, and patients in end-of-life care.

Dependent and independent variables

Worry and underlying signs and symptoms

Worry and the nine indicators underlying worry were integrated into electronic nursing files as a checklist of the DENWIS indicators. For each of their patients, nurses measured their worry about the patient's condition and detailed any DENWIS indicators present. The nurses decided when to score their patients, whether at the moment of worry, when assessing vital signs, or at the beginning or end of their shifts.

Vital signs

Vital signs were recorded once per shift, but when the patient was stable only once a day. The frequency could be increased depending on the patient's total score in the hospital's aggregated scoring system, the early warning score (EWS). Vital signs recorded included respiratory rate, saturation, oxygen supply, systolic blood pressure, heart rate, consciousness level and temperature. Each vital sign was awarded zero to four points depending on severity and the RRT initiated for a total score of seven or higher. Missing vital signs were substituted with measurements taken from eight hours before to four hours after the missing measurement. If an appropriate substitution measurement could not be found, the first measurement taken within 24 hours before the missing measurement were used instead.

Nurses' responses to worry

In order to investigate whether nurses called the attending physician or RRT after expressing worry, electronic nursing files were retrospectively studied (GD) for all positive worry measurements and any subsequent interventions examined.

Subsequent interventions were then judged as 'appropriate' in consultation with an intensivist and expert nurse. Interventions included oxygen therapy, fluid therapy, administration of medication, procedures such as nasogastric tube placements or wound management occurring within eight hours of worry being expressed and unplanned surgery within 24 hours of worry being expressed. Interventions that were indicative of simply following protocol or appeared to be part of daily rounds were classified as 'care as usual'. Finally, we used electronic nursing files to determine if unplanned ICU/HDU-admission or mortality occurred within 24 hours after worry was expressed.

In order to determine appropriate use of medical assistance when nurses expressed worry with normal vital signs (EWS of zero), two intensivists (DT and BF) unaffiliated with our study evaluated independently the necessity of the calls and interventions using patients' electronic medical and nursing files. Judgments were made based on their expertise. A third, independent intensivist (DB) was consulted to resolve differences of opinion.

To describe nurses' worry at different levels of deterioration, we differentiated between deviations where vital signs were only slightly changed (EWS 1-3), deviations where vital signs were significantly changed but below the trigger thresholds for calling the RRT (EWS 4-6) and deviations where vital signs reached the trigger thresholds (EWS ≥ 7). For each of these groups, we describe the number of calls to the attending physician, the presence of subsequent interventions and any indicators present.

Sample size

Data were collected during one year from March 2013 until April 2014.

Data analysis

A descriptive analysis was performed on the collected data, with frequencies, percentages, mean, median, range and standard deviation (SD) calculated where appropriate. All calculations were performed using version 20 of SPSS (IBM Corp., 2011).

Results

A total of 46,571 measurements were taken from 3,742 patients, with a median of seven measurements per patient and a median of 189.5 measurements per nurse. Of the total 46,571 measurements, nurses expressed worry 3,650 times (7.8%). A total of 207 adverse events were recorded within 24 hours of a positive or negative worry measurement: 64 instances of unplanned surgery on 62 patients, 120 unplanned ICH/HDU-admissions of 111 patients, and 23 patient deaths in the ward.

Nurses' responses to worry

Worry with normal vital signs

A total of 18,727 measurements with normal vital signs were recorded. Of these, worry was expressed 605 times (3.2%) for 392 patients, with a mean of 1.54 measurements per patient (median 1, minimum-maximum 1-13). Although the majority of these expressions of worry (n = 543 [89,8%]) were followed by 'care as usual', in 62 cases (10.2%) nurses called the attending physician for assistance. After more than half of these calls (n = 36 [58.1%]), one or more interventions were initiated. Independent intensivists evaluated most of these interventions (n = 33 [91.7%]) as necessary. Within 24 hours after these 33 calls, two patients had unplanned ICU/HDU-admissions and two patients underwent unplanned surgery, one of which was also admitted to the ICU postoperatively. No patients in this category died. Meanwhile, of the 26 calls (41.9%) to the attending physician that were not followed by an intervention, only one resulted in a patient's admission to the ICU within 24 hours of the call. Finally, within the group of patients receiving 'care as usual', four patients had unplanned ICU-admissions and two underwent unplanned surgery, of which one was admitted to the ICU postoperatively. None of these patients died within 24 hours of a worry measurement, and no calls to the RRT were made within eight hours of a measurement. Figure 1 provides an overview of these results.

Worry with slightly changed vital signs (EWS 1 - 3)

Of the 24,744 measurements with slightly changed vital signs (EWS 1 - 3), 1,880 (7.6%) expressed worry. Subsequent calls for assistance were made in 392 (20.9%) of these cases, in turn resulting in one or more interventions on 278 occasions (70.9%).

Worry with vital signs beneath the trigger threshold to call the RRT (EWS 4 - 6)

In the 2,649 measurements with an EWS between 4 and 6, nurses expressed worry 860 times (32.5%). Calls for assistance were made in 283 (32.9%) of these cases and followed by an intervention in on 208 occasions (73.5%).

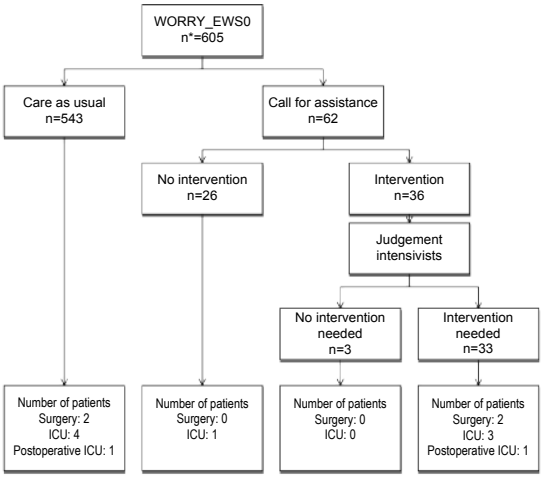

Figure 1. **Overview of nurses' responses to worry when vital signs are normal, detailing whether calls for assistance were followed by an intervention. ***

n = number of measurements; EWS = Early Warning Score; ICU = Intensive Care Unit

Worry with vital signs at or above the trigger threshold to call the RRT (EWS ≥ 7)

In the 450 measurements where the EWS reached 7 or higher, worry was expressed 305 times (67.8%), resulting in 136 (44.6 %) calls for medical assistance. These calls were followed by one or more interventions in 115 (84.6%) instances. Figure 2 depicts these results.

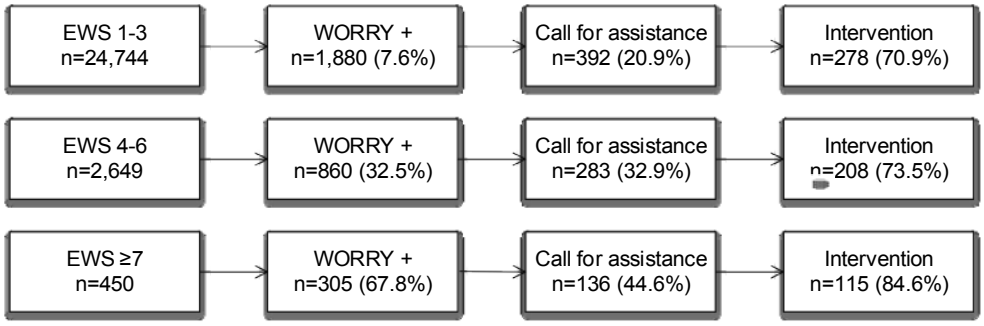

Figure 2. **Overview of nurses' responses to worry at different levels of deviating vital signs and subsequent medical treatment**

DENWIS indicators at different EWS levels

Overall, the presence of DENWIS indicators when worry was expressed increased along patients' EWS. The 'change in breathing' indicator was the most affected, with a fourfold increase in occurrence for patients with an EWS ≥ 7 (75.1%) compared to patients with an EWS of 0 (17.9%). Of all the DENWIS indicators, only pain was reported less frequently as EWS levels increased, decreasing from 26.3% for an EWS of 0 to 17.4% for an EWS ≥ 7. The indicator most frequently present when worry was expressed, and vital signs were not significant changed (EWS 0 - 3) was 'unexpected trajectory'. Meanwhile, when vital signs reached higher EWS (EWS ≥ 4), the most frequently recorded indicators were 'changes in circulation' and 'changes in breathing'. Table 1 details these findings.

Table 1. Presence of DENWIS indicators with a positive worry score for different EWS-levels

DENWIS indicators	EWS = 0 n = 605	EWS = 1-3 n = 1880	EWS = 4-6 n = 860	EWS ≥ 7 n = 305
Changes in breathing	108 (18%)	505 (27%)	520 (61%)	231 (75%)
Changes in circulation	207 (34%)	813 (43%)	534 (62%)	198 (65%)
Rigors	13 (2%)	75 (4%)	47 (6%)	25 (8%)
Changes in mentation	113 (19%)	426 (23%)	234 (27%)	113 (37%)
Agitation	58 (10%)	180 (10%)	110 (13%)	67 (22%)
Pain	159 (26%)	454 (24%)	136 (16%)	53 (17%)
Unexpected trajectory	263 (44%)	933 (50%)	466 (54%)	186 (61%)
Patient indicates not feeling well	128 (21%)	439 (23%)	252 (29%)	116 (38%)
Subjective nurse observation	97 (16%)	494 (26%)	318 (37%)	155 (51%)

Discussion

In this study, we explored the presence of nurses' worry and underlying DENWIS indicators in daily practice in surgical wards. Critically, we found that nurses are able to foresee a possible risk of deterioration for a small number of patients when vital signs are still normal. However, overuse of medical assistance at this stage could not be determined, as the

majority of subsequent actions were deemed necessary. Unsurprisingly, the presence of worry and DENWIS indicators largely increased in parallel with EWS levels, and accordingly calls for assistance and subsequent medical interventions intensify. The 'change in breathing' indicator was the indicator present most frequently when vital signs reached the trigger threshold to call the RRT. Only the presence of the pain indicator decreased at the highest EWS levels.

The results of this quantitative study confirm earlier qualitative and retrospective study results suggesting that nurses' worry is present at an early stage of deterioration when no or only slightly changes to vital signs can be observed.[13,29-33] While other studies focus on suboptimal ward care,[34-36] our findings clearly demonstrate that nurses already judge a patient's situation and respond adequately at an early stage of deterioration.

Over our year-long data collection, surgical ward nurses expressed worry when vital signs were normal a total of 605 times, almost twice a day. We did not find other studies reporting on the prevalence of nurses' worry at such an early stage. For almost six percent of adverse events, nurses foresaw the patient's deterioration when their vital signs were still normal. These adverse events were evenly divided between patients receiving 'care as usual' and those for whom nurses called for assistance. However, despite these early calls for medical assistance, six adverse events took place within 24 hours of the nurse's expression of worry: two surgeries and four ICU admissions. These results suggest that nurses' judgment and interpretation of the patient's situation was adequate and has potential for identifying patients at risk of deterioration at an early stage.

Our study was unable to determine overuse of medical assistance in RRSs at an early stage. This finding is in contrast with a prior study that found that nurses overestimate the risk of a critical event and the necessity of intervention in simulation scenarios.[24] In our study, the hospital's RRS was never deployed, and only 10.2% (n = 62) of worry observations resulted in calls for medical assistance. Slightly over half of these calls (58%) resulted in interventions that were considered necessary by experts.

As the first signs nurses observe in a patient, DENWIS indicators are typically the first signs that nurses act upon. Our results indicate that the breathing indicator is particularly critical, as it was the most frequently encountered indicator when the patient's EWS was 7 or higher. Other studies have also emphasised the importance of shortness of breath as an indicator of deterioration.[37-39] In particular, Considine (2005) underlines nurses' responsibility for assessing, interpreting and initiating adequate interventions specifically in relation to respiratory dysfunction.[40] Unexpectedly, the occurrence of the DENWIS pain indicator in our

study decreased with increasing patient EWS levels, despite the importance of pain as an indicator before cardiac arrest or mortality.[37,41] In surgical wards in the Netherlands, postoperative pain is well assessed and treated early, with acute pain teams visiting patients daily after surgery and routine pain assessments with protocols for the frequency of assessment and subsequent medication performed every shift.[42] While this may explain why pain appeared less frequently in the highest EWS group, effective treatment of postoperative pain derogates the importance of pain as an explicit sign of unwellness and suggests that nurses need to be critical when interpreting pain levels. Nevertheless, all DENWIS indicators were already present when vital signs were yet to deteriorate, suggesting that the assessment of patients must extend beyond routine measurement of vital signs.

Limitations

This study has a number of limitations. First, our decision to retrospectively gather information on calls for assistance allows for the possibility that some calls may not have been registered, an omission that may have negatively influenced our results with respect to the number of calls and interventions. Second, certain interventions were excluded from our study, such as extra vital signs measurements and diagnostics and consultation by specialists other than the RRT as these interventions were not directly intended to address the reason for calling or deterioration. However, these interventions may nevertheless have contributed to better patient outcomes, but we are unable to quantify their impact. Third, we substituted missing vital signs with the nearest measurement before worry was observed, which may have influenced the patient's EWS level.

Implications and recommendations

The presence of worry and DENWIS indicators when vital signs have not significantly deviated from normal values provides nurses with an opportunity to intervene at an early stage of patient deterioration. This in turn increases nurses' chances to prevent further deterioration and enact optimal treatment more rapidly. For these reasons, we believe that nurses should always take their worry seriously. Making worry explicit by using DENWIS indicators can contribute to transparent, transferable interdisciplinary communication about a patient's condition and thus contributes to a shared situational awareness. Systematic assessment of these indicators is recommended. Incorporating the significance of worry and underlying indicators into educational programs for students as well as general ward nurses, will empower them to effectively act upon their observations. Ultimately, further research is needed to establish how worry and DENWIS indicators may support the performance of RRSs. Our findings should be validated in other hospital settings.

Conclusion

This study demonstrates that surgical ward nurses are able to foresee and act upon patient deterioration at an early stage when vital signs have not yet deviated by using observations of worry and DENWIS scores as trigger tools. Although infrequent, early calls for assistance based exclusively on these observations lead to adequate responses for the majority of patients and overuse of medical assistance could not be determined. In conclusion, worry has potential as an early indicator of deterioration, enabling nurses to start timely interventions. The DENWIS indicators formalise worry when vital signs do not support the judgment

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Chapter 4

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

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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. 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.

Methods: A prospective cohort study was performed in a 500-bed tertiary University affiliated teaching hospital. Adult, native speaking surgical patients, admitted to three surgical wards (traumatology, vascular- and abdominal/oncological surgery) were included. We excluded mentally incapacitated patients, patients with a non-ICU policy or no curative treatment policy. 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 3,522 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 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.

Conclusion: In this single-centre 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.

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).[1,2] As a consequence, treatment on the ward is optimized to prevent further deterioration at an early stage. RRTs 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).[3]

In addition to vital signs, nurses' worry can be a calling criterion to activate RRTs, but it is used and valued inconsistently.[3-5] Furthermore, nurses experience barriers to call an RRT such as a lack of confidence,[6,7] the need to justify a call,[8-10] or fear of criticism.[11] Apart from these feelings of uncertainty, also underestimation of the pathophysiology underlying clinical signs[12] or a belief that patients should or can be managed on the ward[13] 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[14] and identified underlying signs and symptoms of the worry criterion that nurses pick up and subsequently act upon. The signs were categorized into ten 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 sign based RRT calling system.

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 three 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, 7 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 to 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 threshold of 7, nurses first consulted the attending physician, who should assess the patient within 30 minutes and consult the RRT. In case of delay, nurses were allowed to call the RRT directly.

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-life care. Only patients with the first two codes were included. Mentally incapacitated and non-native speaking patients were excluded.

Measurements

We developed a clinical assessment tool, the Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) (Table 1), based on previously determined worry signs.[14]

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 threshold 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 8 h shift, however this frequency could be changed according to the prevailing EWS-protocol: when stable once a day, EWS 5-7 every 2h and EWS ≥7 every hour. Based on this protocol we assumed vital signs to be normal if

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

Indicator	Underlying signs and symptoms
Changes in breathing	Noisy breathing and/or short of breath and/or unable to speak full sentences and/or use of accessory muscles
Changes in circulation	Colour changes and/or clammy and/or coldness and/or impaired perfusion and/or oedema
Rigors	Rigors
Changes in mentation	Lethargic and/or confused
Agitation	Restless and/or anxious
Pain	New pain and/or increasing pain
Unexpected trajectory	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 behaviour and/or doesn't look good and/or look in the eyes

Signs were scored when present

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 hours 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 hours 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.

Data collection

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

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 fulfil the rule of a minimum of 10 events per variable in a prediction model.[15] Based on earlier experience we estimated that approximately 4,000 ward admissions should be included and used a termination criterion to stop inclusion if during data collection a minimum of 100 events was reached.

Nursing sample

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

Data-analysis

Continuous variables are reported as mean ± 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 analysed in a univariate 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 hours 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 ≥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 ≥7. If both were not present we used a random measurement.

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.

Results

We included 3,522 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 Figure 1). Demographic data are shown in Table 2.

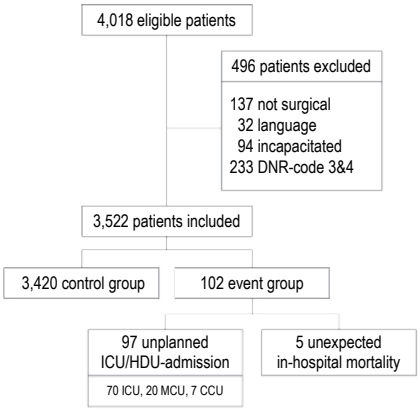

Figure 1. Study population

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

Table 2. Clinical and demographic variables

		Event group** n=102			
	Control* n=3,420	ICU/HDU (n=97)	Mortality (n=5)	Total event group (n=102)	*p*-value (total)
Men, n (%)	1,576 (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
H-LOS 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 (%)	1,170 (34.2%)	36 (37.1%)	3 (60%)	39 (38.2%)	0.399
Indication hospital admission, n (%)					
GI/oncological surgery	1,227 (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

*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

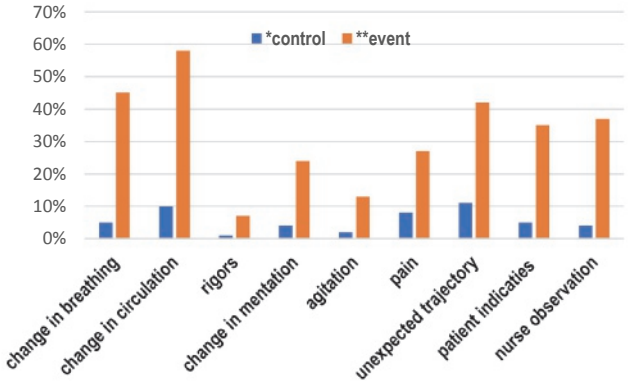

Figure 2. Frequency of DENWIS indicators in control- and event group
*Control group: patients without unplanned Intensive Care Unit/High Dependency Unit admission or unexpected mortality
**Event group: patients with unplanned Intensive Care Unit/High Dependency Unit admission or unexpected mortality

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 3).

Table 3. 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
Unexpected trajectory	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

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.

Discussion

In this single-centre study we showed that adding an EWS based on vital signs to the nine DENWIS indicators improves the prediction of unplanned ICU/HDU admission 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 or mortality.[4,16-18] Furthermore, Finlay et al. (2014) show improved prediction of deterioration when items from the electronic nursing files were combined with an EWS.[19]

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.[20] 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 favour of the continuous data, favouring 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.[21] 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.[22,23] 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.[24-28] Respiratory rate is the most frequently missing vital sign[24] with percentages of 30-66% missing, reported.[25,29] 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.

Conclusion

In this single-centre 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.

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Chapter 5

Capturing early signs of deterioration: the Dutch-Early-Nurse-Worry-Indicator-Score and its value in the Rapid Response System

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Abstract

Introduction: Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) comprises nine indicators underlying nurses' worry about a patient's condition. All indicators independently show significant association with unplanned intensive care/high dependency unit admission or unexpected mortality. Prediction of this outcome improved by adding the DENWIS to an Early Warning Score based on vital signs. The aim of this study is to determine the predictive value of individual and combined DENWIS indicators at various Early Warning Score levels, differentiating between Early Warning Scores reaching the trigger threshold to call a Rapid Response Team and Early Warning Score levels not reaching this point.

Methods: An observational cohort study was conducted on three surgical wards in a tertiary University-affiliated teaching hospital. Included were surgical, native-speaking, adult patients. Nurses scored presence of worry and/or DENWIS indicators every shift or when worried. Vital signs were measured according to the prevailing protocol. Unplanned intensive care/high dependency unit admission or unexpected mortality was the composite endpoint. Percentages of worry and DENWIS indicators were calculated at various Early Warning Score levels in control and event groups. Entering all DENWIS indicators in a multiple logistic regression analysis, we calculated a weighted score and calculated sensitivity, specificity, positive predicted value and negative predicted value for each possible total score.

Results: In 3,522 patients, 102 (2.9%) had an unplanned intensive care/high dependency unit admission (n = 97) or unexpected mortality (n = 5). Patients with such events and only slightly changed vital signs had significantly higher percentages of worry and DENWIS indicators expressed than patients in the control group. Increasing number of DENWIS indicators showed higher positive predictive values.

Conclusion: DENWIS indicators alert in an early stage of deterioration, before reaching the trigger threshold to call a rapid response team and can improve interdisciplinary communication on surgical wards during regular rounds, and when calling for assistance.

Introduction

Introduction of Rapid Response Systems (RRS) is associated with improvements in patient outcomes like cardiopulmonary arrests in general wards, unplanned Intensive Care Unit (ICU) admissions, and mortality.[1-5] Timely activation of a Rapid Response Team (RRT) is essential as delayed activation can lead to increased mortality.[6-8] Abnormal vital signs can trigger a call and activate an RRT in a one parameter system or combined in an aggregated system (Early Warning Score [EWS]), facilitating ward nurses to unambiguously communicate deterioration when calling for assistance.[9] However, in this scenario, patients need to deteriorate first in order to escalate care. Jones *et al*. (2012) advocate a more proactive approach and propose to improve care at an earlier stage to prevent further deterioration.[10]

Worry as a calling criterion provides an opportunity for nurses to call for assistance when other criteria do not yet meet a trigger-threshold to call an RRT. As such worry potentially contributes to optimize care in general wards at an early stage of deterioration. However, existing reluctance to call an RRT[11-16] and inconsistent use of the worried criterion are barriers to escalate care in an early stage. Moreover, doctors prefer quantitative data to base their decisions on in case of deterioration.[17] This emphasis on vital signs can make it difficult for nurses to convince doctors that the patient is at risk of deterioration when vital signs are normal or only slightly deviated.[15] Delay in escalating care can also be caused by poor interprofessional communication.[18] In addition, suboptimal interactions between professionals may have a negative impact on nurses' decision-making.[19,20]

To objectify and improve the use of the worried criterion, the underlying signs were determined and summarised in a bundle of 10 indicators.[21] The Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) was developed based on these indicators and comprises nine domains (Table 1). All indicators independently showed a significant association with unplanned ICU/High Dependency Unit (HDU) admission or unexpected mortality and improved the discrimination of patients at risk of unplanned ICU/HDU admission or unexpected mortality when added to an EWS based on vital signs.[22] Moreover, when vital signs did not reach the trigger-threshold to call the RRT, worry showed acceptable predictive value with an area under the receiver characteristics curve (AUROC) of 0.74, suggesting potential to detect high-risk patients in an early stage of deterioration. Additionally, in the present study we aimed to determine the predictive value of individual and combined DENWIS indicators at various EWS levels, differentiating between EWS reaching the trigger threshold to call an RRT and EWS levels not reaching this point. As such we establish how

DENWIS indicators can support nurses to improve recognition of patients at risk for deterioration specifically when vital signs have not or only have slightly changed.

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

Indicator	Underlying signs and symptoms
Changes in breathing	Noisy breathing and/or short of breath and/or unable to speak full sentences and/or use of accessory muscles
Changes in circulation	Colour changes and/or clammy and/or coldness and/or impaired perfusion and/or oedema
Rigors	Rigors
Changes in mentation	Lethargic and/or confused
Agitation	Restless and/or anxious
Pain	New pain and/or increasing pain
Unexpected trajectory	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 behaviour and/or doesn't look good and/or look in the eyes

Signs were scored when present. Adapted from International Journal of Nursing Studies 2016; 59:134 – 140

Methods

Data were prospectively collected in the period March 2013 - April 2014 in a 500-bed tertiary University affiliated teaching hospital. All (student) nurses of three surgical wards (traumatology, vascular and abdominal/oncological surgery) participated in the study. The RRT consisted of an intensivist, an ICU resident and an ICU nurse, all available 24 hours a day, seven days a week. Following protocol, ward nurses first contacted the ward physician, who should assess the patient within 30 minutes and contact the ICU resident or intensivist. Ward nurses always could contact the ICU nurse when worried. The EWS used, included respiratory rate, oxygen supply, arterial oxygen saturation, heart rate, systolic blood pressure, temperature, and conscious level. Each could be awarded zero to four points, depending on the severity of decline. The trigger point to call the RRT was a total score of seven or higher. The study was approved by the local ethics committee, and the need for informed consent was waived.

In- and exclusion criteria

We included surgical, native speaking, adult patients (≥ 18 years) and excluded mentally incapacitated patients and patients with restrictions in treatment: no (invasive) ventilation and/or renal support or palliative or end-of-life care.

Measurements

The DENWIS was incorporated into the electronic nursing files. After thorough instruction and training, nurses scored worry (yes or no) and DENWIS signs (when present) once per eight-hour shift or at the moment they felt worried about the patients' condition. Vital signs were measured three times a day, once in every shift. When vital signs were stable, frequency decreased to once or twice a day. With increasing EWS values, the frequency of measurements increased to every two hours for an EWS from five to seven, and every hour for an EWS of seven and higher. We considered vital signs to be normal when they were measured once a day.

Vital signs and DENWIS measurements from the same shift were linked. Missing vital signs were substituted with a measurement that was closest, in the eight hours before or four hours after the screening of the DENWIS signs. If still missing, the period was extended to 24 hours before the DENWIS measurement. If then still missing we assumed the missing vital sign to be normal and awarded zero points on the respective EWS subscore, as measurements should have been repeated when abnormal. The total EWS was calculated according to the prevailing EWS protocol. The composite endpoint was unplanned ICU/HDU admission or unexpected in-hospital mortality. All data were extracted by the Data warehouse of the hospital from the electronic patient files using SAS Enterprise Guide (SAS Institute, Huizen, the Netherlands).

Statistics and data analysis

Descriptive statistics are reported as mean ± SD, frequencies and percentages where appropriate. Differences in the group of patients with unplanned ICU/HDU admission or unexpected mortality and the group of patients without such an event were compared using the Fisher's Exact Test for nominal data and Student's *t*-test for continuous data and the Mann-Whitney test for non-normally distributed continuous data. As worry can also be the result of deviating vital signs, we calculated frequencies and percentages of worry and the DENWIS indicators at EWS 0, EWS 1-3, EWS 4-6 and EWS ≥ 7.

In our previous study, we analysed the DENWIS indicators in a multiple logistic regression analysis and calculated the AUROC (95% Confidence Interval (CI)) to define the value of the DENWIS model to predict unplanned ICU/HDU admission or unexpected mortality.[23] As

each patient had more than one measurement taken, we used the first measurement to occur in the 24 hours before our composite endpoint in the multiple logistic regression analyses. This was the measurement with either 'worry with an EWS < 7' or an EWS ≥ 7. If both were not present, the last measurement before an event was used (we refer to this group of patients as the event group). 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 ≥ 7. If both were not present, we used a random measurement.[23]

Additionally, in the current study we constructed a new prediction model, weighing all DENWIS indicators by multiplying the regression coefficients by five to accomplish full advantage of the discriminative value between the indicators. To establish the value of the DENWIS indicators as predictor of unplanned ICU/HDU admission or unexpected mortality, when the EWS trigger threshold to call the RRT was not yet met (EWS < 7), we calculated sensitivity, specificity, positive predicted value (PPV) and negative predicted value (NPV) for each possible total score of the weighted DENWIS model.

SPSS version 20 (IBM Corp. 2011) was used for all calculations. A *p*-value of <0.05 was considered significant for all tests.

Results

A total of 3,522 patients were included. Hundred and two (2.9%) had an unplanned ICU/HDU admission (n = 97) or died unexpectedly (n = 5), the flow diagram is shown in Figure 1. Relevant patient data are shown in Table 2.

Presence of worry and DENWIS indicators at various EWS levels

Out of 3,522 total measurements, nurses scored 861 times a positive worry and 896 times positive DENWIS indicators. Five percent of the measurements, in the control as well as in the event group, had one or more DENWIS indicators present when a nurse was not worried about the patient's condition. For EWS = 0 and EWS = 1-3 there were significant differences between the event and control groups in the presence of both worry and the DENWIS indicators (p <0.001). In the event group, nurses scored worry as well as positive DENWIS indicators insix out of eight patients (both 75%) when none of the vital signs were abnormal (EWS = 0) within 24 hours before an event.

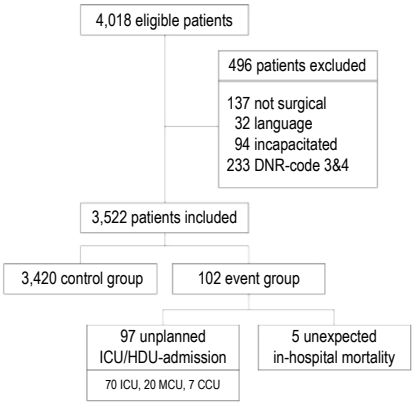

Figure 1. Study population

Table 2. Clinical and demographic variables

	Control group n=3,420	Event* group n=102	*p*-value**
Men, n (%)	1,576 (46.1%)	62 (60.8%)	0.003
Age, years (range; SD)	59.3 (18-96; 18.1)	68.9 (20-97;13.6)	<0.001
Hospital Length of Stay, days (range; median)	5.1 (1-171;3.0)	29.2 (1-158;24.0)	<0.001
Co morbidities, n (%)	1,170 (34.2%)	39 (38.2%)	0.399
Abdominal-oncological surgery, n (%)	1,227 (35.8%)	57 (55.9%)	<0.001
Vascular surgery, n (%)	477 (13.9%)	15 (14.7%)	0.773
Traumatology, n (%)	839 (24.5%)	15 (14.7%)	0.025
Other, n (%)	877 (25.6%)	15 (14.7%)	0.011
DNR; code 2 n (%)	214 (6.3%)	23 (22.5%)	<0.001
Worry (EWS<7) n (%)	752 (22%)	71 (69.6%)	<0.001
Worry, n (%)	774 (22.6%)	87 (85.3%)	<0.001
EWS, mean (range; SD)	1 (0-14;1.3)	3.9 (0-14;2.6)	<0.001

*Event composite endpoint of unplanned ICU admission or unexpected mortality. ** Fisher's Exact Test

When vital signs were slightly abnormal (EWS 1-3, n = 43 in the event group) nurses scored a positive worry for 34 patients (79.1%) and positive DENWIS indicators in 35 patients (81.4%). When the EWS was between 4-6 there were no significant differences between control and event groups in the presence of worry and DENWIS indicators. In the event group 31 patients (88.6%) had a positive worry and 30 patients (85.6%) had positive DENWIS indicators. For the patients (n = 16) for whom the EWS reached the trigger threshold to call the RRT (EWS ≥ 7) nurses scored 100% worry (significant difference with the control group [p <0.001]) and 14 patients (87.5%) had positive DENWIS indicators (no significant difference with the control group (p = 0.710). Data are provided in Table 3.

DENWIS model, leaving all indicators in the model

The AUROC (95% CI) for the DENWIS indicators to predict unplanned ICU/HDU admission or unexpected mortality, leaving all indicators in the model, was 0.85 (0.80-0.89). Four indicators contributed significantly to the predictive value of the DENWIS model: changes in breathing (noisy breathing and/or shortness of breath and/or unable to speak full sentences and/or use of accessory muscles) (p <0.001), changes in circulation (colour changes and/or clammy skin and/or coldness and/or impaired perfusion and/or oedema) (p <0.001), changes in mentation (confused and/or lethargic) (p = 0.005) and the subjective nurse observations (change in behaviour and/or doesn't look good and/or look in the eyes) (p = 0.041). Multiplying the regression coefficients by 5 resulted in weighted DENWIS indicators with a minimum of 1and maximum of 7 points, with a possible maximum score of 28 when all indicators are present (Table 4).

Sensitivity, specificity, PPV and NPV for the weighed DENWIS indicators when the EWS < 7

Sensitivity, specificity, PPV and NPV for each possible total score of the weighted DENWIS model to predict unplanned ICU/HDU admission or unexpected mortality are shown in Table 5. DENWIS 25 was the maximum score. Sensitivity for all possible DENWIS scores had a minimum value of 2% (DENWIS ≥ 25; n = 2) and a maximum of 69.6% (DENWIS ≥ 1; n = 2712). Specificity a minimum of 77.2% (DENWIS ≥ 1) and maximum of 100% (DENWIS ≥ 25). PPV for all possible DENWIS scores had a minimum of 8.4% for DENWIS ≥ 1 and a maximum of 66.7% (DENWIS ≥ 25). NPV had a minimum value of 97.2% (DENWIS ≥ 25) and a maximum of 98.8% (DENWIS ≥ 1). When the four indicators (changes in breathing, circulation, mentation and subjective nurse observation) that add significantly to the model are all present, the total score is 20. In that situation sensitivity, specificity, PPV and NPV are 12.7%, 99.5%, 44.8% and 97.5% respectively.

Table 3. Incidence of worry and DENWIS indicators at various EWS levels

		Control group	Event group	*p*-value*
EWS=0		N = 1,530	N = 8	
	Worry +	186 12.2%	6 75%	p<0.001
	DENWIS +	208 13.6%	6 75%	p<0.001
EWS1-3		N = 1,715	N = 43	
	Worry +	453 26.4%	34 79.1%	p<0.001
	DENWIS +	468 27.3%	35 81.4%	p<0.001
EWS4-6		N = 134	N = 35	
	Worry +	112 83.6%	31 88.6%	p=0.603
	DENWIS +	103 76.9%	30 85.7%	p=0.354
EWS ≥ 7		N = 41	N = 16	
	Worry +	23 56.1%	16 100%	p=0.001
	DENWIS +	32 78.0%	14 87.5%	p=0.710

*Fisher's Exact Test (2-sided)

Table 4. Multivariate logistic regression analysis of DENWIS indicators and final weight in the DENWIS instrument

DENWIS indicator	B	*p* value	Odds ratio	95% C.I.		Final score*
				Lower	Upper	
Changes in breathing	1,373	,000	3,947	2,325	6,700	7
Changes in circulation	1,192	,000	3,295	1,905	5,697	6
Rigors	0,134	,785	1,144	,437	2,997	1
Changes in mentation	0,833	,005	2,300	1,278	4,139	4
Agitation	0,305	,430	1,356	,636	2,892	2
Pain	0,421	,141	1,523	,870	2,664	2
Unexpected trajectory	0,269	,323	1,309	,767	2,234	1
Patient indicates	0,459	,131	1,583	,873	2,870	2
Subjective nurse observation	0,625	,041	1,869	1,026	3,404	3
Total instrument score						28

*regression-coefficients multiplied by 5

Table 5. Sensitivity, Specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV) for different cut-off levels of the DENWIS with an EWS < 7

		N event	N controls	Sensitivity	Specificity	PPV	NPV	*p*-value*
EWS ≥ 7**		16	3,379	15.7%	98.8%	28.1%	97.5%	<0.001
EWS < 7	DENWIS ≥ 1	71	2,641	69.6%	77.2%	8.4%	98.8%	<0.001
	DENWIS ≥ 2	67	2,741	65.7%	80.1%	9.0%	98.7%	<0.001
	DENWIS ≥ 3	65	2,858	63.7%	83.6%	10.4%	98.7%	<0.001
	DENWIS ≥ 4	64	2,925	62.7%	85.5%	11.4%	98.7%	<0.001
	DENWIS ≥ 5	63	2,965	61.8%	86.7%	12.2%	98.7%	<0.001
	DENWIS ≥ 6	59	2,993	57.8%	87.5%	12.1%	98.6%	<0.001
	DENWIS ≥ 7	53	3,077	52.0%	90.0%	13.4%	98.4%	<0.001
	DENWIS ≥ 8	45	3,251	44.1%	92.1%	14.3%	98.2%	<0.001
	DENWIS ≥ 9	44	3,180	43.1%	93.0%	15.5%	98.2%	<0.001
	DENWIS ≥ 10	41	3,229	40.2%	94.4%	17.7%	98.1%	<0.001
	DENWIS ≥ 11	36	3,271	38.2%	95.6%	19.2%	98.1%	<0.001
	DENWIS ≥ 12	36	3,992	35.3%	96.3%	19.5%	98.0%	<0.001
	DENWIS ≥ 13	36	3,292	35.3%	96.3%	22.0%	98.0%	<0.001
	DENWIS ≥ 14	29	3,326	28.4%	97.3%	23.6%	97.9%	<0.001
	DENWIS ≥ 15	24	3,348	23.5%	97.9%	25.0%	97.7%	<0.001
	DENWIS ≥ 16	22	3,360	21.6%	98.2%	26.8%	97.7%	<0.001
	DENWIS ≥ 17	19	3,375	18.6%	98.7%	29.7%	97.6%	<0.001
	DENWIS ≥ 18	15	3,386	14.7%	99.0%	30.6%	97.5%	<0.001
	DENWIS ≥ 19	14	3,392	13.7%	99.2%	33.3%	97.5%	<0.001
	DENWIS ≥ 20	13	3,404	12.7%	99.5%	44.8%	97.5%	<0.001
	DENWIS ≥ 21	12	3,409	11.8%	99.7%	52.2%	97.4%	<0.001
	DENWIS ≥ 22	8	3,414	7.8%	99.8%	57.1%	97.3%	<0.001
	DENWIS ≥ 23	6	3,417	5.9%	99.9%	66.7%	97.3%	<0.001
	DENWIS ≥ 24	2	3418	2.0%	99.9%	50,0%	97.2%	0.005
	DENWIS ≥ 25	2	3419	2.0%	100.0%	66.7%	97.2%	0.002
	DENWIS ≥ 26	0						

*Fisher's Exact Test. ** Trigger point to call the Rapid Response System not preceded by a measurement 'worry with an EWS < 7'

Discussion

Our results support the assumption that worry and the DENWIS assessment tool are of value at an early stage of deterioration when vital signs do not yet meet the trigger threshold to call an RRT. With slightly changed vital signs (EWS < 4), nurses already scored a positive worry and positive DENWIS indicators in, respectively, 39 and 40% of the patients within 24 hours before unplanned ICU/HDU admission or unexpected mortality. This difference was significant compared with the control group. When the EWS did not reach the trigger threshold to call an RRT (EWS < 7) a DENWIS of 1 or more already identified that eight out of 100 patients had unplanned ICU/HDU admissions or died unexpectedly (PPV 8.4%), PPV increases with the number of positive DENWIS indicators. When the most important indicators (highest contribution to the prediction) in the DENWIS model (changes in breathing, circulation, mention and subjective nurse observation) are present, a DENWIS score of 20 points is associated with a PPV of 44.8%, suggesting that almost half of the patients are at risk for unplanned ICU/HDU admission or unexpected mortality.

In this study we have clearly shown that it is important for the nurses to act on worry and any positive DENWIS indicator and be explicit which DENWIS indicators are present, in order to get medical assistance at an early stage that may lead to immediate medical interventions that potentially may prevent further deterioration. The DENWIS provides nurses with an instrument that facilitates identifying relevant observations apart from vital signs at an early stage and thus can improve communication, during regular rounds as well as in other situations when it is necessary to call for assistance. This should be followed up with an adequate response to meet the three fundamental steps of escalation of care: identifying, communicating and responding to deterioration.[18,24]

At an EWS 4-6, there is no significant difference in the appearance of worry and DENWIS indicators in the control and event groups. Both groups have high percentages (over 77%) of both worry and DENWIS indicators. This might be explained by the fact that doctors use quantifiable changes in physiological parameters to support their decisions when a patient deteriorates[17] and as such will act on abnormal vital signs and patients in the control group have benefitted from interventions at the ward. But it does not explain why the same percentage of patients do deteriorate.

Results from this prospective study are consistent with the results from retrospective studies reporting on the relevance of the presence of worry without or with minor changes in vital signs before critical incidents.[2,17,25-36] Our study adds to the existing knowledge as we specified the importance of the underlying signs in more detail than others have done.

Signs that alert nurses may lead to vital signs measurements at the time of possible deterioration, as nurses typically verify their feelings of concern with vital signs measurement[37] or increase the frequency of vital sign measurements when worried.[38] This emphasises the importance of assessment of both worry and DENWIS indicators as well as vital signs.

The DENWIS can support nurses in the complexity of clinical nursing which makes more informed decision-making essential to ensure effective and safe care.[39] Situation awareness (SA) is seen as the first step of effective decision-making. Perception, interpretation and being able to foresee what might happen in a specific situation are three levels of SA.[40] In this study, we have shown that DENWIS can support nurses specifically at the perception of the current situation. Nurses still need to interpret the indicators using their knowledge of possible causes for the individual patient with its own specific characteristics. The weighted DENWIS indicators can provide guidance in interpreting information, as we showed that these indicators should not be ignored. Individual factors, interpersonal behaviours and shared SA, influence SA and effective decision-making.[41] We speculate that the overview of relevant indicators and their predictive value potentially empower nurses on an individual level and in interpersonal communication by stimulating self-confidence and assertion and as such improving cognitive abilities which are closely associated with SA.[42] Probably, the best results will be achieved when both the medical and nursing disciplines will embrace the DENWIS and improve shared SA and as such effective decision-making to institute the appropriate medical response.

Human factors such as poor interprofessional communication have been shown to enhance failure to rescue or diminish effective escalation of care among surgical patients.[43] Communication tools like the Situation, Background, Assessment, and Recommendation (SBAR) instrument provide a framework *how* to (interdisciplinary) communicate (Institute for Healthcare Improvement). Additionally, the DENWIS indicators can support nurses *what* to communicate and how to assess these indicators, which helps them to recommend what needs to be done.

The limitations of our study have been discussed extensively in our last publication on DENWIS.[23] Interrater reliability and validity was not measured since this was practically impossible due to the nursing sample of about 100 nurses. Second, we had missing vital signs that were substituted with values from previous measurements within eight to 24 hours before. Vital signs were measured according to instructions from the RRS protocol with increasing frequencies of measurements as the EWS values increased. Furthermore, we had more complete vital signs measurements in the event group. The third limitation is

related to the choice of the measurements in the analysis. We chose measurements which occurred first during hospital stay for the control group and within 24 hours before unplanned ICU/HDU admission or unexpected mortality for the event group: 'worry with an EWS<7' or an EWS ≥7. So, in this analysis EWS ≥7 concerns only the measurements not preceded by a measurement with 'worry at an EWS<7'. This must have influenced sensitivity, specificity, PPV and NPV of all EWS ≥7 measurements. Furthermore, the results only concern surgical patients and data are from a single center.

Conclusion

In this study we showed that nurses' worry is important as early indicator of deterioration. Moreover, the DENWIS assessment tool is of high predictive value at an early stage of deterioration when vital signs do not yet meet the trigger threshold to call an RRT. Nurses can use the DENWIS indicators to be explicit in why they are worried. As both worry and DENWIS indicators are present when vital signs only changed slightly (EWS < 4), they may have an important role in interdisciplinary communication on the ward both during regular rounds, as when calling for assistance. Validation of the results in other hospitals and on medical wards is required.

Relevance to clinical practice

We recommend nurses working on surgical wards to screen all patients for all DENWIS indicators when they feel worried on the actual condition of the patient or when one or more DENWIS indicators are observed. Additionally, a full set of vital signs should be assessed, especially those incorporated in EWS RRS instruments. Also, nurses should start nursing interventions in this early stage. DENWIS and vital signs should be discussed during any regular ward round or when calling for assistance, preferably using communication frameworks such as the SBAR tool. Increasing numbers of positive DENWIS indicators indicate a higher chance that the patient is at risk for unplanned ICU/HDU admission or unexpected mortality, and an increase in DENWIS indicators often precedes the EWS RRS threshold. Therefore, when there is no adequate medical follow-up on the ward after a DENWIS alert, calling of the RRT should be considered. While we calculated weighted values per indicator for our analysis, we recommend not to use these values to create a trigger threshold to call for assistance. Nurses should consider calling on any indicator, as they are all significant in predicting patients at risk for unplanned ICU/HDU admission or unexpected in-hospital mortality.[23]

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Chapter 6

The sooner the better? Does systematic assessment of nurses' worry and subjective signs of deterioration, contribute to earlier transfer of surgical ward patients to the Intensive Care Unit? A prospective cohort study

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Abstract

Background: Early Intensive Care Unit (ICU) admission may result in shorter ICU and hospital length of stay. Rapid Response Systems facilitate detection of deteriorating patients by vital signs measurement and escalation of care, potentially leading to lower severity of illness at ICU admission. Ward nurses recognize deterioration by subtle signs summarized in the Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS). We addressed whether systematic assessment of nurses' worry and DENWIS indicators a) identifies patients at risk for ICU admission, b) results in ICU admissions of less severely ill patients and c) results in shorter ICU and hospital length of stay.

Methods: We prospectively studied nurses using worry and DENWIS indicators, in addition to vital sign measurement to assess surgical patients' clinical condition, early and late after implementation. The area under the receiver operating characteristics curve (AUROC) was calculated to assess the ability of worry and DENWIS indicators to discriminate between patients at risk for unplanned ICU admission and those who are not at risk. We also compared the number of ICU admissions, severity of illness at ICU admission, and ICU- and hospital length of stay during two periods.

Results: The respective AUROCs (95% CI) to predict unplanned ICU admissions were: 0.83 (0.80 - 0.87), DENWIS indicators 0.89 (0.83-0.91) vital signs combined in an early warning score 0.87 (0.85-0.93). In period I (n = 1,958) 59 (3.0%) patients were admitted to the ICU versus 38 (2.1%) in period II (n = 1,788; p = 0.099). Median APACHE-II score was 19 (IQR:15.0-23.0) in period I versus 17.5 (IQR:13.8-22.3) in period II (p = 0.574). Median ICU length of stay was four days in period I and two days in period II (p = 0.049) and median hospital length of stay 29 days versus 22.5 days, respectively (p = 0.052).

Conclusion: Nurses' worry and DENWIS indicators can discriminate between patients at risk for unplanned ICU admission and those who are not at risk. The non-significant decline in APACHE II scores of surgical patients at ICU admission might be clinically relevant. The decline in ICU and hospital length of stay suggests that nurses' worry and DENWIS indicators combined with vital signs measurement may improve outcome.

Introduction

Implementation of Rapid Response Systems (RRSs) in general hospitals is associated with decreases in cardiopulmonary arrests, unplanned Intensive Care Unit (ICU) admissions, and/or mortality.[1-4] Nevertheless, delayed ICU transfer can result in increased mortality and longer hospital length of stay (LOS).[5] Results from a scenario analysis suggest that admitting patients less severely ill to the ICU may result in shorter ICU and/or hospital LOS and reductions in overall ICU costs.[6] However, implementation of RRSs does not always lead to a decrease in severity of illness at the moment of admission of a patient to the ICU.[2]

Early recognition of deteriorating patients is commonly based on deviating vital signs summarized in a track and trigger system. When a certain predetermined trigger threshold is reached, care can be escalated to a higher level. Some track and trigger systems encompass nurses' worry as subjective calling criterium.[7] Our earlier studies[8,9] showed that nurses' worry and/or underlying indicators summarized in the Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) were good predictors of the combined outcome, unplanned ICU/High Dependency Unit admission or unexpected mortality. Moreover, worry and DENWIS indicators are already present before vital signs reach the trigger threshold to escalate care. These results suggest opportunities for earlier referral of patients to the ICU, which might result in a lower severity of illness at ICU admission and shorter ICU and hospital LOS.[10]

We assumed that including nurses' worry and DENWIS indicators in systematic assessment of surgical ward patients, will increase awareness of ward staff about the role of worry and DENWIS indicators as early predictors of deterioration and thus will improve identification of patients at risk for ICU admission. The aim of this study is to determine if systematic assessment of nurses' worry and DENWIS indicators a) contributes to identification of patients at risk for ICU admission, b) results in ICU admissions of less severely ill patients and c) consequently results in shorter ICU and hospital LOS.

Methods

This prospective study was performed in a 500-bed tertiary University affiliated teaching hospital. The local ethics committee approved the study and waived the need for informed consent.

Patients and setting

We included adult, Dutch speaking surgical patients, admitted to three surgical wards (abdominal/oncological surgery, vascular surgery and traumatology) with a total capacity of 68 beds. Mentally incapacitated patients were excluded. The hospital has a mixed medical/surgical 12-bed level 3 ICU, providing the highest level of intensive care and a 4-bed Medium Care department.

Rapid Response System

In 2007 the RRS was implemented in the hospital. An ICU nurse, an ICU resident, and a consultant intensivist are available 24/7. The aggregated track and trigger system to escalate care includes the following vital signs: respiratory rate, arterial oxygen saturation, oxygen supply, systolic blood pressure, heart rate, temperature, and consciousness level. Vital signs are awarded 0-4 points corresponding with the degree of deterioration. Nurses first consult the attending physician at the predetermined trigger threshold of seven or higher. Within 30 minutes the attending physician should assess the patient and start treatment and consider consultation of the ICU. However, nurses' worry was an additional criterion that enabled nurses to consult the RRS nurse, separate from and independent of calling the attending ward physician.

Data collection

DENWIS indicators and worry

Before the data collection started, the DENWIS (Table 1) was added to the electronic nursing files and all surgical ward nurses received oral and written instructions. During the study period, nurses assessed the patient's condition once per shift or at any moment of worry. The presence of DENWIS indicators and whether they were or were not worried about a patient's condition was recorded in the electronic nursing file.

Vital signs

Vital signs were recorded following the local protocol once every eight-hour shift, and when stable once a day. Frequency was increased with higher EWS levels. EWS was calculated according to the local protocol. In case of missing data, missing vital signs were substituted by measurements taken within eight hours prior to the worry measurement or within four hours after. If still missing, the closest measurement within 24 hours before the worry measurement was used to substitute the missing vital sign.

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

Indicator	Underlying signs and symptoms
Changes in breathing	Noisy breathing and/or short of breath and/or unable to speak full sentences and/or use of accessory muscles
Changes in circulation	Colour changes and/or clammy and/or coldness and/or impaired perfusion and/or oedema
Rigors	Rigors
Changes in mentation	Lethargic and/or confused
Agitation	Restless and/or anxious
Pain	New pain and/or increasing pain
Unexpected trajectory	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 behaviour and/or doesn't look good and/or look in the eyes

Signs were scored when present. Adapted from International Journal of Nursing Studies 2016; 59:134 – 140

Recorded patient characteristics included: age, gender, comorbidity, restrictions in treatment policy, comorbidity (coded according to the ICD-10-CM diagnosis codes,[11] and the Charlson Comorbidity Index (CCI).[12] Organisational characteristics collected included: type of surgical ward and reason for ICU admission.

The primary outcomes of our study were (1) unplanned ICU admissions; (2) the severity of illness of admitted patients. Acute Physiology and Chronic Health Evaluation (APACHE) II scores, APACHE II predicted mortality rates, Sepsis-related Organ Failure Assessment (SOFA) scores, lactate and creatinine levels (all at ICU admission) were used to determine the severity of illness at ICU admission; (3) ICU- and hospital LOS in days. Secondary outcomes to determine severity of illness were the need and duration of Continuous Veno-Venous Hemofiltration (CVVH) or intermittent haemodialysis in hours, duration of invasive or non-invasive ventilation in hours, ICU mortality and hospital mortality.

We compared two periods, early (period I) and late (period II) after implementation. Period II was considered as the period in which patients might benefit from the increasing awareness of ward staff about the role of worry and DENWIS indicators in identifying patient at risk for ICU admission or mortality. Period I was from March 8, 2013 - September 17, 2013 and period II from September 18, 2013 until March 31, 2014.

Data were extracted from the ICU database and the hospital's data warehouse using SAS Enterprise Guide (SAS institute, Huizen, the Netherlands).

Data-analysis and statistics

Normally distributed continuous data are reported as mean (standard deviation [SD]) and not normally distributed data as median (Inter Quartile Range [IQR]). Nominal variables are reported as frequencies and percentages.

To determine whether systematic assessment of DENWIS indicators and nurses' worry is associated with decrease in severity of illness among patients admitted to the ICU, we compared outcomes from the two study periods using the Fishers Exact Test, the Students t-test and Independent Mann Whitney U-test for respectively nominal, continuous and non-normally distributed continuous data. To minimize potential bias from other (ICU) improvements, we also compared the results with the patient population admitted to the ICU from the medical wards in the same periods.

The ability of nurses to discriminate between patients at risk for ICU admission from those who are not at risk, was determined by calculating the Area Under the Receiver Operating Characteristics curve (AUROC) (95% Confidence Interval [CI]) with the predictor variables: worry, DENWIS, EWS, worry added to the EWS and DENWIS added to the EWS. In the analysis, we used the first positive worry measurement with an EWS not reaching the trigger threshold to call the RRT (EWS<7), if not present the first measurement of EWS ≥7, if not present a random measurement all within the 24 hours before ICU admission. For the patients not admitted to the ICU, the control group, we used the same procedure during hospital stay.

All calculations were performed using SPSS version 20.[13]

A *p*-value < 0.05 was considered significant for all tests. All data were handled anonymously.

Results

From a total of 3,746 surgical ward patients included in the study, 97 patients were admitted to the ICU. The respective AUROCs (95% CI) to predict unplanned ICU admissions (n = 97) were: Worry 0.83 (0.80-0.87), DENWIS 0.89 (0.83-0.91), EWS 0.87 (0.85-0.93), EWS & worry combined 0.91 (0.88-0.94) and EWS & DENWIS combined 0.93 (0.90-0.96).

Patient and organizational characteristics in period I and II

Surgical wards

In period I 1,958 patients and in period II 1,788 patients were included. Characteristics of the patients are shown in table 2. Significant differences in characteristics between the two periods concerned comorbidities and referring wards. In period II, more patients presented comorbidities: 400 patients (20.4%) in period I versus 450 (25.2%) in period II (p = 0.001).

Table 2. Characteristics, frequencies of unplanned ICU admissions, hospital lengths of stay and mortality rates of all included surgical and medical ward patients

	Surgical					Medical				
	Period I		Period II		*p*-value	Period I		Period II		*p*-value
Included patients; n	1958		1788			5513		5475		
Male patients; n (%)	901	(46.0)	800	(44.7)	.450	2711	(49.2)	2652	(48.4)	.445
Mean age (SD)	61.1	(18.4)	60.7	(18.6)	.530	64.9	(18.4)	65.5	(18.4)	.115
Comorbidity; n %	400	(20.4)	450	(25.2)	.001	2170	(39.4%)	2282	(41.7%)	.014
CCI*; mean (SD)	3.5	(2.4)	3.1	(2.2)	.018					
Patients with treatment limitations**; n (%)	105	(5.4)	111	(6.2)	.293	-	-	-	-	
Surgical wards										
GI*/oncological n (%)	593	(30.3)	730	(40.8)	<.001					
Vascular; n (%)	616	(31.5)	488	(27.3)	.006					
Traumatology; n (%)	749	(38.3)	570	(31.9)	<.001					
Patients with unplanned ICU*** admission: n (%)	59	(3.0)	38	(2.1)	.099	60	(1.1)	61	(1.1)	>.999
H LOS**** days; median (IQR)	3.0	(1-8)	3.0	(1-7)	.234	3	(1-7)	3	(1-7)	>.999
In hospital mortality n (%)	29	(1.5)	23	(1.3)	.676	159	(2.9)	167	(3.1)	.613

Charlson Comorbidity Index; **Treatment limitations: Do not resuscitate and no mechanical ventilation or Continuous Veno Venous Hemofiltration (CVVH); *** ICU: Intensive Care Unit; ****LOS: length of stay

However, the mean CCI was lower in period II: 3.5 (SD 2.4) in period I versus 3.1 (SD 2.2) in period II (p = 0.018). In period II there were significantly less patients referred from the vascular surgery and traumatology wards and significantly more patient from the GI/oncological ward (p <0.001, p = 0.006, and p <0.001, respectively).

Medical wards

In period I 5,513 patients were admitted to the medical wards, and 5,475 in period II (table 2). On medical wards we also recorded significantly more patients with comorbidities in period II compared to period I (p = 0.014), with overall higher percentages of patients with comorbidities on medical wards compared to surgical wards. We could not retrieve data on restrictions in treatment policy from patients in medical wards and were also unable to calculate the CCI for patients in medical wards.

Patient and organizational characteristics of patients admitted to the ICU unplanned

Surgical ward

Characteristics of the patients admitted to the ICU from the surgical wards are shown in table 3. In period II we noticed a significant increase of the number of patients with treatment limitations (not to be mechanically ventilated or dialyzed): 4 (6.8%) in period I versus 9 patients (23.7%) in period II (p = 0.030). In both periods, most patients were referred from the GI-oncological ward (57.6% in period I and 55.3% in period II). GI-complications and sepsis were the most frequent reasons for ICU admission in both periods.

Medical wards

Characteristics of the medical ward patients over the two periods are shown in table 3. We found no significant differences comparing periods.

Table 3. Patient and organizational characteristics of patients admitted to the ICU unplanned

	Surgical wards					Medical wards				
	Period I		Period II		*p*-value	Period I		Period II		*p*-value
	n =59		n=38			n=60		n=61		
Male gender; n (%)	42	(71.2)	19	(50.0)	.052	29	(48.3)	39	(63.9)	0.101
Mean age (SD)	69.7	(12.5)	70.2	(11.8)	.861	67.7	(12.8)	69.5	(15.9)	0.504
Patients with co morbidity; n (%)	17	(28.8)	12	(31.6)	.822	36	(60.0)	39	(63.9)	0.710
CCI* mean (SD)	4.4	(2.9)	4.0	(2.8)	.751					
Patients with treatment limitations**; n (%)	4	(6.8)	9	(23.7)	.030	-		-		
Surgical wards										
GI***/oncology; n (%)	34	(57.6)	21	(55.3)	.837	-		-		
Vascular; n (%)	14	(23.7)	7	(18.4)	.619	-		-		
Traumatology; n (%)	11	(18.6)	10	(26.3)	.451	-		-		
Reason ICU admission										
GI***-complications; n (%)	20	(33.3)	8	(21.6)	.255	3	(5.0)	3	(4.9)	>.999
Sepsis; n (%)	20	(33.3)	10	(27.0)	.652	14	(23.3)	12	(19.7)	0.663
Pulmonary; n (%)	7	(11.7)	8	(21.6)	.249	23	(38.3)	20	(32.8)	0.572
Other; **** n (%)	11	(18.3)	11	(29.7)	.219	20	(33.3)	26	(42.6)	0.350

*Charlson Comorbidity Index; **Treatment limitations: Do not resuscitate and no mechanical ventilation or Continuous Veno-Venous Hemofiltration (CVVH); ***GI: Gastro-intestinal surgery; ****Other (Diabetic, bleeding, (cardio-)vascular, renal failure) n (%)

Severity of illness

Surgical ward

We noticed no significant differences in outcome variables in both time periods (see table 4). Although the median APACHE II score was 1.5 points lower in period II: 19 (IQR: 15.0-23.0) in period I versus 17.5 (IQR: 13.8-22.3) in period II, this difference did not reach statistical difference (p = 0.574).

Medical wards

Median APACHE II score was 22 (IQR 17-27.5) in period I, and 21 (IQR: 16-27.5) in period II (p = 0.692). None of the other outcome parameters were significantly different between periods (Table 4)

Table 4 Patient outcomes unplanned ICU admissions

	Surgical wards					Medical wards				
		Period I n=59		Period II n=38	*p* value		Period I n=60		Period II n=61	*p* value
APACHE II; median (IQR)	19.0	(15.0-23.0)	17.5	(13.8-22.3)	.574	22.0	(17-27.5)	21.0	(16.-27.5)	.682
APACHE II predicted mortality; median (IQR)	0.32	(0.23-0.50)	0.30	(0.20-0.48)	.498	0.46	(0.25-0.66)	0.44	(0.26-0.66)	.920
SOFA at ICU admission; median (IQR)	4.0	(0.8-2.7)	4.0	(1.1-2.2)	.827	5.5	(4.0-8.0)	5.0	(3.0-7.0)	.185
Lactate at ICU admission; median (IQR)	1.4	(0.8-2.7)	1.6	(1.1-22)	.221	1.7	(1.2-2.7)	1.8	(1.2-2.8)	.783
Creatinine at ICU admission; median (IQR)	95.0	(62.5-152.0)	84.0	(60.5-124.3)	.473	92.0	(66.0-183.0)	85.5	66.3-132.5()	.319
CVVH; n (%)	11	(18.6)	2	(5.26)	.069	6	(10.0)	2	(3.3)	.163
CVVH hours; median (IQR)	109.7	(26.5-215.5)	114.1	(4.0-114.1)	.769	42.0	(8.3-66.8)	8.7	(8.4-8.7	.429
Invasive ventilation; n (%)	38	(64.4)	26	(68.4)	>.999	26	(43.3)	25	(41.0)	.855
Invasive ventilation hours; median (IQR)	168.8	(21.1-330.8)	93.1	(23.3-173.7)	.240	62.1	(24.5-102.9)	28.7	(7.2-59.2)	.572
Non-invasive ventilation; n (%)	11	(18.6)	9	(23.7)	617	10	(16.7)	11	(18.0)	>.999
Non-invasive ventilation hours; median (IQR)	10.9	(2.1-46.3	5.8	(2.7-21.7)	.370	28.7	(7.3-59.2)	11.7	(3.9-32.0)	.395
ICU-LOS; days; median (IQR)	4.0	(2.0-11.0)	2.0	(1-6.3)	.049	4.5	(2.0-7.8)	3.0	(2.0-7.0)	.416
Hospital LOS days; median (IQR)	29.0	(19.0-46.0)	22.5	(15.0-36.0)	.052	15.5	(7.0-29.8)	14.0	(6.0-24.0)	.786
Mortality										
• ICU mortality; n (%)	8	(14.0)	6	(15.8)	>.999	15	(25.0)	14	(23.0)	.834
• Hospital mortality; n (%)	9	(15.3)	7	(18.4)	.781	18	(30.0)	16	(26.2)	.689

ICU LOS, hospital LOS and mortality in patients admitted to the ICU unplanned

Surgical wards

The median ICU LOS in period II was significantly shorter: median two days compared with median four days in period I ($p = 0.049$), as was the median hospital LOS in period II (median 22.5 days versus 29 days in period I; $p = 0.052$). ICU and in hospital mortality rates of patients admitted to the ICU did not differ between periods. See Table 4.

Medical wards

There were no significant differences in ICU and hospital LOS, ICU and hospital mortality between periods I and II for patients from medical wards. See Table 4.

Discussion

This study shows that nurses' worry and presence of underlying DENWIS indicators, can discriminate surgical ward patients at risk for ICU admission from those who are not at risk. We found a decline of 1.5 points in the median APACHE II score and a reduction in ICU- and hospital LOS when screening of nurses' worry and underlying DENWIS indicators are incorporated in nurses' assessment of deterioration in surgical ward patients.

Although none of the indicators of severity of illness were significantly lower after the implementation period (period I), the decline in the median APACHE II score by 1.5 points may be considered a clinically relevant outcome.[6] However, we also noticed a similar decline in the same period on the medical wards (1-point difference). Although the medical wards were not involved in the study and nurses did not record worry and DENWIS indicators, these indicators were known in the hospital which might have influenced both nurses on medical wards as well those in the RRT in their judgment. In line with results reported by Simmes et al. (2014)[6] we observed a marked shorter ICU and hospital LOS. This trend was not seen in the total surgical and medical ward patient population nor in the patients admitted to the ICU from the medical wards. This makes it unlikely that other hospital wide and surgical improvement projects have confounded our observed improvements.

The shorter ICU LOS may have been influenced by higher numbers of patients with treatment limitations (no mechanical ventilation and/or dialysis in addition to a do not resuscitate order). These patients have a higher chance to be transferred back to the general ward or to die. However, as hospital LOS was reduced, and increased mortality was not observed, this aspect does not seem to play an important role.

Decisions to admit patients to the ICU are made by intensivists. We did not implement the assessment of the DENWIS indicators as an intervention to use in mutual communication about deteriorating patients. Not including subjective signs in risk management tools like the EWS can make it more difficult for nurses to convince physicians when they are worried about a patient, particularly when vital signs do not support the feeling.[14] Nurses do strive for shared situation awareness with other professionals[15], but perceptions of a situation are influenced by differences in professional thinking[16] and thus nurses may interpret a situation different than physicians. Interprofessional training is known to improve shared situational awareness[17] but at the time of the study, interprofessional training was not yet a policy in the study hospital.

In our study we focused on improvement of detection of deterioration from a nurse perspective. However, there are other developments which focus on improvement of vital signs monitoring. Technological developments allowing continuous vital signs monitoring in general ward patients is promising[18-21] but also criticized.[22] Moreover, a recent systematic review, found insufficient evidence to recommend routine use in general wards at this moment.[9] In this present study and our previous work[8,9,23] we show that reliance on vital signs alone is not enough to ensure early recognition of deterioration and that combining the DENWIS with the EWS results in the best identification of patients at risk for ICU admission.

Apart from these new and promising results on improvement of earlier recognition of deterioration on the general wards, our study has several limitations that should be considered when interpreting results. First, we determined the first half of the data collection as early after implementation period. This might have influenced the results in two ways: a) in period II the sample size, concerning the ICU population (n = 38) from the surgical wards was small. This small sample size made it more difficult to get significant results. And b) nurses might have reached the learning curve at an earlier stage during period I.

Second, the recording of vital signs was not always complete. This is known to be a common problem[24-27] that influences all studies addressing vital signs measurements. We substituted missing vital signs with the closest measurements to reduce consequences of this problem. Last, worry and vital signs were not necessarily measured at the same time, but during the same shift. This leaves the question open whether nurses measured vital signs because they were worried or whether deviating vital signs made them worried.

Conclusion

Nurses' worry and DENWIS indicators can discriminate between patients at risk for unplanned ICU admission and those who are not at risk. During the period of systematic assessment and recording of nurses' worry and DENWIS indicators we observed a decline in APACHE II scores at ICU admission. Although, not significant these results might be clinically relevant for surgical patients, suggesting patients were admitted to the ICU at an earlier stage. The decrease in ICU and hospital LOS further supports this observation and suggests potential benefits to improve outcomes for deteriorating surgical patients. Future research should address the DENWIS and nurses' worry in interprofessional communication concerning deteriorating patients and further validation in other hospitals and healthcare systems is warranted.

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Chapter 7

General Discussion

General Discussion

Patients on general wards can be at risk of deterioration and, without timely recognition or treatment, the ljkelihood increases that this clinical deterioration may ultimately lead to an unplanned Intensive Care Unit (ICU) admission, the development of a cardiac arrest, or even unanticipated death.[1] Evidence is growing that these adverse events are reduced by the implementation of Rapid Response Systems (RRSs).[2,3] Although RRSs have been implemented in many hospitals, ongoing initiatives to improve the system are necessary.[4]

As first responders in cases of clinical deterioration, nurses play the most important role in the afferent limb of RRSs: identification of deterioration and escalation of care. The RRSs rely heavily on deviating vital signs as a means of detecting deterioration among ward patients. As a result, many initiatives, aimed at improving early detection of deterioration, focus on the frequency and completeness of vital signs measurements.[5]

Nurses, however, often detect the first signs of deterioration through intuition, which alerts them to be more vigilant.[6] Some RRSs take this aspect into account, adding the subjective worry of nurses as a calling criterion in the escalation process. However, results of systematic reviews show that only 14 - 28% of the included track and trigger systems have nurses' worry as calling criterion.[7,8] The aim of this thesis is to explore nurses' worry and its role in the process of early recognition of deteriorating surgical ward patients to empower nurses to call for assistance at an early stage.

Key findings

First, we performed a systematic review of the literature and defined the signs and symptoms underlying worry, as used by expert general ward nurses in their clinical judgement and decisions to call for medical assistance (Chapter 2). At an early stage, nurses can foresee and act upon patient deterioration when vital signs have not yet deviated from normal values. Although not frequently encountered, early calls for assistance based on only subjective observations lead to adequate responses in the majority of patients. (Chapter 3). All non-quantifiable signs and symptoms found in the systematic review, were summarised in a new developed assessment tool, the Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS), consisting of nine indicators (Table 1). Worry and underlying DENWIS indicators, both individually and combined, are good predictors of unplanned ICU/High Dependency Unit (HDU) admissions or unexpected mortality (Chapter 4) even when vital signs are normal or deviate only slightly from normal values (Chapter 5). Combined with the Early Warning Score (EWS), used in the study hospital, DENWIS indicators are excellent predictors of unplanned ICU/HDU admission or unexpected mortality, aiding with the identification of patients at risk

of adverse events. As a predictor of unplanned ICU/HDU admission or unexpected mortality, the indicator changes in breathing (noisy breathing and/or shortness of breath and/or unable to speak full sentences and/or use of accessory muscles) demonstrates the highest odds ratio (Chapter 4). The incorporation of nurses' worry and underlying DENWIS indicators into the assessment of surgical ward patients by general ward nurses is likely to lead to improvement in patient outcomes. This is supported by the non-significant, albeit likely clinically relevant, decrease in severity of illness of patients at admission to the ICU several months after the initial implementation of DENWIS. The significant reduction in ICU length of stay further supports this assumption (Chapter 6).

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

Indicator	Underlying signs and symptoms
Changes in breathing	Noisy breathing and/or short of breath and/or unable to speak full sentences and/or use of accessory muscles
Changes in circulation	Colour changes and/or clammy and/or coldness and/or impaired perfusion and/or oedema
Rigors	Rigors
Changes in mentation	Lethargic and/or confused
Agitation	Restless and/or anxious
Pain	New pain and/or increasing pain
Unexpected trajectory	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 behaviour and/or doesn't look good and/or look in the eyes

Adapted from International Journal of Nursing Studies 2016; 59:134 – 140

Objectifying and exploring nurses' worry

RRSs are developed based on the finding that ward staff frequently fail to recognise and act upon early signs of deterioration. 'Failure to rescue' has been described as a nurse-sensitive indicator, with several key elements: failure to recognise, communicate, and make decisions about changes in a patient's condition.[9] We studied worry as a concept that nurses use to recognise deterioration and in their decisions to intervene or escalate care to a higher level, either to the ward physician or the RRT. The signs and symptoms identified in our systematic review are based on triggers that experienced general ward nurses use in their decisions to escalate care.[10] Nurses not only base decisions on objective indicators, such as deviating vital signs or laboratory results, but also on observations that cannot be quantified, including shortness of breath, clammy skin, agitation, and confusion (Fig. 1). We show the clear importance of these latter indicators, summarised in the DENWIS, and of nurses' worry as

predictors of deterioration, with and without the presence of deviating vital signs.[11,12] As such, nurses' worry and the underlying DENWIS indicators are important for early identification of patients at risk and are likely to empower nurses to act.

In psychology, worry is considered valuable for solving future problems.[13-15] Perception of a situation, followed by an interpretation and subsequent ability to foresee what might happen, are all important skills that precede problem-solving. These skills are the three levels of situational awareness (SA)[16] which, in nursing, enables clinical judgement and decision-making.[17,18] DENWIS not only helps nurses to express the importance of observations, it also facilitates the objectification of worry, specifically when vital signs have not yet deviated. As such, DENWIS can support nurses in improving and evaluating the perception and interpretation of a patient's condition, and subsequently facilitate the decision as to whether to call for assistance.

Nurses use a variety of reasoning patterns, including intuitive and analytical elements, when reaching a decision.[19] With growing experience, nurses are known to use more intuitive judgement and decision-making skills.[20-25] Intuitive judgements are unconscious and quick[26] and strongly associated with recognition of patterns, that nurses identify as abnormal, based on past experiences.[6,27] However, intuition can also lead to the misinterpretation of a situation when other signs and possible cues are trivialised and not taken into consideration.[28] This can lead to over- or underestimating a patient's condition, resulting in incorrect decisions.[28-30] Cognition and decisions range from intuitive to analytical, based on respectively ill- and well-structured judgement tasks.[26] Deliberate, analytical, and well-structured judgement makes the decision process more transparent for others.[31,32] The DENWIS provides a structure to explain worry and for the assessment of important non-quantifiable indicators of deterioration. It can therefore contribute to conscious and transparent decisions based on analytical reasoning, supporting new and experienced nurses alike. Experienced nurses are encouraged to make their quick intuitive judgements explicit by (re)considering every sign of deterioration. Providing this overview of the relevant indicators of deterioration can support new or student nurses, even at an early stage, before vital signs begin to deviate from normal values.

In RRSs, the use of the Situation Background Assessment Recommendation (SBAR) communication tool is recommended to structure communication and make it more effective.[33,34] Most RRSs have a two-tier system, with nurses first calling and communicating deterioration with the ward physician. Commonly, these are junior doctors who may be confronted with an overwhelming workload.[35,36] Difficulties in communication exist.[35,37,38]

Nurses are confronted with the need to justify calls,[37-39] and fear of criticism is reported.[40,41] These barriers can result in delayed medical treatment.[42]

We objectify nurses' worry and provide a tool for nurses to unambiguously make their worry explicit during shift handover, and regular doctors' rounds, or while calling for assistance for a deteriorating patient. However, to be successful, the importance of the DENWIS indicators should also be acknowledged by doctors, ensuring mutual understanding of SA in order to improve effective decision-making.

Worry and DENWIS compared to existing track and trigger systems in the RRS

RRSs and track and trigger systems were developed following multiple studies showing the presence of deviating vital signs in the hours before cardiac arrest, unplanned ICU admission, and unanticipated mortality.[33,43-47] Aggregated calling systems include multiple vital signs which are valued corresponding to the severity of a decline, and a total score can then be calculated from these. At a predetermined trigger threshold, care is escalated. Aggregated systems perform better when identifying patients at risk than when using single parameter systems.[48] Improvement in aggregated systems mostly involves adjustment of the value appointed to the deviation from normal values per vital sign, and the number of parameters included in the system. The National Early Warning Score (NEWS)[49] outperforms 33 other track and trigger systems[50] (all without worry as a criterion) and has been implemented throughout the United Kingdom and in multiple Dutch hospitals. NEWS does not include worry as a criterion, though its protocol does emphasise that concern about a patient's condition should always overrule the NEWS.[51] However, not incorporating subjective parameters in track and trigger systems makes it more difficult for nurses to get assistance.[35,42,52]

We specifically address identification of patients at risk, from a nurse perspective. We show that nurses' worry and the DENWIS indicators improve the local track and trigger system based on vital signs.[11] The value of worry as a single parameter is in line with other study results showing nurses' judgement to be important for identifying patients at risk of deterioration.[53,54] However, nurses' clinical judgement has also been criticised as an important reason for escalation protocols not being followed up by physicians, potentially resulting in the delay of swift and optimal treatment.[55,56] This might be due to an over- or underestimation of own ability, as mentioned before.[28-30] Monitoring practices differ between nurses, depending on the competence of the individual.[57] In our study,[58] we observe nurses making adequate decisions with an appropriate use of medical assistance. Including DENWIS in patient assessment could strengthen awareness of a patient's condition and empower nurses and doctors to intervene.

Indicators that we include in the DENWIS are identified in earlier studies as significant predictors of adverse events like cardiac arrest, unplanned ICU admissions, and mortality: respiratory distress,[59,60] pain,[59-61] agitation, failure to respond to treatment,[59] poor peripheral circulation, and altered mentation.[61] However, later initiatives to improve identification of patients at risk of deterioration, including the NEWS and Cardiac Arrest Triage (CART),[62,] do not include any of these indicators and do not explain why not. Thus, important signs of deterioration that trigger nurses' worry during their daily work are ignored in these systems. We show that the indicators are all individually significant indicators of deterioration,[11] and the more indicators are present, the higher the patient's risk of deterioration.[12]

Two recent initiatives to improve early detection of deterioration incorporate some of the DENWIS indicators. The DULK-score, identifying patients with anastomotic leakage after abdominal surgery, includes clinical condition and abdominal pain, combined with laboratory results (pro-actively measured on specific days post-surgery) and respiratory rate.[63,64] The 'clinical condition' is something which nurses observe but which can be difficult to specify, leaving it to individual interpretation by doctors and nurses.

The Rothman-Index combines nursing documentation, vital signs, laboratory results, and cardiac rhythms to calculate a score which is shown as a graph and updated with all new available information. The Rothman-Index is seen to perform better than the Modified EWS.[65] The Rothman-Index has been developed using a specific electronic patient file which means it is not directly available to other systems. The strength of the Rothman-Index is its use of technology to combine available predictors of deterioration and update instantaneously when values change. However, nurses must write their documentation before the score can be calculated, which makes it less useful in acute situations.

Nurses are the professionals closest to the patient and working at the heart of the process of deterioration recognition and escalation of care, before diagnostic tests are ordered. DENWIS is a simple tool that structures assessment and judgement of a patient's condition. Our results show that patients benefit most when nurses' worry and DENWIS indicators are incorporated into patient assessment and combined with vital signs measurements. Moreover, nurses' worry and the presence of DENWIS indicators initiate vital signs measurement.[10] As such, they are of particular value during the time intervals between prescribed RRS vital signs measurements.

Technological developments in optimising identification of deteriorating ward patients

A consensus was reached by experts to routinely measure vital signs in order to detect

deterioration.[5] However, there is a lack of sound evidence of the effectiveness of routinely measuring vital signs to detect deterioration[66] and the necessary frequency.[67-75] There are claims that ongoing improvements in RRS escalation protocols ensure its effectiveness in identifying patients at risk, without increasing workloads for ward staff.[76] However, adherence to escalation protocols can be low,[67,77-79] and scores miscalculated,[80,81] which can cause delay in treatment and in failure to rescue. Respiratory rate is the least frequently obtained vital sign[68,73,75,82] and the most inaccurately measured.[83,84] After implementation of track and trigger systems, improvement in frequency and completeness of vital sign measurements is observed,[75,85,86] and new technological developments aim to further optimise measurement and registration of vital signs and the escalation process.

Modern technology offers opportunities to optimise the measurement and registration of vital signs and calculate the EWS in a prompt and accurate manner. Spot check monitors or continuous monitoring devices can be connected to electronic medical files, importing vital signs into patient files without delay or errors. Studies show improvements in mortality rates,[87-90] hospital length of stay,[90] frequency of cardiac arrest,[89,90] and number of patients admitted unexpectedly to the ICU with lower severity of illness[89] when EWSs are calculated automatically and automated alerts notify ward staff[91] or RRT[89] when vital signs reach threshold values that urge patient evaluation. Awareness of a patient's situation can be heightened by the display of vital signs next to the bed or in the nursing station, with different colour codes corresponding to the degree of deviation from normal physiology to emphasise the situation.[89,92] These developments have great potential, but also down sides. The number of alarms that require no action will have consequences for both nurses and patients. Nonactionable alarms will unnecessarily disturb patients, and can cause alarm fatigue and delayed nurse response.[92-94]

Continuous monitoring measures multiple parameters, or just respiratory rate and heart rate, wireless or otherwise.[92,95-99] Despite promising results, until 2014, there was a lack of evidence to recommend continuous monitoring for routine use on general wards to reduce adverse events.[95] Nurses value continuous monitoring and believe it will enhance patient safety,[41,95,96,99] which surely addresses the current omissions in vital sign monitoring described before. However, a possible reduction in contact moments with patients was reported as a disadvantage, as this would deprive nurses of the opportunity for visual assessment, which is considered essential for clinical judgement.[41] Moreover, we show that nurses are able to detect deterioration and act on it when vital signs are only marginally changed, or even not at all.[10-12,58] Dependency on technological developments might then

delay (nursing) interventions and, therefore, reduce opportunities for prevention of deterioration at an early stage, before changes in vital signs raise the alarm.

Patient assessment

We show that the assessment of vital signs alone is not always sufficient to detect deterioration in patients on surgical wards at an early stage.[11,12] Nurses' judgement, resulting in worry and the presence of one or more of the nine DENWIS indicators, is at least as important as vital sign deviation, as this triggers nurses to intervene at an early stage and to escalate care.[58] Failure to recognise deterioration is still reported,[55,56] but solely emphasising improvement of vital signs monitoring excludes other methods of assessing a patient.

Assessment models based on the primary survey method (airway, breathing, circulation, disability, and exposure method) have been promoted as a pro-active approach to patient assessment on general wards.[100,101] Although the primary survey method is evidence-based, it was originally developed to systematically assess patients at an advanced stage of deterioration, by assessing the most life-threatening problems first in order to treat first what kills first. On general wards, emphasis should be on preventing this stage of deterioration. At an early stage, patient deterioration does not necessarily present itself in the order of the primary survey method: it can well be agitation or increasing pain that first alerts nurses. The strength of the DENWIS lies in its presenting an overview of subtle signs that should alert and trigger nurses to intervene. Deterioration does not wait until it is time for a systematic assessment. It can present itself after an assessment is performed or at any other time, and this is the moment that nurses should (learn to) catch. Patients benefit most from nurses who are vigilant and observant throughout their shift, using their senses of sight, hearing, touch, and smell. Although we promote systematic assessment - preferably at the start of a shift to provide a baseline - systematic assessment alone is not sufficient.

Methodological considerations

Our studies are among the first published studies to incorporate nurses' systematic judgement of a patient's condition and of physiological signs, other than vital signs, over a prolonged period. We objectified worry and developed a practical tool to support nurses in daily practice to express their worry and make it explicit. However, the studies have several limitations which should be taken in consideration when interpreting the results.

First, there are limitations in the development of the DENWIS. The indicators are based on results from the systematic review including studies with mostly observational and qualitative designs. These designs are not considered strong in the hierarchy of evidence but given the exploratory or evaluating nature of the research involved, more rigorous study designs would

not have been appropriate. Furthermore, the set of indicators we present, might be incomplete. However, we are confident that the set was the most complete available, as during data collection nurses had the possibility of adding signs not incorporated into the DENWIS. There were no other signs mentioned, besides measurable parameters such as urine production, low blood glucose, and deviating vital signs. Another limitation is that we do not measure interrater reliability and validity of the DENWIS, as this is practically impossible due to more than 100 nurses participating in the study and worry occurring at unpredictable moments.

Second, there are limitations concerning data collection. Data were collected in a single centre and, for practical reasons, only on surgical wards. The results might not be generalisable and should be interpreted with these limitations in mind, as presentation of deterioration in medical patients might differ in surgical patients.[102] However, the indicators included in the DENWIS are based on both surgical and medical ward nurses' experiences, which makes them potentially useful for both patient groups. In our study, we cope with nonadherence to the escalation protocol, which is also described in other studies,[67,77-79] resulting in missing vital signs. Nevertheless, we see a larger number of completed sets of vital signs in the event group than in the control group. A last limitation of the data collection is that the vital signs measurements were not necessarily recorded at the same time as the DENWIS indicators. To ensure nurses' cooperation, we allowed their own judgement and discretion as to when to assess the DENWIS indicators. It is unknown whether nurses documented worry first, which prompted the collection of vital signs, or whether the order of events was reversed.

Third, we did not include organisational factors. Studies show that increasing workload and educational qualifications of nurses has an impact on the effectiveness of RRSs[103] and patient mortality.[104,105] However, we did not measure these variables, and these factors may have influenced the results.

Implications for future research

Our study was limited to a single centre and to surgical wards. To validate our results, the study should be repeated in other settings and with other patient populations. Our results are based on nurses' use of the DENWIS. However, like the level of nursing care, the level of medical care on general wards has also been reported to be a reason for delay in treatment or escalation of care to an RRT.[106-108] Future research is needed to establish if and how worry and DENWIS indicators support the performance of the RRS when it is also used in the escalation process by the responding team, or the responding ward physician in the two-tier system.

We show that nurses' worry and DENWIS indicators are present before vital signs deviate from normal levels. Continuous monitoring studies indicate that trends in deviation are present in the hours before deterioration.[94,96,97,99] Validation of our results using continuous monitoring could clarify if and how both systems support early recognition of deterioration. Our assumption is that the use of DENWIS empowers nurses to escalate care. We recommend that nurses act upon any changing indicator.

In line with our own results,[58] other research shows that nursing interventions are not necessarily present or of good quality when signs of deterioration are present.[109] Simple, basic nursing interventions may prevent patients from developing complications; for instance, supporting an immobile patient into an upright position for optimal breathing, providing instructions and repeated encouragement on optimal breathing. Further research should focus on which nursing interventions should be used.

Implications for education

Recent research reveals a lack of knowledge, skills, and behaviour adhering to monitoring and escalation processes.[110] Simulation training is a method used to prepare students and nurses for handling deterioration. Although knowledge improves, deficits in identification of deteriorating patients remain.[111-113] Incorporating the DENWIS into preferably interdisciplinary training, and educating (student) nurses to be observant when using the assessment tool, could not only close that gap, but also improve shared SA.

Implications for practice

We objectified nurses' worry providing a tool to support nurses in daily practice optimising detection and communication of deterioration, even at an early stage. The clear description of subtle signs of deterioration makes communication transparent and transferrable and will promote agreement in judgement of a patient's condition. Nurses should be aware of the significance of both their worry and the DENWIS indicators and their own role in acting upon them.

As nurses already spend almost half their time on administrative tasks,[114] we do not want to promote useless screening for every patient. However, with the complexity of today's patient population on general wards, screening DENWIS indicators at the start of a shift could provide a baseline from which nurses can judge further developments. A survey in our study shows that the DENWIS helped 75-80% of the participating nurses in clinical reasoning by providing a complete overview of the patient's condition.[115] Therefore, we recommend a full assessment of DENWIS indicators, vital signs used in the hospitals track and trigger system and relevant measures such as fluid balance and laboratory results when one or more

DENWIS indicators is present. Subsequently, nurses must decide whether or not to call for assistance.

In our study, we focus on nurses' roles in preventing patients' further deterioration. However, when treatment policies change to restriction of ICU/HDU-admittance or to palliative care, it remains important to detect deterioration in time. Nurses' worry and DENWIS indicators can enable nurses to make timely decisions that contribute to comfort, support, and advice for family and patients.

Final conclusion

The signs not incorporated into common RRS escalation protocols trigger nurses' worry about patients' conditions, even before vital signs have deviated from normal physiology. We developed the DENWIS assessment tool by summarising those trigger signs as nine indicators. Both worry and DENWIS are good predictors of deterioration and contribute to better identification of surgical patients at risk of unplanned ICU/HDU admission or unexpected mortality. Our results suggest that RRS escalation protocols would benefit from including worry and DENWIS. The promising results should be validated in other hospital settings and further research should establish the most effective use of worry and DENWIS in the RRS.

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Chapter 8

Summary

Summary

Early recognition and treatment of critically ill patients on general wards in acute care hospitals reduces the risk of cardiac arrest, unplanned Intensive Care (IC) admissions and mortality. A systematic approach to improvement was introduced with the implementation of Rapid Response Systems (RRSs). RRSs bring Intensive Care Unit (ICU) staff to general wards when a patient deteriorates, and are mostly called in, following a degree of deviation from normal values of vital signs. Nurses play a crucial role in recognition of deterioration, being the professionals who observe the patient most frequently and are therefore most likely to detect deterioration first. However, nurses not only recognise deterioration through deviating vital signs, they may also pick up on subtle signs in the early stages of deterioration which makes them worried about a patient's condition. With the emphasis of RRSs on deteriorating vital signs, it is difficult for nurses to communicate these subtle signs, which can result in delayed escalation of care.

The aim of this thesis is to explore nurses' worry and its role in the process of early recognition of deteriorating surgical ward patients, in order to empower nurses to call for assistance at an early stage **(Chapter 1)**.

Chapter 2 describes a systematic review of the literature on signs and symptoms underlying nurses' worry. We searched the databases PubMed, CINAHL, PsycINFO and Cochrane Library (Clinical Trials) using synonyms related to the three concepts: 'nurses', 'worry' and 'deterioration'. The search resulted in 4,006 references, and 18 studies were included in the review. As well as deviating vital signs or abnormal laboratory results, there are more subtle signs that trigger nurses' calls for assistance, even before vital signs are seen to deviate. We summarise these signs as the following indicators: change in breathing (noisy breathing and/or shortness of breath and/or unable to speak full sentences and/or use of accessory muscles); change in circulation (colour changes and/or clammy skin and/or coldness and/or impaired perfusion and/or oedema); rigors; change in mentation (lethargic and/or confused); agitation (restless and/or anxious); pain (increasing/persistent pain and/or new pain); unexpected trajectory (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 behaviour and/or does not look good and/or look in the eyes) and knowing without a rationale (knowing something is not right, gut feeling or intuition).

In the subsequent studies **(Chapters 3, 4, 5 and 6)**, we conside the indicator of 'knowing without a rationale' the overall indicator, equivalent to nurses' worry, with the other nine

indicators underlying and objectifying worry. This set of indicators is the Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) which was implemented in the electronic patient file of the study hospital. All nurses of three surgical wards (traumatology, vascular surgery and abdominal/oncological surgery) participated in the study and prospectively scored worry and DENWIS indicators for each patient on every shift for one year. Vital signs were measured according to the local RRS protocol with an aggregated Early Warning System (EWS) and trigger threshold of ≥ 7 to escalate care.

Chapter 3 explores the occurrence of nurses' worry, which DENWIS indicators are present at different levels of deterioration, and whether acting on worry with normal vital signs leads to appropriate actions. The electronic patient files were examined for data on calls for assistance and whether interventions were initiated. Whether calls and interventions at normal vital signs levels were appropriate was judged by intensivists not involved in the study. In total, nurses scored presence or absence of worry 46,571 times, vital signs were normal 18,727 times, with worry expressed 605 times (3.2%). This resulted in 62 calls (10.2%) to the attending physician, and more than half of these calls resulted in justified interventions. The number of calls for assistance - and subsequent medical interventions after worry is expressed - intensify in parallel with increasing EWS levels. This study shows that, at an early stage of deterioration, nurses can foresee and act appropriately upon patient deterioration when vital signs do not yet deviate from normal values. Worry has potential as an early indicator of deterioration, alerting nurses to begin timely interventions.

In **Chapter 4**, the value of worry and DENWIS indicators as predictors of the composite endpoint of unplanned ICU/High Dependency Unit (HDU) admission or unexpected mortality is determined and compared with the predictive value of the local EWS. We analyse the DENWIS indicators separately and combine them in a prediction model, along with all indicators in the model. In 3,522 patients there were 102 (2.9%) patients with unplanned ICU/HDU admissions or unexpected mortality. We show that each DENWIS indicator is significantly associated with the composite endpoint. Worry and the combined DENWIS indicators are good predictors of unplanned ICU/HDU admission or unexpected mortality. The area under the receiver operating characteristics curve (AUROC) was resp. 0.81 en 0.85. The EWS had an AUROC of 0.86. The best result - with excellent predictive power (AUROC 0.91)- was reached by combining the DENWIS and the EWS in the analysis. Changes in breathing, circulation, mentation, and subjective nurse observations add significantly to the prediction model. In this study, we show that worry and DENWIS indicators are good predictors of unplanned ICU/HDU admission or unexpected mortality and that they improve RRS calling criteria based on vital signs.

In **Chapter 5**, we analyse whether DENWIS indicators are predictive of unplanned ICU/HDU admission or unexpected mortality at an early stage of deterioration, when the EWS does not yet reach the trigger threshold to escalate care (EWS < 7). DENWIS indicators were appointed weighted scores based on the values in the prediction model in Chapter 4. This results in DENWIS indicator scores ranging from 1 until 7, with a possible maximum score of 28 when all indicators are present. Sensitivity, specificity, positive predicted value and negative predictive value for each possible total score of the weighted DENWIS model were calculated. With increasing DENWIS values, positive predictive value increases from 8.4% at DENWIS ≥ 1 up to 50% at DENWIS 25. Negative predictive value remains stable (resp. 98.8-97.2%). This study shows that the DENWIS assessment tool is of high predictive value at an early stage of deterioration when vital signs do not yet meet the trigger threshold to call an RRT.

In **Chapter 6**, we focus on unplanned ICU admission and again determine the predictive value of worry and DENWIS indicators in comparison with the EWS. We establish whether the additional screening of worry and DENWIS indicators contribute to ICU admittance of less severely ill patients (measured through the APACHE II score), and consequently in shorter ICU- and/or hospital length of stay. Data from the first and second half year of datacollection are compared. Of the 3,746 surgical patients, 97 patients were admitted to the ICU unplanned. Worry and DENWIS are good predictors of unplanned ICU admission with AUROCs of resp. 0.83 and 0.89 (EWS 0.87). The median APACHE II score decreased 1.5 points. The median ICU length of stay declined significantly, from 4 to 2 days, and hospital length of stay from 29 days to 22.5 days. We conclude that nurses worry and DENWIS indicators can identify patients at risk of unplanned ICU admission. Although non-significant, the decline in APACHE-II scores of surgical patients at ICU admission might be relevant. The decline in ICU and hospital length of stay suggests that nurses' worry and DENWIS indicators combined with vital signs measurement may improve outcomes.

In **Chapter 7**, we discuss the results. We show that nurses' worry can be objectified and is a good predictor of deterioration in surgical patients. A summary of the signs and symptoms that experienced nurses use in their decisions to escalate care, results in the nine DENWIS indicators. Worry and DENWIS contribute to improvements in early recognition of deterioration and treatment of surgical ward patients in two ways. First, worry is already present when vital signs do not deviate from normal values, or do so only marginally. Moreover, DENWIS indicators are already of a high predictive value at this early stage, thus, nursing interventions can be initiated at an early stage. Second, when vital signs reach the

trigger threshold to escalate care to the RRT, worry and DENWIS improve prediction of unplanned ICU/HDU admission and unexpected mortality.

The DENWIS could contribute to clear and transparent communication during nurses' shift handover, and doctors' rounds, or when calling for assistance. Track and trigger systems do not always incorporate nurses' worry into the escalation protocol, despite earlier studies showing the value of worry and of indicators also incorporated into the DENWIS. The structure of the DENWIS has the potential to not only empower new or student nurses, but also to benefit and encourage experienced nurses to make their quick and intuitive judgements explicit. Structured communication tools, such as the Situation Background Assessment Recommendation (SBAR), are highly recommended to make communication more effective. DENWIS can give the input for this structured communication, next to the EWS. However, to be successful, the importance of the DENWIS indicators must be acknowledged by doctors, to ensure a shared situational awareness (SA) and effective decision-making. When (technological) developments that concentrate on improving vital signs monitoring are implemented, it is recommended to include nurses' judgement and sound observation given the predictive value of worry and DENWIS indicators before vital signs change.

Chapter 9

Samenvatting (Dutch summary)

Samenvatting

Vroege herkenning en behandeling van vitaal bedreigde patiënten op verpleegafdelingen in ziekenhuizen is belangrijk om de kans op een hartstilstand, ongeplande Intensive Care (IC) opname of onverwacht overlijden te verminderen. Door implementatie van Spoed Interventie Systemen (SIS) wordt bij achteruitgang in de conditie van de patiënt op een systematisch wijze IC personeel ingezet ter ondersteuning van de behandeling op de verpleegafdeling. Het oproepen van het Spoed Interventie Team (SIT) gebeurt meestal op basis van achteruitgang in de vitale functies. Verpleegkundigen spelen in dit proces een belangrijke rol als professionals die het dichtst bij de patiënt staan. Verpleegkundigen herkennen verslechtering echter vaker door een niet pluis gevoel dan door routinematig meten van vitale functies. Al in een vroeg stadium kunnen subtiele veranderingen bij de patiënt reden zijn tot ongerustheid. Doordat dit vaak lastig onder woorden te brengen is en in het SIS de nadruk op afwijkende vitale functies ligt, kan het gevolg zijn dat in zo'n vroeg stadium een kans op vroege interventie gemist wordt. Het doel van dit proefschrift is de rol van het verpleegkundig niet pluis gevoel te onderzoeken binnen het proces van vroege herkenning van verslechtering bij chirurgische patiënten.

In **Hoofdstuk 1** gaan we in op de achtergronden van het SIS met daarin de rol van verpleegkundigen, het niet pluis gevoel en klinische beoordeling en besluitvorming van verpleegkundigen. Vervolgens worden de doelen beschreven en een overzicht gegeven van de onderzoeksdesign van de verschillende studies.

In **Hoofdstuk 2** beschrijven we de systematische literatuurstudie naar signalen en symptomen die ten grondslag liggen aan het niet pluis gevoel van verpleegkundigen. De databases PubMed, CINAHL, PsycINFO and Cochrane Library (Clinical Trials) werden doorzocht met zoektermen gerelateerd aan 'verpleegkundigen','niet pluis gevoel' en 'verslechtering'. Van de 4,006 gevonden publicaties voldeden 18 studies aan de selectiecriteria. We vonden 37 verschillende signalen en symptomen. Naast afwijkende vitale functies of laboratoriumuitslagen waren er andere subtiele signalen, ook bij niet (sterk) afwijkende vitale functies. Deze signalen hebben we samengevat in de volgende indicatoren: verandering in ademhaling (hoorbare ademhaling, kortademigheid, niet in volzinnen kunnen praten, gebruik van hulp ademhalingsspieren), verandering in circulatie (kleur bleek/grauw, transpireren/klam, koud aanvoelen, verminderde doorbloeding, oedemen), temperatuur (rillingen), mentale verandering (apathie/slaperig, verward), agitatie (rusteloos, angstig), pijn (nieuwe pijn, aanhoudende pijn), een niet verwacht traject (geen vooruitgang, opgezette buik/misselijk/braken, bloeding, duizelig, (flauw) vallen), de patiënt geeft aan (zich niet goed te voelen, gevoel van naderend onheil te hebben), de subjectieve

observatie van een verpleegkundige (verandering in gedrag, ziet er niet goed uit, blik in de ogen) en weten zonder het te beredeneren (weten dat iets niet goed is, onderbuikgevoel/ intuïtie).

In de volgende hoofdstukken **(Hoofdstukken 3, 4, 5 en 6)** beschouwen we de indicator, weten zonder te beredeneren, als de overkoepelende indicator en gelijkwaardig aan het niet pluis gevoel. De overige negen indicatoren zijn daaraan onderliggend en objectiveren het niet pluis gevoel. Deze set van indicatoren werd de Dutch-Early-Nurse-Worry-Indicator-Score (DENWIS) genoemd. De DENWIS werd geïmplementeerd in het elektronisch patiëntendossier van het ziekenhuis waar de dataverzameling plaatsvond. Verpleegkundigen van drie chirurgische afdelingen (traumatologie, vaatchirurgie en buik-oncologische chirurgie) participeerden in de studie. Zij scoorden gedurende een jaar prospectief bij elke patiënt en in elke dienst of zij een niet pluis gevoel hadden en welke van de onderliggende signalen daarbij aanwezig waren. Het lokale SIS-protocol werd gevolgd betreffende de frequentie van meten van vitale functies en het oproepen van het SIT (bij een Early Warning Score (EWS) van ≥7).

In **Hoofdstuk 3** onderzoeken we hoe vaak het niet pluis gevoel voorkomt bij verschillende niveaus van verslechtering en welke DENWIS indicatoren daarbij aanwezig zijn. Bovendien onderzoeken we of dit bij normale vitale functies tot adequate acties leidde. Retrospectief dossieronderzoek leverde gegevens over oproepen van de arts en of daarna interventies werden afgesproken. Onafhankelijke intensivisten, die niet bij het onderzoek betrokken waren, beoordeelden deze gegevens. Verpleegkundigen scoorden in totaal 46,571 keer of zij wel of niet een niet pluis gevoel hadden. Bij 18,727 scores waarbij de vitale functies normaal waren werd 605 keer (3,2%) het niet pluis gevoel positief gescoord. Dit resulteerde in 62 oproepen (10,2%) van de arts en bij meer dan de helft van deze oproepen werden adequate interventies afgesproken. Parallel aan een stijging in de EWS neemt de frequentie van het aantal oproepen en medische interventies na een niet pluis gevoel toe. Deze studie laat zien dat het niet pluis gevoel van verpleegkundigen een potentieel vroege indicator van verslechtering is waarop adequate actie ondernomen wordt, nog voordat vitale functies verslechteren.

In **Hoofdstuk 4** wordt de waarde van het niet pluis gevoel en DENWIS indicatoren als voorspellers van verslechtering vergeleken met de voorspellende waarde van de lokale EWS. Verslechtering werd geoperationaliseerd als samengestelde uitkomstmaat: ongeplande opname op een bewakingsafdeling (IC, Medium Care of hartbewaking) of onverwacht overlijden. De DENWIS indicatoren werden individueel en gezamenlijk met alle indicatoren in het predictiemodel geanalyseerd. Van de 3,522 patiënten werden 102 (2.9%)

patiënten ongepland op een bewakingsafdeling opgenomen of overleden onverwacht. Voor elke individuele DENWIS indicator werd een significant verband met verslechtering aangetoond. Het niet pluis gevoel en de gezamenlijke DENWIS indicatoren als predictiemodel, bleken goede voorspellers van ongeplande opname op een bewakingsafdeling of onverwacht overlijden. De area under the receiver operating characteristics curve (AUROC) was resp. 0.81 en 0.85. De EWS had een AUROC van 0.86. De combinatie van de EWS samen met de DENWIS gaf het beste resultaat, AUROC 0.91. Verandering van ademhaling, circulatie, mentale verandering en de subjectieve observatie van de verpleegkundige droegen significant bij aan het predictiemodel. Deze studie laat zien dat het niet pluis gevoel en DENWIS indicatoren goede voorspellers zijn van verslechtering en dat zij de SIS-oproepcriteria gebaseerd op afwijkende vitale functies, verbeteren.

In **Hoofdstuk 5** onderzoeken we of DENWIS indicatoren voorspellend zijn voor ongeplande opname op een bewakingsafdeling of onverwacht overlijden in een vroeg stadium van verslechtering wanneer de EWS nog niet de waarde heeft bereikt om het SIT te bellen (EWS < 7). Aan de DENWIS indicatoren werd een gewogen waarde gegeven, gebaseerd op de hoogte van de regressie coëfficiënten in het predictiemodel uit Hoofdstuk 4. Dat resulteerde in DENWIS scores van 1 tot en met 7, met een totale score van 28 bij aanwezigheid van alle indicatoren. Van het gewogen DENWIS model en bij een EWS < 7, werd bij verschillende DENWIS afkapwaardes de sensitiviteit, specificiteit, positief en negatief voorspellende waarde bepaald. Met stijgende DENWIS waardes steeg de positief voorspellende waarde van 8.4% bij afkapwaarde DENWIS ≥ 1 naar 50% bij DENWIS 25. De negatief voorspellende waarde bleef vrijwel gelijk (resp. van 98.8 naar 97.2%). In deze studie tonen we aan dat de DENWIS een hoge voorspellende waarde heeft in het stadium dat de EWS nog geen aanleiding geeft het SIT te bellen.

In **Hoofdstuk 6** ligt de focus op alleen ongeplande IC opname van chirurgische patiënten als uitkomstmaat. We bepalen we nogmaals de voorspellende waarde van het niet pluis gevoel en DENWIS indicatoren. Daarnaast onderzoeken we of aanvullend screenen van het niet pluis gevoel en DENWIS indicatoren bijdraagt aan IC opnames van minder zieke patiënten (gemeten door middel van de APACHE II score) en daaruit voortvloeiend kortere IC- en/of ziekenhuisligduur. Hiervoor werden de data uit de 1ste en 2de helft van de dataset met elkaar te vergeleken. Van de 3,746 chirurgische patiënten werden 97 onverwacht op de IC opgenomen. Het niet pluis gevoel en de DENWIS indicatoren waren goede voorspellers van onverwachte IC opname (resp. AUROC 0.83 en 0.89), de EWS had een AUROC van 0.87. We zagen een niet significante daling van 1,5 punt in de mediaan van de APACHE II score. De mediaan van de IC ligduur daalde significant van 4 naar 2 dagen en de mediaan

van ziekenhuis ligduur daalde van 29 naar 22.5 dagen. We concludeerden dat het verpleegkundig niet pluis gevoel en de aanwezigheid van DENWIS indicatoren bijdraagt aan identificatie van patiënten met risico op IC opname. De daling in APACHE II scores bij chirurgische patiënten was niet significant maar mogelijk wel klinisch relevant. De daling in IC- en ziekenhuis ligduur suggereert dat screenen van het niet pluis gevoel en de aanwezigheid van DENWIS indicatoren, aanvullend op het meten van vitale functies, mogelijk uitkomsten voor patiënten verbeterde.

In **Hoofdstuk 7** bediscussiëren we de resultaten. Het niet pluis gevoel kan geobjectiveerd worden en bleek een goede voorspeller van verslechtering bij chirurgische patiënten. De signalen en symptomen die ervaren verpleegkundigen gebruiken in hun besluitvorming om de arts te bellen, werden samengevat en resulteerden in negen DENWIS indicatoren. Het niet pluis gevoel en DENWIS indicatoren dragen op twee manieren bij aan verbetering van vroege herkenning van verslechtering en vroege behandeling van bij chirurgische patiënten. Ten eerste, het niet pluis gevoel kan al aanwezig zijn als vitale functies nog niet of slechts weinig afwijken van normale waardes. Bovendien hebben DENWIS indicatoren al een voorspellende waarde in dit vroege stadium. Dit betekent dat verpleegkundigen al in een vroeg stadium interventies kunnen starten. Ten tweede, als de vitale functies de grens bereiken waarop het SIT ingeschakeld kan worden, verbeteren het niet pluis gevoel en de DENWIS de voorspelling op ongeplande opname op een bewakingsafdeling of onverwacht overlijden. Toch wordt, ondanks eerdere studies die de waarde aantonen van het niet pluis gevoel en indicatoren die ook in de DENWIS opgenomen zijn, het niet pluis gevoel of ongerustheid van verpleegkundigen niet altijd meegenomen in SIS-protocollen. Onze studies laten zien dat hiermee een kans op vroege escalatie en behandeling gemist kan worden.

Het gebruik van de DENWIS bij de beoordeling van een patiënt kan bijdragen aan duidelijke en transparante communicatie tijdens de overdracht, het visite lopen of bij het oproepen van een arts. De structuur die de DENWIS biedt, heeft potentie om niet alleen voor studenten of beginnende verpleegkundigen empowerment te vergroten, ook ervaren verpleegkundigen kunnen er hun voordeel mee doen en aangespoord worden snelle intuïtieve besluitvorming expliciet te maken. Voor effectieve communicatie worden gestructureerde communicatie tools, zoals de Situation Background Assessment Recommendation (SBAR), ten zeerste aanbevolen. De DENWIS kan hierin input geven aanvullend op de EWS. Om succesvol te zijn moet het belang van de DENWIS ook door artsen erkend worden om bij te kunnen dragen aan een gedeelde Situational Awareness en effectieve besluitvorming. Bij implementatie van (technologische) ontwikkelingen die zich concentreren op het (continu)

meten van vitale functies zal de verpleegkundige beoordeling en gedegen observatie van de patiënt moeten worden meegenomen, zeker gezien de voorspellende waarde van het niet pluis gevoel en de DENWIS indicatoren in een vroeg stadium voordat vitale functies verslechteren.

List of abbreviations

APACHE	Acute physiology and chronic health evaluation
AUROC	Area under the receiver operating characteristics curve
CA	Cardiac arrest
CART	Cardiac arrest triage
CCI	Charlson Comorbidity Index
CCU	Cardiac Care Unit
CI	Confidence Interval
CVVH	Continuous Veno-Venous Hemofiltration
DENWIS	Dutch-Early-Nurse-Worry-Indicator-Score
DNR	Do Not Resuscitate
EWS	Early warning score
GI	Gastro Intestinal
HDU	High Dependency Unit
ICU	Intensive Care Unit
IQR	Inter Quartile Range
LOS	Length of stay
MCU	Medium Care Unit
MET	Medical emergency team
NPV	Negative predictive value
NEWS	National Early Warning Score
OR	Odds ratios
PPV	Positive predictive value
RRS	Rapid Response System
RRT	Rapid Response Team
SA	Situation Awareness
SBAR	Situation, Background, Assessment, Recommendation
SD	Standard deviation
SOFA	Sepsis-related Organ Failure Assessment
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
US	United States of America
UK	United Kingdom

AvZ	Arthur van Zanten
BF	Bernard Fikkers
DB	Dominique Bonthuis
DT	Dave Tjan
GD	Gooske Douw
LS	Lisette Schoonhoven
TvA	Theo van Achterberg
TH	Tineke Holwerda

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koppelen. Wat een ingewikkelde klus, de syntax ‘Janine’ bewaar ik veilig. Statistici Ton de Haan en Rogier Donders, vooral ook voor jullie eindeloze geduld bij de zoektocht naar een terecht niet pluis gevoel. Bernard Fikkers, fantastisch dat je het dossieronderzoek wilde doen voor hoofdstuk drie. Dank voor je enthousiasme en je kritische noten, ik kijk met veel plezier terug op onze ontmoetingen tot in Australië toe. Annick Bakker-Jacobsen en Jenny Wegh, het lukte toch steeds weer een datum te plannen voor overleg met de begeleidingscommissie. Medewerkers van IQ-healthcare en PhD kandidaten, dank voor jullie constructieve feedback en inhoudelijke discussies tijdens PhD-bijeenkomsten. Friede, er waren veel paralellen in onze levens, ik heb veel gehad aan onze gesprekken. Je ezelsbruggetje ‘snot en sport’ is hilarisch; *se**n**sitiviteit-**sn**ot*, zegt iets over ziekte, *sp**e**cificiteit-**sp**ort*, zegt iets over gezond. Ik vergeet het nooit meer.

Dank ZGV-medewerkers. Dave Tjan, voor de uitnodiging om in 2015 op het Rapid Response Systems congres in Amsterdam de eerste resultaten van het onderzoek te presenteren. Dat leidde tot uitnodigingen in Melbourne (2016) en Chicago (2017) en heeft bijgedragen aan een optimale verspreiding van de resultaten op internationaal niveau. Bovendien deed je dossieronderzoek voor hoofdstuk 3. Dominique Bonthuis, dank voor je bereidheid om als 3de intensivist de casussen te beoordelen daar waar de beoordelingen van Bernard en Dave verschilden. Dik Blokland dank voor je super snelle aanlevering van de IC-data en Jort van Woggelum voor je hulp bij het verwerken van data en berekeningen in Excel waar ik niet veel kaas van had gegeten. Caroline Roozenboom en Karin de Lange dank voor jullie professionele bijstand en geestelijke ondersteuning. Het was steeds weer een genoegen met jullie op te trekken, als ik facebook had, zou ik gelijk vrienden met de bieb worden. Wout van Orten, het voelt een beetje als partners in crime, ‘even’ een artikel submitten…. ahh, even bestaat niet. Wat fijn om met jou de ins en outs te delen van promotieonderzoek doen, ik hoop dat ik snel bij jouw promotie aanwezig mag zijn. Harm, je gaf me bij de start van de dataverzameling een enorme drive om door te gaan. Je testte voor mij de niet pluis lijst en deed dat nadat je rapportage schreef. Je merkte op dat je dat de volgende dag voor de rapportage ging doen omdat het structuur gaf. Mooi dat we nu af en toe kamergenoten zijn, zowel in Ede als in Nijmegen en dat we over onderzoek en kwaliteit van verpleegkundige zorg kunnen sparren. Succes, ‘van Noort *et al.’* smaakt naar meer. Ik kom graag bij jouw verdediging. Go for it!

Ook buiten het ziekenhuis waren er mensen die een bijdrage leverden. Peter Klompmaker, bedankt voor het opschonen van de data; bloeddruk 1000, saturatie 38.3, ademfrequentie 99… gelukkig zitten die data niet in de dataset. Herman Eijsackers, als buitenstaander, maar wel als wetenschapper heb je diverse keren geholpen met artikelen en die eerste belangrijke

internationale presentatie. Verre vriend Bob in de US, jouw US English werd weliswaar soms weer door Lisette veranderd in UK English, maar je hebt me enorm geholpen door mee te kijken naar abstracts of zelfs hele artikelen. Patrick Staal bedankt voor je ontwerpen, voor presentaties maar zeker ook van de cover van dit proefschrift.

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van de vitale functies keek en concludeerde dat het goed ging, keek ik naar je, Tan. Wij zagen dat het niet goed ging. Dat beeld heb ik me vaak voor ogen gehaald op momenten dat het met het onderzoek even tegen zat. Hans, vader van mijn kinderen, je bracht de wetenschap in mijn leven toen er in het ziekenhuis nog geen evidence-based practice bestond. Wat heb ik me altijd verwonderd over de verschillen tussen die twee werelden. Zonder jou was mijn belangstelling voor wetenschap misschien niet op deze manier uitgepakt. Lieve kids, Frank en Goosje, dank voor jullie geduld en bijdrage. Frank, toen ik na de premaster nog het verplichte wiskunde-A certificaat moest halen, hebben jouw nuchtere opmerkingen (dat moet je niet willen snappen, dat is gewoon zo) en geduldige duidelijke uitleg me door de paar weken blokken, heen gesleept. Zonder dat geen master, zonder master geen promotieonderzoek. En Goos, doortastende dochter van me, dank voor je sprankelende aanwezigheid die me enorm veel energie gaf en geeft. Je hulp bij de lay-out niet alleen van dit proefschrift maar ook bij presentaties en artikelen heb ik enorm gewaardeerd. En met Menno samen dank voor die schitterende kleinkinderen die een onuitputtelijke bron van energie, blijdschap en inspiratie zijn. Sarah (4) en Tim (3) jullie ontdekken nu de wereld en de toekomst is aan jullie. Jullie vrolijke, blije, lachende snuitjes zijn een verademing en jullie onbevangen nieuwsgierigheid zou het goed doen in de wetenschap.

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Curriculum vitae

Gooske Douw was born in Zierikzee, the Netherlands, on June 28, 1951. After graduating from secondary school in 1967 she began a combined study and work program in a bacteriological laboratory as a medical analyst providing diagnostic tests for hospitals in the province of Zeeland. After a break from paid work while living in the United States for more than a year, she started her (in-service) nursing education in 1977 in the Pieter Pauw Hospital in Wageningen.

After graduation in 1980 until 2012 Gooske worked as a nurse on surgical wards. The first 12 years on a general surgical ward in Wageningen and after the merger of four regional hospitals into a single organization (Hospital Gelderse Vallei) on a gastro-intestinal and oncological surgery ward, first in Bennekom and later in Ede.

Throughout her carrier Gooske was involved in various quality improvement projects at ward level such as coordinating and writing protocols for the gastro-intestinal and oncological surgical ward patients. As an employee member of the business council of the hospital (1982-1991) Gooske was involved in the merger of the four regional hospitals into one organization. From 1992-1994 Gooske mentored nurses on several wards of the hospital to support a change in approach to patient care from team- or task oriented, to a patient-centered system. From 2006-2009, as an auditor and from 2009-2017 as a member of the root cause analysis team, she contributed to awareness and improvement of patient safety strategies on the wards. As a member of the Nurse Advisory Board (2009-2017) she provided input in the nursing profession policy and the empowerment of nurses at the Gelderse Vallei Hospital.

Gooske began work on her master's degree in Nursing Science at Utrecht University in 2006 and graduated in 2009. In the same year she became involved in a study of wireless monitoring of vital signs to detect deterioration of surgical ward patients at an early stage. Inspired by this study she started a PhD project resulting in this thesis at the Scientific Centre for Quality of Healthcare (IQ healthcare) of the Radboud university medical centre, in 2010.

Prior to retirement, Gooske contributed to improvement projects as an academic nurse at the Gelderse Vallei Hospital, transitioning from work as a bedside nurse. After official retirement in December 2016, she continues to fulfil a position as nurse researcher on the necrology committee of Hospital Gelderse Vallei.