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An intervention including the national early warning score improves patient monitoring practice and reduces mortality : a cluster randomised controlled trial

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1 AN INTERVENTION INCLUDING THE NATIONAL EARLY WARNING SCORE
2 IMPROVES PATIENT MONITORING PRACTICE AND REDUCES MORTALITY: A
3 CLUSTER RANDOMISED CONTROLLED TRIAL.
4

ABSTRACT

Aims

To investigate the impact of the national early warning score on the frequency and the quality of vital sign registration and to study the association between protocol compliance and patient mortality.

Design

We conducted a post-hoc data analysis of a stepped wedge cluster randomised controlled trial in six hospitals.

Methods

All adult, non-pregnant patients admitted to 24 wards were included. The intervention comprised an observation protocol using the national early warning score combined with a pragmatic medical response strategy. Datacollection lasted from October 2013 to May 2015. Patient comorbidity scores and vital signs were sampled every four months on each ward. All vital signs in the 24 hours before a serious adverse event were collected.

Results

60,956 patients were included of which 32,722 in the intervention group. Comorbidity scores were sampled in 3600 patients and vital signs in 2951 patients. In 668 patients, vital signs were collected before a serious adverse event. The mean number of vital signs per observation increased significantly in the intervention group. The observation frequency increased in patients with a serious adverse event and decreased in patients without a serious adverse event. Protocol compliance was negatively associated with patient mortality adjusted for comorbidity and age.

Conclusion

Our intervention improved patient monitoring practice and reduced mortality.

Impact

The impact of early warning scores on patient monitoring practice and patient outcomes remains unclear. Our intervention improved the observation of patients and reduced patient mortality. These results could support hospitals in their decision to implement rapid response systems.

TRIAL REGISTRATION

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38 We have registered this study in the clinicaltrials.gov database (identifier:
39 NCT01949025).

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KEYWORDS

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43 Rapid Response System

44 Early Warning Score

45 Vital sign

46 Nurses

47 Protocol compliance

48 Mortality

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MAIN PAPER

INTRODUCTION

Many unexpected deaths in acute hospitals are preceded by a long period of physiological instability that is often not recognised and inadequately managed by hospital staff (Findlay, Shotton, Kelly, & Mason, 2012). Problems associated with preventable deaths are most likely to occur on medical and surgical wards and involve poor clinical monitoring, diagnostic errors and a deficient response to clinical deterioration (Hogan et al., 2012). A system-based approach is needed for the detection and management of deteriorating patients. Timely recognition of deterioration and appropriate action may reduce morbidity and mortality. This fundamental idea led to the conceptual development of the Rapid Response System (RRS) which is an umbrella term for all system-based approaches aimed at detecting, interpreting and responding to deterioration (Lyons, Edelson, & Churpek, 2018). The aim of RRSs is to improve relevant patient outcomes. Two large randomised controlled trials, however, could not find a survival benefit in adults or children (Hillman et al., 2005; Parshuram et al., 2018). Only four studies investigated the effect of an RRS on nurses' clinical performance in vital sign registration of which three had a before and after design (De Meester et al., 2013; Kyriacos, Jelsma, James, & Jordan, 2015; Mitchell et al., 2010; Paterson et al., 2006). Although these studies suggest a positive impact on the quality of the registration of vital signs, they had small sample sizes or were of limited methodological quality (Lee, Kim, Kim, & Oh, 2018).

Background

In 31% of all in-hospital preventable deaths, deterioration was not detected because of poor clinical monitoring (Hogan et al., 2012). As a solution to this problem, physiological track and trigger scores were developed (Lee et al., 2018). These scores are designed to evaluate the patient's clinical status objectively and routinely by measuring vital signs and by comparing them with predefined reference ranges. It allows hospitals to utilise local resources effectively and to ensure that specialised staff is alerted in time if vital signs deviate (McNeill & Bryden, 2013). A variety of track and trigger scores are being used that can be categorised into single-, multiple-parameter, and aggregated weighted scoring systems (AWSS). The National Early Warning Score (NEWS) has a greater ability to discriminate adult patients at risk of cardiac arrest, unanticipated Intensive Care Unit (ICU) admission or death within 24 hours of measurement compared with 33 other scoring systems (Smith, Prytherch, Meredith, Schmidt, & Featherstone, 2013). The NEWS is an AWSS developed and validated by the Royal College of Physicians (United Kingdom) using a large vital signs database (Royal College of Physicians, 2012). It was designed as an unambiguous and easy to use instrument with the aim to standardise the clinical assessment of adult, non-pregnant patients throughout the UK healthcare system (Royal College of Physicians, 2017). Although the NEWS is widely adopted today, the impact on the frequency and quality of vital sign registration and nurses' compliance to this intervention has never been studied in a large-scale multicentre randomised controlled trial (RCT). Hands et al. reported that the observation frequency proposed in the NEWS guideline, which is at least every 12 hours, is an unachievable routine in the current healthcare system (Hands et al., 2013). They attributed protocol non-compliance to increased workload, insufficient diagnostic equipment and the limited face validity of RRS activation criteria.

Furthermore, an association between compliance with the NEWS protocol and patient outcomes has never been proven (Lee et al., 2018). The current practice of observing patients and taking vital signs in hospitals is predominantly based on tradition and not on science (Mok, Wang, Cooper, Ang, & Liaw, 2015). A standard policy for observing hospitalised patients is needed to ensure consistency and quality. Traditionally, patients on general wards are monitored at fixed intervals in accordance with ward practices and doctor's orders. Nurses report that these practices are time-consuming and sometimes overwhelming, resulting in failure to collect complete and accurate vital signs. A patient-tailored monitoring approach should be used to determine the observation frequency which could theoretically improve patient monitoring practice as well as decrease workload (Storm-Versloot et al., 2014).

THE STUDY

Aims

The aim of this study was twofold. Firstly, to investigate the impact of an RRS using the NEWS on the frequency and on the quality of the registration of vital signs. Secondly, to study the association between compliance with the NEWS protocol and patient mortality.

Design

We conducted a post-hoc analysis of data from a pragmatic, stepped wedge cluster randomised controlled trial in Belgian acute hospitals from October 2013 to May 2015. The general study design and block randomisation method were explained extensively in a previous publication (including a CONSORT style flow diagram) (Haegdorens et

al., 2018). This study lasted five periods of four months each (T0-T4) with phased introduction of the intervention.

Sample

We initially included seven of 14 eligible acute hospitals in Belgium with two medical and two surgical wards each. One hospital did not collect data concerning patient's vital signs. Therefore, 24 wards in six hospitals were included in the current study. Acute care hospitals were eligible for participation in the study when they had at least two medical and two surgical wards with each at least 850 admissions per year, an Intensive Care Unit (ICU), a resuscitation team available 24/7, and no implemented RRS or EWS. All patients admitted to the participating wards within the study period were included. Patients were excluded if they were pregnant or younger than 17 years of age.

Intervention

In the control group standard care was provided where nurses observed patients according to local protocols or standard practice. Practices were generally tradition-based and differed across wards, hospitals, and even between nurses. The intervention comprised the detection (afferent) and response (efferent) limb of an RRS. We introduced a standardised observation protocol based on the National Institute for Health and Care Excellence (NICE) guidelines using the NEWS combined with a pragmatic medical response strategy (Royal College of Physicians, 2012). Furthermore, we introduced a standard way of communicating using the Situation, Background, Assessment and Recommendation (SBAR) method (De Meester, Verspuy, Monsieurs, & Van Bogaert, 2013). Hospitals integrated the NEWS in their

own paper-based or electronic patient record. Nurses calculated the NEWS by using the patient's respiratory rate, oxygen saturation, supplemental oxygen administered, temperature, systolic blood pressure, heart rate and level of consciousness (alert, verbal, pain or unresponsive).

The baseline observation frequency for all hospitalised patients was one NEWS every 12 hours. Nurses were free to register extra observations if needed. According to the clinical risk category resulting from the NEWS (zero, low/green, medium/orange, high/red), the observation frequency had to increase or decrease in agreement with the NICE guidelines (Royal College of Physicians, 2012). Deviations from observation frequencies and call criteria were allowed on doctor's orders but had to be noted and signed in the patient record by the attending doctor.

The pragmatic and standardised medical response was nested in existing ward and hospital structures. We did not implement a rapid response team or medical emergency team in the study. The response strategy was tailored to the levels of clinical risk resulting from the NEWS.

The implementation of the intervention protocol was supported and organised by a designated project manager in each hospital. All project managers met on a monthly basis together with the researchers to discuss problems and to exchange ideas. This was also part of the strategy to ensure the homogeneity of the intervention between hospitals. Small adaptations to the medical response strategy were allowed to ensure adoption while avoiding a mismatch between the intervention and the ward's unique characteristics. No changes were allowed in the calculation of the NEWS or in the observation frequency.

One week before the start of the intervention ward nurses received an interactive training session concerning the measurement and interpretation of vital signs, clinical

observation, communication skills, and practical tips and tricks about NEWS and SBAR. The trainers (FH and MM) were experienced practicing nurses. It was emphasised that the goal of our intervention was certainly not to increase the nurses' workload, but instead to shift time to care from stable to deteriorating patients. During this training we also explained that this project was supported by the hospital management, therefore acknowledging the problems the nursing staff had experienced with deteriorating patients. The mandatory training lasted four hours and was based on the innovation-decision theory by Rogers to maximise adoption (Rogers, 1995).

Data collection

Data was collected between October 2013 and May 2015. We collected (I) patient outcomes (unexpected death, cardiac arrest with CPR and unplanned ICU admission), (II) patient characteristics (gender, age, and length of stay), (III) patient comorbidity scores and (IV) clinical monitoring data (registered vital signs). All primary patient outcomes are defined in our first publication (Haegdorens et al., 2018). The combined mortality rate was a composite outcome composed of unexpected death and death within 72 hours after cardiac arrest with CPR or unplanned admission to the ICU.

Patient comorbidity was measured using the Charlson Comorbidity Index (CCI) and collected from 30 consecutive patient admissions across all wards starting on the last Monday of the second month of each period (T0-T4).

Clinical monitoring data comprised two datasets: a cross-sectional sample and an SAE sample. The cross-sectional sample included all registered vital signs and NEWS values of admitted patients to the study wards in a 24-hour timeframe on a randomly chosen Tuesday in the second month of each period (T0-T4). Patients experiencing a

Serious Adverse Event (SAE; unexpected death, cardiac arrest with CPR and unplanned ICU admission) were excluded from this first sample. The SAE sample included all registered vital signs and NEWS values collected in a 24-hour period before the actual event in all patients experiencing a SAE throughout the study.

Nurse protocol compliance was calculated for all patients in the cross-sectional sample in the intervention group. Protocol compliance was defined as a registered NEWS at least every 12 hours including all six vital signs and supplemental oxygen per patient.

Validity and reliability

The computerised randomisation procedure was performed by a statistician who was not involved in the further conduct of the study. The hospital management was blinded for the intervention date on their wards until one month before inclusion in the intervention group. The ward staff was only informed of their inclusion in the study two weeks before the intervention started.

An extensive patient record review was performed to determine the primary outcomes. We reviewed each patient record in case of a crude outcome indicator (crude mortality, resuscitation team calls and all transfers to the ICU). We used a standardised electronic checklist to collect data. Outcome indicator definitions were matched against patient records. In case of uncertainty, the patient record was reviewed and discussed by two independent researchers to achieve agreement.

Ethical considerations

Approval of the ethics committee of Antwerp University Hospital and of the ethics committees of all local hospitals was obtained before the start of the study (registration number: B300201317835).

Data analysis

All data were analysed using IBM SPSS Statistics version 24 for MAC OS. Patient outcome measures were presented per 1000 patient admissions. Continuous data were tested for normality using the absolute skewness (≤ 2) and kurtosis (≤ 7) for sample sizes greater than 300, using z-scores (between -3.29 and 3.29) for sample sizes between 50 and 300 or using z-scores (between -1.96 and 1.96) for sample sizes smaller than 50 (Kim, 2013). In case of a non-normal distribution we chose an appropriate non-parametric test. All proportions between two or more groups were tested with the Pearson's Chi-squared test. When studying correlations between protocol compliance, age, gender, comorbidity and patient outcomes, we aggregated our database to the ward level ($n=24$) and included only data from the intervention group. The percentage of patients with protocol compliance, mean age, percentage males, mean CCI, unplanned ICU admission rate, cardiac arrest rate, unexpected death rate and combined mortality rate were calculated for each ward in the intervention group. We used Pearson product-moment correlation coefficients if all included variables had a normal distribution. To study the impact of a ward's mean CCI we categorised all mean ward CCIs in quartiles. Using a univariate linear regression analysis, we studied the association between protocol compliance and the combined mortality rate in the intervention group per CCI quartile. Subsequently, we also used a multiple linear regression analysis while controlling for the mean CCI and mean age.

RESULTS

Six hospitals with each four wards (n=24) were included in this study. We included 60,956 patient admissions from October 2013 until May 2015 accounting for 303,559 patient days. The intervention group contained 32,722 patient admissions. CCI's were collected in 3600 patients spread over all 24 wards of which 1740 in the control group. The cross-sectional sample comprised 2951 patients of which 1361 in the control group (Table 1). The SAE sample comprised 668 patients of which 266 in the control group.

Analyses comparing the control and intervention group

Patient and sample characteristics were compared between the control and intervention group in Table 1. In both samples, patients in the intervention group (cases) were younger compared to the control group (controls). In the cross-sectional sample, the length of stay (LOS) was significantly shorter in the intervention group. We found an increase of LOS in patients experiencing a SAE in the intervention group. In the cross-sectional sample 4.6% of all patients did not have a single registered observation and 3.0% of all patients experiencing an SAE had no observations before the event. We found no statistical difference in the percentage of patients without observation comparing the control and intervention group in both samples.

In Figure 1 we compared the percentages of registered vital signs between the control and the intervention group in both samples. In the cross-sectional sample of the control group (Figure 1A), the blood pressure was the most registered vital sign while the patient's consciousness was only measured in 1% of all observations. The most registered vital sign in the cross-sectional sample of the intervention group was the temperature while the administered oxygen was the least registered parameter.

In the SAE sample of the control group (Figure 1B), the heart rate was the most registered vital sign while the patient's consciousness and respiratory rate were only measured in 2% of all observations. The most registered vital sign in the SAE sample of the intervention group was the blood pressure while the patient's consciousness was the least registered parameter. The NEWS was registered in 64% of all observations in the cross-sectional sample of the intervention group. In the 24 hours before an SAE, we found a registration of the NEWS in 54% of all observations. All vital signs were measured more frequently in the intervention group of both samples. Table 2 compares the observation frequency expressed in mean number of hours between two observations and mean number of vital signs per observation between controls and cases for the two samples. In the cross-sectional sample we found an increase of the mean number of hours between observations in the intervention group versus the control group. This can be interpreted as a decrease of the observation frequency. Contrastingly, in the SAE sample we found a decrease of the mean number of hours between observations in the intervention group versus the control group. Thus, patients experiencing an SAE were more frequently observed in the intervention group. The mean number of vital signs per observation increased significantly in both samples.

Analyses of the intervention group data

In the cross-sectional sample of the intervention group 47.7% of all patients (n=1590) were observed in agreement with the NEWS protocol (protocol compliance). In the total intervention group, 51.5% of all patients (n=32,722) were men and the average age was 60.5 years (SD 18.0). The mean CCI in the intervention group was 1.58 (SD 1.07). Furthermore, the unplanned ICU admission rate was 10.7 per 1000 admissions, the cardiac arrest rate was 1.0 per 1000 admissions, and the unexpected death rate was 0.6 per 1000 admissions. In 0.9 per 1000 admissions, the patient died within 72 hours after an unplanned admission to the ICU. In 0.6 per 1000 admissions, a patient died within 72 hours after a cardiac arrest with CPR. The combined mortality rate, which was composed of unexpected death, death within 72 hours after an unplanned ICU admission or following cardiac arrest with CPR, was 2.1 per 1000 admissions.

In the analysis in Table 3 we aggregated all data to the ward level (n=24) and calculated correlation coefficients between all shown variables in the intervention group. The percentage protocol compliance showed a weak negative association with the combined mortality rate ($r -0.364$, $p=0.080$), a moderate negative association with the unexpected death rate ($r -0.451$, $p=0.027$), a moderate positive association with the mean CCI ($r 0.419$, $p=0.042$), and a moderate positive association with the percentage of males ($r 0.544$, $p=0.006$).

In a univariate linear regression analysis, we studied the association between protocol compliance and the combined mortality rate per 1000 admissions in the intervention group per CCI quartile (Figure 2). The first CCI quartile ranged from 0.23 to 0.60, the second from 0.70 to 1.14, the third from 1.24 to 2.35, and the fourth from 2.37 to 3.86. Four regression lines are shown in Figure 2, one for each CCI quartile. In the first and second CCI quartile we found no significant association between the protocol

compliance and the combined mortality rate. In CCI quartile three, the association was statistically significant considering an α of 0.100 with an adjusted R^2 of 38%. Lastly, in CCI quartile four, the association was statistically significant considering an α of 0.05 with an adjusted R^2 of 86%.

In Table 4, a multiple linear regression analysis shows the association between the percentage protocol compliance and the combined mortality rate per 1000 admissions adjusted for the mean CCI and the mean age in each ward ($n=24$). The variance in the combined mortality rate is explained for 45% by this model. When male gender was added to this model the coefficient of determination did not change significantly and the association between independent and dependent variables remained the same, therefore this variable was omitted from the model. We found a significant negative association between the percentage protocol compliance and the combined mortality rate per 1000 admissions adjusted for the CCI and the age.

DISCUSSION

In this study we have shown that our intervention resulted in an increase of the registration of all six vital signs and supplemented oxygen. Furthermore, we found a reduction of the observation frequency in clinically stable patients and an increase of the observation frequency in deteriorating patients. These results were anticipated and in accordance with the training we supplied but somewhat contradictory when compared with previous research. In two recent systematic reviews concerning the effect of Early Warning Scores on the clinical performance of nurses, the authors concluded that the recording of vital signs improved after implementing EWSs (Saab et al., 2017) (Lee et al., 2018). In most studies, an increase in the number of vital signs

registered per observation was found which corresponded with our results. However, in the only two studies investigating EWSs where observation frequency was measured, patients were more frequently observed after the intervention (De Meester et al., 2013) (Mitchell et al., 2010). Different versions of the Modified Early Warning Score (MEWS) were used in these studies, which is an older, more complex and less validated EWS compared to the NEWS. The decrease in observation frequency in our study could be explained by our emphasis during the nurses' training sessions on shifting time to care from stable to deteriorating patients.

Our second aim was to study the possible association between compliance with the NEWS protocol and patient outcomes. The MERIT study, a randomised controlled trial in 23 Australian hospitals, studied the effect of a Medical Emergency Team (MET) on patient outcomes but was inconclusive (Hillman et al., 2005). In a post-hoc analysis, a negative dose-response relationship between MET calling rates and patient outcomes was found (Chen et al., 2009). However, MET calling criteria were only based on deviations of a single vital sign. Moreover, in order to call a medical emergency team, deterioration must be effectively and efficiently detected beforehand. Our current study is, to our knowledge, the only study confirming a dose-response relationship between NEWS protocol compliance and patient outcomes. Reductions in mortality have been found in most studies investigating RRSs but they may have been biased by shifting risk without truly providing "rescue" (i.e. ward deaths are avoided by moving patients to the ICU) (Lyons et al., 2018). We found a significant negative association between compliance with the NEWS protocol and patient mortality expressed as unexpected death including failure to rescue after a serious adverse event (death after cardiac arrest or death after an unplanned admission to the ICU). This result remained valid after adjusting for patient comorbidity and age. Consequently, this could imply that the

detection of deterioration using NEWS is a key part in the conceptual framework of an RRS. To achieve maximal adoption in this study we used a pragmatic medical response strategy and a training programme for nurses which could be imperative to adequate RRS performance. Given the significant cost of an RRS and the impact it has on the nurses' work environment, any implementation of an RRS should be well thought-out (Jensen, Skår, & Tveit, 2018). We found that only wards in the two highest comorbidity quartiles possibly benefitted from adhering to our protocol. This may imply that wards admitting patients with low comorbidity scores (e.g. day surgery or the maternity ward) may benefit less from implementing an RRS.

Limitations

The most important limitation of this study was that it comprises a post-hoc analysis of data collected for another study. Therefore, it was not possible to prove causal relationships. This study included a large sample of hospitalised surgical and medical patients admitted to Belgian hospitals. An aggregated database was generated providing estimations of patients' vital sign measures, age and comorbidity per study ward. No linked data concerning these measures were available on the patient level. Therefore, no statements could be made about individual patients. Another limitation was that we used the CCI as a risk adjustment measure which has a lower predictive ability for mortality compared with other scores (Needham et al., 2005). However, the CCI requires less data to calculate which makes it a feasible method for risk adjustment in healthcare research.

CONCLUSION

Implementation of an RRS including NEWS improves nurses' performance in observing patients without increasing workload in clinically stable patients. Furthermore, compliance with the NEWS protocol was negatively associated with unexpected death (including failure to rescue after a serious adverse event) adjusted for age and comorbidity. An RRS including NEWS is an efficient and effective method to detect and manage clinically unstable patients on the general ward. Sufficient evidence is available to support adoption of this intervention on medical and surgical wards in acute hospitals.

REFERENCES

- Chen, J., Bellomo, R., Flabouris, A., Hillman, K., Finfer, S. (2009). The relationship between early emergency team calls and serious adverse events. *Crit Care Med*, 37(1), 148-153. doi:10.1097/CCM.0b013e3181928ce3
- De Meester, K., Haegdorens, F., Monsieurs, K. G., Verpooten, G. A., Holvoet, A., & Van Bogaert, P. (2013). Six-day postoperative impact of a standardized nurse observation and escalation protocol: a preintervention and postintervention study. *J Crit Care*, 28(6), 1068-1074. doi:10.1016/j.jcrc.2013.07.061
- De Meester, K., Verspuy, M., Monsieurs, K. G., & Van Bogaert, P. (2013). SBAR improves nurse-physician communication and reduces unexpected death: a pre and post intervention study. *Resuscitation*, 84(9), 1192-1196. doi:10.1016/j.resuscitation.2013.03.016
- Findlay, G. P., Shotton, H., Kelly, K., & Mason, M. (2012). Time to Intervene? A Review of Patients Who Underwent Cardiopulmonary Resuscitation as a Result of an In-hospital Cardiorespiratory Arrest: A Report by the National Confidential Enquiry into Patient Outcome and Death. Retrieved
- Haegdorens, F., Van Bogaert, P., Roelant, E., Meester, K., Misselyn, M., Wouters, K., & Monsieurs, K. G. (2018). The introduction of a rapid response system in acute hospitals: a pragmatic stepped wedge cluster randomised controlled trial. *Resuscitation*. doi:10.1016/j.resuscitation.2018.04.018
- Hands, C., Reid, E., Meredith, P., Smith, G. B., Prytherch, D. R., Schmidt, P. E., & Featherstone, P. I. (2013). Patterns in the recording of vital signs and early warning scores: compliance with a clinical escalation protocol. *BMJ Qual Saf*, 22(9), 719-726. doi:10.1136/bmjqs-2013-001954
- Hillman, K., Chen, J., Cretikos, M., Bellomo, R., Brown, D., Doig, G., . . . MERIT, S. I. (2005). Introduction of the medical emergency team (MET) system: a cluster-randomised controlled trial. *Lancet*, 365(9477), 2091-2097. doi:10.1016/S0140-6736(05)66733-5
- Hogan, H., Healey, F., Neale, G., Thomson, R., Vincent, C., & Black, N. (2012). Preventable deaths due to problems in care in English acute hospitals: a retrospective case record review study. *BMJ Qual Saf*, 21(9), 737-745. doi:10.1136/bmjqs-2011-001159

- Jensen, J. K., Skår, R., & Tveit, B. (2018). The impact of Early Warning Score and Rapid Response Systems on nurses' competence: An integrative literature review and synthesis. *J Clin Nurs*, 27(7-8), e1256-e1274. doi:10.1111/jocn.14239
- Kim, H. Y. (2013). Statistical notes for clinical researchers: assessing normal distribution (2) using skewness and kurtosis. *Restor Dent Endod*, 38(1), 52-54. doi:10.5395/rde.2013.38.1.52
- Kyriacos, U., Jelsma, J., James, M., & Jordan, S. (2015). Early warning scoring systems versus standard observations charts for wards in South Africa: a cluster randomized controlled trial. *Trials*, 16, 103. doi:10.1186/s13063-015-0624-2
- Lee, J.-R., Kim, E.-M., Kim, S.-A., & Oh, E. G. (2018). A Systematic Review of Early Warning Systems' Effects on Nurses' Clinical Performance and Adverse Events Among Deteriorating Ward Patients. *Journal of patient safety*.
- Lyons, P. G., Edelson, D. P., & Churpek, M. M. (2018). Rapid Response Systems. *Resuscitation*. doi:10.1016/j.resuscitation.2018.05.013
- McNeill, G., & Bryden, D. (2013). Do either early warning systems or emergency response teams improve hospital patient survival? A systematic review. *Resuscitation*, 84(12), 1652-1667. doi:10.1016/j.resuscitation.2013.08.006
- Mitchell, I. A., McKay, H., Van Leuvan, C., Berry, R., McCutcheon, C., Avard, B., Lamberth, P. (2010). A prospective controlled trial of the effect of a multi-faceted intervention on early recognition and intervention in deteriorating hospital patients. *Resuscitation*, 81(6), 658-666. doi:10.1016/j.resuscitation.2010.03.001
- Mok, W., Wang, W., Cooper, S., Ang, E. N., & Liaw, S. Y. (2015). Attitudes towards vital signs monitoring in the detection of clinical deterioration: scale development and survey of ward nurses. *Int J Qual Health Care*, 27(3), 207-213. doi:10.1093/intqhc/mzv019
- Needham DM, Scales DC, Laupacis A, Pronovost PJ (2015). A systematic review of the Charlson comorbidity index using Canadian administrative databases: a perspective on risk adjustment in critical care research. *Journal of Critical Care*, 20(1), 12-19.
- Parshuram, C. S., Dryden-Palmer, K., Farrell, C., Gottesman, R., Gray, M., Hutchison, J. S. (2018). Effect of a Pediatric Early Warning System on All-Cause Mortality in Hospitalized Pediatric Patients: The EPOCH Randomized Clinical Trial. *JAMA*, 319(10), 1002-1012. doi:10.1001/jama.2018.0948

- Paterson, R., MacLeod, D. C., Thetford, D., Beattie, A., Graham, C., Lam, S., & Bell, D. (2006). Prediction of in-hospital mortality and length of stay using an early warning scoring system: clinical audit. *Clin Med (Lond)*, 6(3), 281-284.
- Rogers, E. M. (1995). *Diffusion of Innovations, Fourth Edition*. New York: The Free Press.
- Royal College Of Physicians (2012). National Early Warning Score (NEWS): Standardising the assessment of acute- illness severity in the NHS. Report of a working party.
- Royal College Of Physicians (2017). National Early Warning Score (NEWS) 2: Standardising the assessment of acute-illness severity in the NHS. Updated report of a working party.
- Saab, M. M., McCarthy, B., Andrews, T., Savage, E., Drummond, F. J., Walshe, N., Hegarty, J. (2017). The effect of adult Early Warning Systems education on nurses' knowledge, confidence and clinical performance: A systematic review. *J Adv Nurs*. doi:10.1111/jan.13322
- Smith, G. B., Prytherch, D. R., Meredith, P., Schmidt, P. E., & Featherstone, P. I. (2013). The ability of the National Early Warning Score (NEWS) to discriminate patients at risk of early cardiac arrest, unanticipated intensive care unit admission, and death. *Resuscitation*, 84(4), 465-470. doi:10.1016/j.resuscitation.2012.12.016
- Storm-Versloot, M. N., Verweij, L., Lucas, C., Ludikhuize, J., Goslings, J. C., Legemate, D. A., & Vermeulen, H. (2014). Clinical relevance of routinely measured vital signs in hospitalized patients: a systematic review. *J Nurs Scholarsh*, 46(1), 39-49. doi:10.1111/jnu.12048