Safer and more efficient vital signs monitoring to identify the deteriorating patient: An observational study towards deriving evidence-based protocols for patient surveillance on the general hospital ward

Keywords

Patient deterioration; early warning scores; National Early Warning Score (NEWS); nursing workforce; observation frequency; patient monitoring

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Declaration of interests

All authors received grant support from the National Institute for Health Research (NIHR) for the conduct of this study, remuneration for employment from their employing institution and may be in receipt of other funding for non-commercial independent research outside the current work.

Briggs was provided with free accommodation and travel expenses by Wilmington Healthcare Ltd for speaking at the Patient Safety Congress. He is a member of a NIHR Artificial Intelligence in Health and Care Award panel.

Redfern's university position has been supported by a Drayson (now Sensyne Health) Research Fellowship and is a member of the study oversight group for a University of Southampton study funded by NIHR.

Watkinson holds shares in Sensyne Health and it has supported his work. He holds or is applying for various patents in the area. He has been a member of a number of NIHR groups or panels.

Important

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A final version (which has undergone a rigorous copy-edit and proofreading) will publish as part of a fuller account of the research in a forthcoming issue of the Health and Social Care Delivery Research journal.

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The research reported in this 'first look' scientific summary was funded by the HSDR programme as project number 17/05/03. For more information visit https://fundingawards.nihr.ac.uk/award/17/05/03

The authors have been wholly responsible for all data collection, analysis and interpretation, and for writing up their work. The HSDR editors have tried to ensure the accuracy of the authors' work and would like to thank the reviewers for their constructive comments however; they do not accept liability for damages or losses arising from material published in this scientific summary.

This 'first look' scientific summary presents independent research funded by the National Institute for Health Research (NIHR). The views and opinions expressed by authors in this publication are those of the authors and do not necessarily reflect those of the NHS, the NIHR, NETSCC, the HSDR Programme or the Department of Health and Social Care. If there are verbatim quotations included in this publication the views and opinions expressed by the interviewees are those of the interviewees and do not necessarily reflect those of the authors, those of the NHS, the NIHR, NETSCC, the HSDR Programme or the Department of Health and Social Care.

Scientific summary

Background

The frequency that patients in hospital should have their vital signs (e.g. blood pressure, pulse, oxygen saturations) measured is currently unknown. Current monitoring protocols (from NHS England) are based on expert opinion supported by little empirical evidence. The challenge is to find the balance between insufficient monitoring of patients (which risks missing early signs of deterioration and delays in treatment) and over-observation of stable patients (which wastes resources needed in other aspects of patient care).

Guidance suggests monitoring frequency should be determined by a patient's severity of illness - often measured using risk scores. One such score is the National Early Warning Score (NEWS), which provides a simple integer value showing how much a patient's vital signs are outside normal ranges. A high NEWS score means the patient is at high risk of deterioration, prompting a range of responses from increasing observations to review by a doctor and changes to treatment. While there is evidence that NEWS can predict patient risk of adverse outcomes (such as death or transfer to ICU), there is no evidence to suggest the appropriate monitoring frequency based on that risk.

With so much discussion about pressures on NHS resources, especially workforce issues, this is an important topic.

Objectives

This study aimed to fill the evidence gap and guide development of future monitoring protocols taking into account the risk of deterioration and the impact on nursing workload and associated cost.

We addressed the following research questions:

- What is the current practice for recording a patient's vital signs? Who typically takes vital sign observations? How long does it take to record a set of vital signs required to calculate a NEWS score? And how do nursing staff fit observation in alongside other clinical work?
- Can we predict a patient's risk of deterioration over time based on their NEWS score? Can we use these risk predictions to identify acceptable monitoring frequencies for each NEWS value?
- Can we estimate the economic impact and cost-effectiveness of new monitoring protocols to identify whether these are feasible for use in practice?

Methods

Our study consisted of two parts: (a) an observational study of nursing staff to ascertain the time it takes to perform vital sign observations; and (b) a retrospective study of historic data on patient admissions to explore the relationships between NEWS and risk of outcome over time. These were underpinned by opinions and experiences from stakeholders.

Observational study

We observed nursing staff on 16 randomly selected adult general wards at four acute general NHS hospitals. All wards included in this study used NEWS2, the 2017 update to NEWS. Three hospitals used electronic systems to record vital signs and automate NEWS2 calculation. In one hospital, vital signs were recorded on paper charts at the patient's bedside and the NEWS2 was calculated manually. We observed each ward for a total of eight hours, spread across four sessions, with a total of 715 sets of vital sign measurements observed.

Data were collected in real-time by non-participating observers using bespoke software on a tablet computer. They also collected contextual data, including the total number of patients on the ward, numbers of registered nurses, healthcare assistants and student nurses on shift during the observation session. Further, they recorded factors influencing the measurement and recording of vital signs, including reasons for, and the nature of, interruptions. After each observation session, data were uploaded onto a server managed by the raters' institution. We did not store any personal data.

We quantified the time it took to record a set of vital signs using three different estimates: (i) length of the round per number of vital signs observation sets, (ii) time at the patient's bedside, and (iii) variants of (i) and (ii) removing interruptions. We used an iterative approach and thematic coding to group the different activities that delayed or interrupted vital sign observations.

Retrospective study

We extracted, linked and analysed routinely collected data from two large NHS trusts providing acute care: Portsmouth Hospitals University NHS Trust (PHU) and Oxford University Hospitals NHS Foundation Trust (OUH). Datasets included information on:

- patient demographics
- vital sign observations
- admission specific data including admission specialty, whether the patient died, had a cardiac arrest or was transferred to ICU
- information on treatment such as visit to operating theatre, receiving blood transfusions or chemotherapy

Data were extracted by each trust's data team and pseudonymised prior to transfer to the research team. Patient records were filtered to remove people who had registered with the NHS national opt-out.

In both hospitals, vital signs were monitored electronically. At PHU, NEWS was automatically calculated at the bedside, while OUH used a different score and NEWS values were calculated retrospectively. Monitoring protocols also varied across the different sites.

For analysis and modelling, three study cohorts were created:

1. Development dataset: admissions to PHU 1st January 2014 - 30th June 2017
2. Internal validation dataset: admissions to PHU 1st July 2017 - 30th June 2019
3. External validation dataset: admissions to OUH 1st July 2017 - 30th June 2019

We excluded data from vital sign observation outside recorded admission and discharge periods, incomplete vital sign sets, surgical day admissions and admissions to maternity or paediatric specialties.

We analysed patient sub-groups separately to identify whether these patients had different monitoring requirements: admissions to medical, surgical and 'elderly medicine' specialties, admissions with and without visit to operating theatre, elective admissions, emergency admissions, admissions with and without an observation in the last 24h, patients aged 80 or older, patients aged 30 or younger.

We considered the following adverse events as outcomes:

- DEATH: in-hospital death
- COMB: combined outcome of either in-hospital death or cardiac arrest or unexpected admission to a high-care ward, whichever comes first

- NEWS7: any of the events included in COMB or a NEWS value greater than 6
- NEWSINC: combined outcome or NEWS >6 or a NEWS increase of 2 or more

For each dataset and patient sub-group, we summarised patient demographics, admission characteristics, observation frequency, average NEWS values and outcomes.

We further investigated changes in NEWS over the course of a hospital admission, by tracking the mean NEWS in the days following admission and the days leading up to an event.

Using the development dataset, we created survival models to predict the risk of each outcome at 15-minute intervals over a 24-hour period based on NEWS from the time of observation. We randomly sampled each dataset 2000 times to avoid bias towards admissions that had more vital sign observations, and then calculated average predicted risk. The model was validated internally (including patient sub-groups) and externally by assessing model calibration and discrimination.

Monitoring protocols were created by setting a consistent risk threshold before which the next observation should be taken, based on predicted risk for a given NEWS value. In generating alternative monitoring schedules, we considered relative workloads and the proportion of observations that will be missed.

We explored the effect of three alternative monitoring regimes on risk thresholds, nursing workload and associated cost. Possible observation intervals were limited to integer hour values (1h, 2h, 4h, 6h, 8h, 12h).

Combining the expected number of observations and the average time taken to complete each, we calculated the nursing time required and the nursing cost per patient day under each alternative protocol. Staffing costs were estimated by applying representative unit costs for registered nurses and healthcare assistants, weighted to reflect the proportion of vital signs observations undertaken by each, based on observational study data.

Stakeholder involvement and engagement

We organised stakeholder events to identify factors relevant to the selection of an optimal monitoring protocol. Stakeholders included patients and their carers, and healthcare staff who were either responsible for taking vital signs, escalating patients for more senior clinical review, or introducing monitoring systems into one or more institutions. Their experiences of current practices influenced decisions made in the retrospective study, particularly when considering the practicalities of alternative observation frequencies.

Results

Observational study

Across the four hospitals we studied, we found a variety of practices, with two hospitals having registered nurses take the majority of vital sign observations, while the other two hospitals favoured healthcare assistants or student nurses. However, whoever took the observations spent roughly the same length of time. The average of 5:01 minutes per observation over a "round" included the preparation time associated with locating and preparing the equipment and travelling to the patient area. An average of 3:45 was spent at each patient bedside (excluding interruptions not related to the vital sign taking), rising to 4:24 at the bedside with all interruptions included.

Interruptions included jobs needing to be done at a set time of day, jobs convenient to do at the same time as vital sign observations, communication with other health professionals, emergencies, work prompted by the proximity to the patient, and absence or unavailability of patient.

Other clinical work seemed to take priority during core time (9am-5pm) but staff made up for this by scheduling the main rounds of observations around the main shift change times (early morning and early evening) when there were fewer competing tasks. Any future protocol reducing the frequency of observations might support timely recording during core times, though they would probably still be prioritised below fixed-time activities.

Any change to existing protocols might have knock-on effects on proximity-related care. For example, reducing the frequency of observations would reduce the opportunities for the patient to ask a question or benefit from other interaction with the nurse. Correspondingly, increasing the frequency could improve the quality of care provided. Our stakeholders proposed that "social interaction" could be separated from vital sign observations, with a short "check-in" approach adopted for lower-risk patients.

In conclusion, while individual components of observation work are quite small, when aggregated over many patients and multiple observations per patient per day, they add up to a substantial amount of daily nursing workload that has to be integrated, prioritised and resourced.

Retrospective study

Our analysis included data from over 400,000 patient admissions and 9,000,000 vital sign observations. Differences in the distribution of NEWS values suggested there was a difference in case-mix between the two hospital trusts in the study. While patient demographics were broadly comparable, length of stay (LOS) and mortality rates were higher at PHU (mortality 3.9%) than at OUH (2.6%). Rates for outcomes NEWS7 and NEWSINC were more consistent across the two sites.

Elective patients, admissions without an observation in the last 24h and patients receiving blood transfusions or chemotherapy were identified as patient sub-groups where outcomes and/or monitoring frequency were different to others.

Daily patterns of observations showed peak activity at four different times: 0600, 1100, 1600 and 2000, with more distinct peaks at OUH than PHU. This is consistent with findings from the observational study that showed staff batch observations to avoid meal times and fit observations in with other regular activities.

As expected, average NEWS values increased in the days prior to adverse outcome, with trends of deterioration starting up to 9 days prior to the event. Patients with the worst outcomes (death, unanticipated ICU admission) averaged the highest NEWS scores and had the earliest increases. Patients who were discharged without an adverse outcome had higher initial average NEWS values compared to those with outcomes NEWS7 or NEWSINC, but showed a steady reduction in the last 5 days prior to discharge. Consistent with previous studies, breathing rate and oxygen saturation were identified as the vital signs most predictive of deterioration.

We created survival models that predicted the risk of outcomes over time since the patient was last observed. For low-risk patients, there was not much difference in risk between 4h and 24h post observation. Model validation showed acceptable performance in both PHU and OUH validation cohorts. The tendency of the model to overestimate risk of outcome in the OUH cohort can be explained by lower observed outcome rates. These results suggest that a single monitoring protocol might be appropriate for the general adult hospital population, offering significant operational advantages.

We explored a number of different scenarios with our stakeholders, based on how "risk" could be managed in different ways. Vital sign observations are often done more frequently than necessary from a bald assessment of the patient's risk. A changed protocol could redeploy existing resources to achieve better outcomes for some patients without compromising the safety of the rest. However,

reducing the risk to some patients (by observing them more frequently) is offset by a theoretical increase in risk to others (by observing them less frequently). We cannot be certain that the net effect is positive (though it is likely). Stakeholders felt an increased risk for patients at low-risk was acceptable to reduce the risk for high-risk patients.

As an observational study, our analysis could not evaluate the *actual* impact of new monitoring protocols on outcomes. Nevertheless, our approach did assess protocol cost-effectiveness, allowing us to rule out any protocols that would require unfeasible changes in outcomes or costs and so help identify plausible candidate protocols whose performance could be assessed in clinical trials. For example, theoretically a 61% reduction in nursing resource could be achieved without raising any patient's risk above the current maximum. . A 34% saving could be achieved while halving the maximum risk, but both scenarios *increase* the risk for all low-risk patients (the majority). A 65% increase in resource would reduce the patient risk threshold by a factor of 10.

Conclusions

We developed a framework using clinical data to propose new observation protocols and a way of evaluating them both clinically (in terms of patient outcome) and economically (possible cost effectiveness).

Our work supports the approach of the current monitoring protocol, whereby patients' NEWS2 score guides observation frequency. Existing practice is to observe higher-risk patients more frequently and our findings have shown that this is objectively justified. It is worth noting that important nurse-patient interactions take place during vital sign monitoring and should not be eliminated under new monitoring processes.

Our study contributes to the existing evidence on scheduling vital sign observations, but our retrospective design did not allow us to take into account all factors impacting monitoring frequency. Ultimately, it is for relevant professionals to collectively decide how our work should be used: nationally this could be the RCP reviewing NEWS; locally, it could be clinicians/ managers determining local practice.

This project was funded by the National Institute for Health Research (NIHR) HS&DR programme and will be published in full in XXX Journal; Vol. XX, No. XX. The project is registered as ISRCTN10863045.