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Do the use of Early Warning Scores and Systems that assist staff recognise patient deterioration have any effect on key outcomes in adult (non-pregnant) patients in the acute healthcare setting? A systematic review.

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III. I would like to dedicate this masters to my ever supportive husband Mark, whose patience and encouragement were at all times present for this and every other endeavour in our lives. In addition, to my children, Shay, Amy, Andrea, Audrey: thank you for your love, ongoing patience and support.

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V. LIST OF ABBREVIATIONS

AE	Adverse Event
AKI	Acute Kidney Injury
AUROC	Area Under the Receiver Operating characteristic
AVPU	Alert, Voice, Pain, Unresponsive
BP	Blood Pressure
BPA	Best Practice Alert
CA	Cardiac Arrest
CD	Clinical Deterioration
CCI	Charlson Co-morbidity Index
CI	Confidence Interval
DANARREST	Danish in-Hospital Cardiac Arrest Registry
CPR	Cardio Pulmonary Resuscitation
DNR	Do Not Resuscitate
E-NEWS	Electronic version of the NEWS
ED	Emergency Department
EHR	Electronic Health Record
EMR	Electronic Medical Record
EWS(s)	Early Warning Score(s)
EWSS	Early Warning Score Systems
FTR	Failure to Rescue
G-DRG	German Diagnosis Related Group
hr	Hours
HIPE	Hospital In-Patient Enquiry
HIS	Hospital Information System
HR	Hazard Ratio
HR	Heart Rate
HSE	Health Services Executive
ICU	Intensive Care Unit
IHCA	In-Hospital Cardiac Arrest
MET	Medical Emergency Team
mmHG	millimetres of mercury
MR	Mortality Rate
NEWS	National Early Warning Score
NICE	National Institute of Clinical Excellence
NIS	Nurse Information System
MEWS	Modified Early Warning Score
N	Number
O_2 Sats	Oxygen saturation
LOS	Length of stay
SBP	Systolic Blood Pressure
RCT	Randomised Controlled Trial
ROC	Receiver Operating Characteristics
RR	Respiratory Rate
RRT	Rapid Response Team
SA	Situational Awareness
SAE	Serious Adverse Event
Sd	Standard deviation
SDU	Step down Unit
S_pO_2	Peripheral Oxygen Saturation
SPSS	Statistical Package for Social Sciences
SBP	Systolic BP
Temp	Temperature

UK	United Kingdom
US	United States
Vs	Versus
Ys	Years

ABSTRACT

Title of Study

Do the use of Early Warning Scores and Systems that assist staff recognise patient deterioration have any effect on key outcomes in adult (non-pregnant) patients in the acute healthcare setting? A systematic review**.**

Background/literature

Early warning scores (EWSs) and early warning systems (EWSS) have been in use within the acute healthcare setting for over 25 years. However, research findings regarding their effect on improving patient outcomes remain mixed.

Aim

This systematic review aimed to examine international research and update previous reviews in the context of whether the use of early warning scores (and its modified forms) and early warning systems that detect patient deterioration had any influence or effect on patient outcomes such as in-hospital mortality, unplanned intensive care admission, length of hospital stay, cardiac arrests and any other serious adverse events on general hospital wards and Emergency Departments in the acute hospital setting.

Methods (databases searched, quality appraisal)

Seven databases including CINAHL, Scopus, Web of Science, Embase, Medline, and Academic Search Complete (EBSCO) along with the Cochrane library and the Cochrane Database of Systematic reviews were searched. A scoping search of the grey literature was also reviewed with regards the Health Service Executive (2022), Google (2022), Google Scholar (2022), National Institute for Healthcare and Clinical Excellence, and the Health Information and Quality Authority (HIQA).

Results (Key findings)

13 studies were identified from 415; there was a cumulative number of 337,092 patients included in the combined studies. Findings were mixed and the review must be interpreted with caution given that the majority of studies did not meet all the quality appraisal criteria. Several themes emerged from the review; however, the intervention outcomes could not be evaluated cumulatively because of the clinical heterogeneity of the studies.

Conclusions/implications/recommendations for future research

Future research should focus on whether or not the EWSs and EWSS are being implemented as planned, as 'failure to rescue' remains an issue in the acute healthcare setting nationally and internationally.

CHAPTER 1:

1. Introduction/Background

This chapter presents the background to the review conducted and provides an overview on warning scores (EWSs) and Early Warning Systems (EWSS), and the different versions of the EWSs. The central terms used throughout the dissertation are defined. This chapter opens with the context in which EWSs and EWSS are used is also detailed in terms of acute hospital care. The concepts of clinical deterioration and "failure to rescue" (FTR) are also explained. In addition, this chapter provides the rationale and justification for the systematic review and the personal motivation for choosing this topic.

1.1. Acute Hospital Care

Acute care is where a patient receives active, short-term treatment for a condition. This can include treatment for a severe injury, period of illness, urgent medical condition, or to recover from surgery (The Health Foundation, 2022). Hospitals complement and amplify the effectiveness of many other parts of the health system, providing continuous availability of services for acute and complex conditions (WHO, 2022). The Health Research Board identified three populations that use acute hospitals: people with chronic diseases regardless of age, older people, and those requiring surgical or medical treatment for an acute illness (Keane *et al.* 2018). Patients referred to acute hospitals comprise all age groups, but the elderly have a higher incidence of acute severe disease and are more frequently admitted to hospital (Blinkenberg, 2022). Data shows that in 2019, there were over 36.2 million hospital admissions in the United States (U.S) and that the elderly account for the largest share of hospital admissions in the U.S. (Statista, 2022). This places a strain on the acute hospital services and Murphy *et al.* (2018) suggest that the National Health Service budget in the United Kingdom (UK) is running over by more than half a billion; with acute hospital providers

specifically reporting deficits of up to 81%. Hospital In-Patient Enquiry (HIPE) is a health information system that collates data on discharges from, and deaths in, acute hospitals in Ireland (HPO, 2020). The most recent figures available indicate that there were 1,278,283 Emergency Department (ED) presentations in 2020 (Health Services Executive, [HSE] 2020). This report goes on to explain that of the patients who attend ED, 27.5% were admitted and that of note, that 54.7% of patients aged over 75 years, who attended ED were admitted. It further states that this is an increase from 53.3% from December 2019 and contends that the impact of COVID is a clear factor in this trend. Data from the Economic and Social Research Institute indicated that 595,340 patients were admitted as inpatients in acute hospitals in Ireland in 2018 (ESRI, 2020).

1.2 Clinical Deterioration

Acute physiological deterioration is a time-critical medical emergency that affects millions of people worldwide (Hegarty *et al.* 2016). Many types of patients can experience unexpected clinical deterioration during hospitalisation, and this deterioration is associated with in-hospital mortality (Lee *et al.* 2018). If changes in patient's vital parameters are recognised early, excess mortality and serious adverse events (SAEs), such as cardiac arrest may be prevented (Alam *et al.* 2014). Jones *et al.* (2013) cited in Grant and Crimmons (2018), suggested a universal definition for deterioration as follows: 'A deteriorating patient is one who moves from one clinical state to a worse clinical state which increases their individual risk of morbidity, including organ dysfunction, protracted hospital stay, disability or death'. Acute deterioration in critically ill patients is often preceded by changes in physiological parameters such as pulse, blood pressure (BP), temperature and respiratory rate (RR) (Alam *et al. 20*14). Patient's physiological observations are routinely recorded in acute settings (DOH, 2020). Patient assessment and measuring vital signs are the main components of monitoring a patient, and are

typically performed by nurses, nursing students and healthcare support workers (Smith and Aitken, 2016). Grant and Crimmons (2018) contend that it is widely understood that patient's vital signs provide essential information to assess their clinical state, and that therefore it could be suggested that any acute change from a patients specific normal vital signs will increase the risk of developing morbidity, organ dysfunction, disability and finally death.

1.3 "Failure to Rescue"

FTR is the failure to prevent a death resulting from a complication of medical care or from a complication of underlying illness or surgery (Burke *et al.* 2022). In the context of an unstable patient, early recognition of clinical deterioration may be the key to preventing FTR (Johnston *et al.* 2015). In this paper, the authors found overall rates of FTR ranged between 0.03% and 16.9% and that the majority of studies reported an overall FTR rate between 8.0 and 16.9%. The importance of an effective track and trigger system and staff education needed to decrease the incidence of in-hospital cardiac arrest (IHCA) and especially, patients admitted to unmonitored general wards being at risk of deterioration unnoticed by the ward staff is explored in the literature (Soar *et al.* cited in Creutzburg *et al.* 2021).

1.4 Early Warning scores and Early Warning Systems

In 1997 Morgan *et al.* first developed the concept of the Early Warning Score (EWS), and suggested that early intervention on detection of deterioration might improve patient outcomes and proposed a score system aggregated from ratings of vital signs that could be used to trigger intervention (Hodgson *et al.* 2022). EWS (also termed 'Track and-trigger systems') have been established in acute care clinical settings to facilitate a timelier response to, and assessment of, acutely ill patients by: classifying the severity of a patient's illness, providing prompts and structured communications tools to escalate care; following a definitive escalation plan (Hegarty *et al.* 2016). EWS systems have been introduced in health services across Europe,

Australia and America to aid healthcare professionals to promptly recognise and respond to the acutely ill deteriorating patient (Royal College of Physicians, 2017). The EWS is a guide used to determine the degree of clinical acuity of a patient and involves a scoring system allocated on pre-determined clinical parameters (Department of Health [DOH], 2015). Early Warning Systems (EWSS) encompass the anticipation, early recognition, escalation, competent clinical response and closed loop governance to assist clinicians and healthcare professionals in preventing irrevocable deterioration and death (Kehoe *et al.* 2022). Healthcare assistants can calculate EWSs and nursing staff can contact an appropriate medical team member depending on the patients score with the view of treatment escalation as indicated (Jayasundera *et al.* 2018). Escalation of care is a process that can be defined as the recognition and communication of patient deterioration to implement definitive management (Johnstown *et al.* 2015).

1.5 Versions of the Early Warning Score

EWSs are often used in the hospital setting to assess worsening or improvement in patients' clinical status over time (Jayasundera *et al*. 2018). Different aggregate weighted Early Warning Scores (EWSs) were developed to facilitate identification of at-risk patients in various clinical settings, most are based on simple physiologic measurements and clinical observations, typically including heart rate HR, RR, BP, level of consciousness (LOC), and other metrics depending on the selected modification tool (Smith *et al.* 2008).

1.5.1 NEWS

The standardized National Early Warning Score (NEWS) was established by the Royal College of Physicians of London and is currently used in several countries (Lee *et al.* 2018). Internationally, NEWS provides a common language in communicating deterioration of hospitalised patients' (Pimentel *et al.* 2019). The National Early Warning Score (NEWS) is an early warning system that predicts clinical deterioration. The impact of the NEWS on the

outcome of healthcare remains controversial (Wu *et al.* 2021). Data from Kivipuro *et al.* (2018) indicates that the NEWS is associated with in- hospital mortality at 30-days. The NEWS is intended to provide reliable, timely, and effective indications of the clinical responses of acutely ill patients. By including seven simple physiological variables, the NEWS also provides a useful and rapid bedside tool (Lee *et al.* 2018).

In the UK, the NEWS2 is the system for scoring the physiological measurements that are routinely recorded at the patient's bedside. Its purpose is to identify acutely ill patients, including those with sepsis, in hospitals in England (NICE, 2020). It was introduced in the UK by the Royal college of Physicians in 2017. This was to take into account the fact that NEWS 1 parameters for oxygen saturations neglect to consider patients who have chronically low oxygen saturation levels, thus leading to inappropriate and frequent triggering of an escalation of care (Grant and Crimmons, 2018). In order to address this, the revised NEWS2 introduced peripheral capillary oxygen saturations (SpO_2). With NEWS2, appropriate clinical responses are given for threshold (trigger) levels, with a recommendation to review and agree these locally: Low risk (aggregate score 1 to 4) – prompt assessment by ward nurse to decide on change to frequency of monitoring or escalation of clinical care. Low to medium risk (score of 3 in any single parameter) – urgent review by ward-based doctor to determine cause and to decide on change to frequency of monitoring or escalation of clinical care. Medium risk (aggregate score 5 to 6) – urgent review by ward-based doctor or acute team nurse to decide on escalation to critical care team. High risk (aggregate score of 7 or over) – emergency assessment by critical care team, usually leading to patient transfer to higher-dependency care area (NICE, 2020). The recommendation for a NEWS2 aggregate score of zero (that is, no change to any parameter) is a minimum 12-hourly review and to continue routine monitoring (NICE 2020).

1.5.2 MEWS

The Modified Early Warning Score is an objective patient acuity scoring system to help the nurse verify deterioration of patient's condition and ascertain whether there is a need to activate the rapid response team (RRT) (Brewer *et al.* 2015). It measures RR, HR, systolic BP (SBP), urine output, temperature, and the patient's neurological response in terms of Alert, Voice, Pain, Unresponsive (AVPU). A score is attributed to each observation based on the degree of physiological abnormality. All of the observation scores are added together to provide a total MEWS (Australian Commission on Safety and Quality in Health Care 2010).

1.5.3 E-NEWS

The E-NEWS is an electronic version of the NEWS (Wu *et al.* 2021).

1.5.4 INEWS

With the Irish National Early Warning System (INEWS), each of seven physiological parameters (RR, O_2 saturations, supplemental oxygen, HR, SBP, LOC and temperature) is allocated a numerical score from '0' to '3' on a color-coded observation chart. A score of '0' represents the least risk while a score of '3' represents the highest risk. Individual scores are then summated to give the patient's INEWS score (Kehoe *et al.* 2022). The INEWS score is captured on the INEWS observations chart, a track and trigger tool, which is an adjunct to clinical judgement for assisting the identification of the acutely unwell patient (DOH, 2020). The frequency of monitoring of observations following admission has been increased to six hourly from 12 hourly for the first 24 hours following admission in acknowledgement of the vulnerability of patients in the 'acute' phase of illness in the 24 hours following admission. The National Clinical Guideline (NCG) No 1 (DOH, 2020) goes on to clarify that for every patient the frequency of monitoring of observations should be consistent with the clinical situation and history of the patient (DOH, 2020).

Foley and Dowling (2018) explain that Ireland and Australia use EWS systems based on VitalPac EWS (ViEWS) compared to the UK's NEWS. The authors go on to clarify that the differences between the two variations can be found in the scoring of some parameters, for example, the UK's NEWS scores a patient's oxygen requirements as a 2 whereas the ViEWS, used by Ireland and Australia, scores it as a 3.

1.6 Rationale/Justification for the systematic Review

Much has been written previously and there are previous systematic reviews (referred to below) completed in relation to EWSs and EWSS for recognising patient deterioration in hospitalised patients. These studies indicate that early warning systems for the early recognition of clinical deterioration in critically ill patients within 24 hours can reduce the incidence of in-hospital patient deterioration and associated mortality in relation to reduced length of stay (LOS), if transferred/admitted to ICU, rate of cardiac arrest or other escalations of care.

Therefore, this systematic review aimed to examine international research and update previous reviews (McNeill and Bryden (2013), Alam *et al*. (2014), Smith *et al*. (2014), Hamilton *et al.* (2018), Gerry *et al.* (2020), Jayasundera *et al.* (2018) and Credland *et al.* (2020)) on this topic. This was in relation to the context of whether the use of early warning scores (and its modified forms) and early warning systems that detect patient deterioration had any influence or effect on patient outcomes such as in-hospital mortality, unplanned intensive care admission, LOS, cardiac arrests and any other serious adverse events on general hospital wards and ED departments in the acute hospital setting. Publication dates were set years from 2017 to 2022. As part of that update, the author was also interested to establish if the emergence of COVID had instigated a body of literature, which focused on using patient alert notifications/instruments to investigate patient deterioration.

1.7 Personal Motivation

Positionality

The Patient Safety Strategy (2019 – 2024) (HSE, 2019) and the Framework for Improving Quality in the Health Service (HSE, 2016) have referenced and identified improvement of care of the clinically deteriorating patient as a key patient safety priority in the Irish Health Services (Kehoe *et al.* 2022). The author of this dissertation was previously involved in the completion a national audit of the NEWS in the Irish Healthcare setting in a representative sample of model 2, 3 and 4 hospitals acute hospitals. The audit found that limited assurance could be provided that the hospitals were compliant with the National Clinical Guideline (NCG) on NEWS (HSE, 2018). Therefore, the author has a personal interest in seeking to review the latest literature in relation to this topic.

The final number of studies selected for inclusion in the review was 13. Of interest, despite the search limits including the years of COVID pandemic (2019 to time of writing) only one study overtly examined the use of established instruments (NEWS, NEWS2) to investigate its usefulness in determining patient deterioration in the context of Covid 19 (Kostakis *et al.* 2021).

Chapter 2 provides the Systematic Review, and includes the review aim, studies inclusion and exclusion criteria, the systematic search strategy as well as the screening process used. It also discusses how the data were extracted and their quality and risk of bias appraised.

In summary, this chapter has provided the reader with the background to the review conducted and the central terms used throughout the dissertation were defined. The dissertation now moves to the scientific paper section.

CHAPTER 2:

Do the use of Early Warning Scores and Systems that assist staff recognise patient deterioration have any effect on key outcomes in adult (non-pregnant) patients in the acute healthcare setting? A systematic review.

The purpose of this chapter is to provide a Systematic Review paper prepared using headings that are broadly similar to those used in the British Journal of Nursing. A decision to select this journal as the target journal for publication was taken as articles are double-blind peer reviewed, and it has a range of inter-professional topics and would capture a larger multi professional demographic. The link for reviewing article submission requirements is available here. This journal has also previously published papers in relation to the topic of early warning scores, e.g. (Grant and Crimmons, 2018) and therefore seems an appropriate journal to publish within in regards this topic. It has an Impact Factor of 0.71.

2. 1 Methods

The systematic review was conducted in conjunction with the Cochrane Handbook for Systematic Reviews of Interventions (Higgins *et al.* 2019) and reported using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) checklist (Page *et al.* 2021).

2.1.1 Eligibility criteria

The PICO question that is used is a 'therapy/intervention question type' as the review was seeking to determine the effectiveness of an intervention (Davies, 2011).

The eligibility criteria for the review were guided by the PICOST framework to include 'S' for setting and 'T' for timeframe.

Inclusion criteria: non-pregnant patients aged 15 years or older, who were inpatients in acute hospitals.

Intervention: The effect of early recognition of patient deterioration using early warning score (EWS) or modified EWS (MEWS) or Early Warning Systems or 'track and trigger' scores/systems to recognise deterioration was reviewed/studied.

Outcome: The effect of interventions aimed at improved mortality, reduced LOS, if transferred/admitted to ICU, rate of cardiac arrest or other escalations of care.

Study Design: randomised controlled trails (RCT), quasi-experimental studies, intervention studies, quantitative studies.

Studies without interventions, comparisons and conducted in settings other than acute care were excluded. Review papers, abstract only articles, pilot studies, editorial and conference papers, literature reviews, pilot studies, and study protocols were also excluded.

Table 1: Review inclusion and exclusion criteria

PICOST framework	Inclusion criteria	Exclusion criteria
Population	Adult ≥15 years (non-pregnant) patients in the acute hospital setting	Patients with a do not Resuscitate (DNR) in place, palliative care patients, paediatric patients <15years and pregnant women (maternity setting).
Intervention	Early recognition of patient deterioration using early warning score (EWS) or modified EWS (MEWS) or track and trigger or Early Warning Systems Primary empirical, peer reviewed research, including RCT's, cohort and case controlled studies, pre and post interventional studies	Studies without an intervention
Comparison	Usual standard of care	Studies with no comparison
Outcomes	Improved mortality, reduced LOS if transferred/admitted to ICU	Studies that do not include, are not relevant to or do not measure an effect on the recognition of patient deterioration

PICOST framework	Inclusion criteria	Exclusion criteria
Settings	Acute hospital healthcare setting,	All other healthcare settings including care of the elderly settings, primary care, maternity care settings.
Timeframe	January 2017-April 2022	Outside of this timeframe

2.1.2. Search strategy

All major electronic sources of information relevant to the topic including CINAHL and the Cochrane library including the Cochrane Database of Systematic reviews, Scopus, Web of Science, Embase, Medline, and Academic Search Complete (EBSCO) were searched to identify published and unpublished studies and previous work in the field (See Appendix I). The search was conducted based on title and abstract using truncation, the explode feature and phrase searching. Truncation, also called stemming, a technique that broadens your search to include various word endings and spellings was used. Concepts were combined using Boolean operators 'OR' and 'AND' as follows:

Mesh heading: "Early Warning Score"
"Early warning scor*" OR "early warning system" OR "track and Trigger*" OR EWS OR "Early Warning System*") OR TI ("early warning scor*" OR "early warning system" OR "track and Trigger*" OR EWS OR "Early Warning System*")
OR Mesh heading: 'Clinical Deterioration'
Abstract ("patient deterioration" OR "clinical deterioration") OR TI ("patient deterioration" OR "clinical deterioration"
OR Abstract (outcome* OR mortality) OR TI (outcome* OR mortality)
AND "randomised controlled trial*" AND RCT OR "interventional Stud* AND hospitalisation OR inpatient*

Similar search terms and search strings were used across all databases to ensure a comprehensive search and in an effort to maintain consistency across the databases.

Grey literature including conference notes, dissertations, government documents and reports were also searched. Hand searching of relevant journals also took place to ensure all relevant publications were captured. Search results were saved by creating accounts in all the databases, e.g. CINAHL, PubMed etc.

A scoping search of the grey literature was reviewed in the following areas: Health Service Executive (2022), Google (2022), Google Scholar (2022), National Institute for Healthcare and Clinical Excellence, Health Information and Quality Authority (HIQA) to determine the key words and synonyms. 'Grey literature' is the information not controlled by traditional academic publishers and can include conference abstracts, theses, government reports, patents, and clinical practice guidelines, (Aromataris & Riitano, 2014).

The searches took place in April 2022 and was limited to peer-reviewed studies published in English within a five-year timeframe (between January 2017 and April 2022). A five-year period was chosen due to the plethora of literature on the topic and the limitation on word count for this dissertation.

Inclusion criteria

Date published was in the period January 2017 to April 2022 in the English language. The participants were non-pregnant adults over the age of 15 in the acute hospital setting. The type of studies were quantitative empirical studies. The study designs included the assessment interventions in controlled studies, and randomised controlled trials. Outcome measures were the effect that early warning scores/systems have on the recognition of patient clinical deterioration in the acute hospital setting. Outcome measures related to mortality rate (MR), LOS, rate of cardiac arrest and rate of admission to intensive care/similar acuity locations, rate of death and other escalations of care.

Exclusion criteria

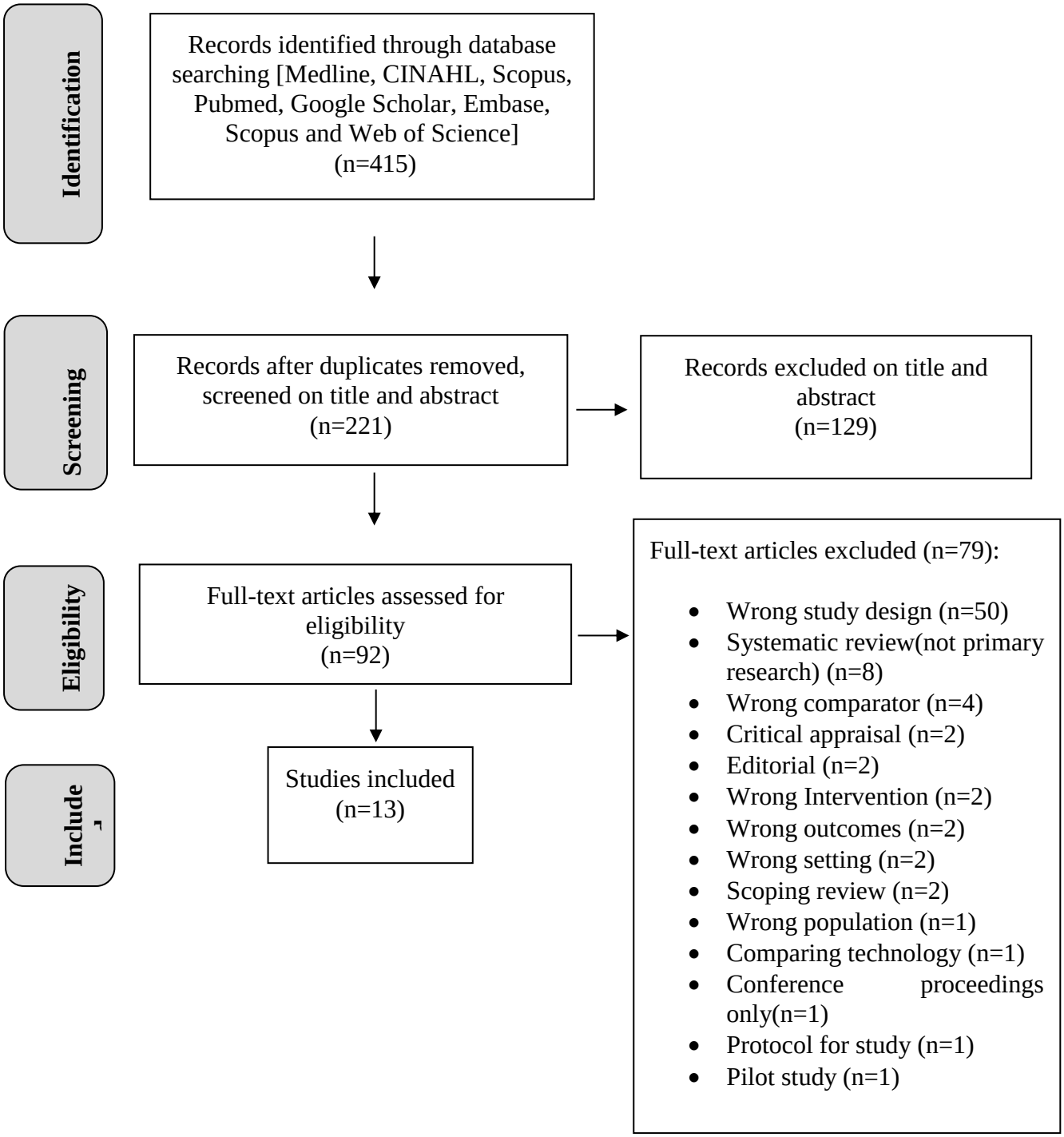
Papers with all other study designs other than those referenced and those studies that are prior to 2017 and that were not peer reviewed. Systematic reviews and meta-analysis were not included as this systematic review focused on primary research only. Other interventions to recognise patient deterioration were not included.

2.1.3 Study selection

Database searches were conducted in April 2022. Identified records were uploaded to Endnote, which is a type of reference management software (University of Limerick, 2022). Records were then transferred to Covidence (N=415). This a web-based software platform that streamlines the production of systematic reviews and other research reviews that require screening citations and full text, assessing risk of bias, or extracting study characteristics and outcomes (Covidence, 2022). Covidence software identified the duplicates (N=193). As critical appraisal is about judgment making, it is advised to have at least two reviewers independently involved in the appraisal process (Hong, 2018). Therefore, the aims and objectives, inclusion and exclusion criteria of the systematic review were shared with the second reviewer (KH) and 221 studies were screened. Discrepancies as to whether a paper met the inclusion criteria were discussed with (KH) until a consensus was agreed. In instances where there were conflicts, a third reviewer (AS) was consulted to resolve so that a final consensus could be agreed. This resulted in 129 studies being deemed irrelevant, 92 full text studies were screened via titles and abstracts. Of those, 79 were excluded for various reasons, 50 were excluded primarily due to the wrong study design (see figure 1). This yielded 13 papers. See Figure 1 flow diagram of the study selection process clearly described.

2.1.4 Diagram of the study selection process

Figure 1: **Study identification, screening, and selection process.**



2.2 Study characteristics

There were 13 studies reviewed (See Table 5). The countries that the studies were conducted in reflected the Credland *et al.* review (2020) and included, USA (N=5), Europe (N=4), [comprised of Denmark (N=2), Belgium (N=1), Germany (N=1)], Egypt (N=1) South Korea (N=1), UK (N=1) and Taiwan (N=1). Studies were carried out between 2017 (Imperato *et al* 2017) and 2022 (Wu *et al.* 2022). Interventions ranged from the implementation of protocols on EWS and NEWS/MEWS/ENEWS, and of education and training programmes on the EWS/EWSS and their effect on clinician behaviour and consequently patient outcomes. All 13 studies were conducted in the acute hospital setting including ED units (N=3) and various wards (N=10). Sample sizes ranged from 263 (Kumar *et al*, 2020) to 85,322 (Bedoya *et al.* 2019). The study designs were 10 quasi-experimental studies; one randomised controlled trial and two cross sectional studies.

Data collection tools included flow charts and healthcare records (HCRs), pen and paper, electronic health records (EHRs), routine databases, measurement logs of the deployed system, civil registration number, an E-NEWS dashboard on a Hospital Information System (HIS) and a Nurse Information Systems (NIS).

2.2.1 Data extraction

Before applying the criteria to the list of potentially relevant studies, a pilot of the screening and selection tools took place (Boland *et al. 20*14). Data collection tools were used to ensure all relevant data is collected, to minimise the risk of transmission errors, to allow the accuracy of the data to be checked, and to serve as a record of the data collected (Pearson *et. al* 2007). The tool that was used was based on Finehout-Overholt *et al.* (2010). The table was based on the study characteristics and included the following headings: author/year, purpose of the

study, design/methods, sample/setting, major variables studied and their definitions, measurement, data analysis, findings and appraisal worth to practice. Findings from individual studies are presented in Table 5. This process facilitated assessing the risk of bias, as well as the findings and the overall worth to practice headings that enabled synthesis. Strong methodological approaches to systematic review improve the transparency, consistency, and scientific rigor of these reports (Viswanathan *et al.* 2017)

2.2.2 Quality appraisal

Tables 2, 3, and 4 represent the critical appraisal of the studies. The major aim of critical appraisal of any type of evidence is to establish the validity of the evidence for practice. Validity refers to the soundness of the evidence, in other words it is about the degree to which we can accept the evidence as trustworthy and believable (Pearson *et al.* 2007). The methodological quality of the studies was assessed using the following tools from the Joanna Briggs Institute (2020): Critical Appraisal Checklist for randomised controlled trials (Tufanaru *et al.* 2020), checklist for quasi-experimental studies (non-randomised experimental studies), and the critical appraisal checklist for analytical cross sectional studies (Moola *et al.* 2020).

The key elements reviewed included, sampling, randomisation, blinding, validity and reliability of outcome measure and appropriateness of analysis. Questions were answered as 'yes', 'no', 'unclear' or 'not applicable'. Quality appraisal was conducted by the first author and crosschecked by KH. Conflicts in quality appraisal were discussed until a consensus was agreed. For quantitative evidence, it is important to identify the risk of bias in the published research in order to decrease the possibility of including biased or misleading results. The assessment of internal validity of quantitative studies involves determining whether the methods used in the study can be trusted to provide a genuine, accurate account of the

intervention (Porritt *et al.* 2014). The quality of the studies reviewed was variable with the RCT study not meeting all the methodological criteria. Nine of the quasi-experimental studies met all of the criteria.

Randomised controlled trial

A randomised controlled trial (RCT) is considered to provide the most reliable evidence on the effectiveness of interventions (Akobeng, 2005). The methodological quality of the RCT (Haegdorens, 2019) was reviewed. It appeared to have randomisation but the concealment of allocation to treatment groups appears not to have occurred. Hospital management were blinded for a month before they were included in the intervention group and ward staff were only made aware of their inclusion two weeks in advance of the commencement of their intervention. Blinding participants to a treatment or intervention is of importance to reduce the risk of performance or ascertainment bias. If participants are not blinded, knowledge of group assignment may affect their behaviour in the trial and their responses to subjective outcome measures (Karanicolas *et al.* 2010).

Groups were measured in the same manner using reliable measurements. Reliability can be measured multiple ways depending on the type of instrument (Polit & Beck, 2012).

Quasi-Experimental Studies

For all the quasi-experimental studies (N=10), it was clear what the cause and effect were, the participants were included in similar comparisons and there were multiple measurements of the outcomes pre- and post- test. Thiese (2014) suggests that the outcomes observed in pre and post intervention studies cannot be reliably attributed to the specific intervention, making this a weaker design than the RCT. Six studies including Bedoya *et al.* (2019), Creutzburg *et al.*

(2021), Escobar *et al.* (2020), Hwang and Kim (2022), Imperato *et al.* (2017), and Ursolino (2019) did not mention that they had a control group, but on closer inspection, they all had pre intervention data that served as a control when measured against the post intervention data. Nine of the studies were of a good methodological quality. However, it has been suggested that the lack of randomisation in a non-randomised controlled trials, which potentially leads to differences between treatment groups in outcome owing to differences between treatment groups in baseline characteristics, results in the study design having limited value (Sedgwick, 2014).

Cross Sectional Studies

The cross sectional studies (Kostakis *et al.* 2021) and Kumar *et al.* (2020) did not meet all the quality appraisal criteria. The identification of confounding factors was unclear in Kumar *et al*. (2020) and the strategies to deal with confounding factors were not clear in either study.

In conclusion, findings from this review must be interpreted with caution given that none of the studies met all of the quality appraisal criteria as identified by JBI.

Following the data extraction tables (2-4) the paper moves on to a review of the findings.

Table 2: Quality appraisal of the included randomised controlled trials using the JBI checklists (n=1)

JBI items	Haegdorens *et al.* (2019)
Was true randomization used for assignment of participants to treatment groups?	Yes
Was allocation to treatment groups concealed?	No
Were treatment groups similar at the baseline?	Unclear
Were participants blind to treatment assignment?	No
Were those delivering treatment blind to treatment assignment?	Yes
Were outcomes assessors blind to treatment assignment?	No
Were treatment groups treated identically other than the intervention of interest?	Yes
Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?	Yes
Were participants analysed in the groups to which they were randomised?	Yes
Were outcomes measured in the same way for treatment groups?	Yes
Were outcomes measured in a reliable way?	Yes
Was appropriate statistical analysis used?	Yes
Was the trial design appropriate and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?	Yes
Total Quality Score	8
Percentage	62%

(Tufanaru *et al.* 2020)

Table 3: JBI checklists for Quasi-Experimental Studies (non- randomized experimental studies) (n=10)

JBI Items	Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?	Were the participants included in any comparisons similar?	Were the participants included in any comparisons receiving similar treatment /care, other than the exposure or intervention of interest?	Was there a control group?	Were there multiple measurements of the outcome both pre and post the intervention/exposure	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	Were the outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Was appropriate statistical analysis used?	Total Quality Score	Percentage
Badr *et al.* (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	100%
Bedoya *et al.* (2019)	Yes	Yes	Yes	Yes*	Yes	Yes	Yes	Yes	Yes	9	100%
Creutzburg *et al.* (2021)	Yes	Yes	No	Yes*	Yes	Yes	Yes	Yes	Yes	8	89%
Escobar *et al.*(2020)	Yes	Yes	Yes	Yes*	Yes	Yes	Yes	Yes	Yes	9	100%
Heller *et al.* (2020)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	100%
Hwang & Kim (2022)	Yes	Yes	Yes	Yes*	Yes	Yes	Yes	Yes	Yes	9	100%
Imperato *et al.* (2017)	Yes	Yes	Yes	Yes*	Yes	Yes	Yes	Yes	Yes	9	100%
Tygesen *et al.* (2021),	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	100%
Ursolino (2019)	Yes	Yes	Yes	Yes*	Yes	Yes	Yes	Yes	Yes	9	100%
Wu *et al.* (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	9	100%

***No specific reference to a control group, however, there was pre interventional data that served as a control to the post interventional data**

(Tufanaru *et. al. 20*20)

Table 4 JBI Critical Appraisal Checklist for Analytical Cross Sectional Studies (n=2)

JBI Items	Kostakis *et al.* (2021)	Kumar *et al.* (2020)
Were the criteria for inclusion in the sample clearly defined?	Yes	Yes
Were the study subjects and the setting described in detail?	Yes	Yes
Was the exposure measured in a valid and reliable way	Yes	Yes
Were objective, standard criteria used for measurement of the condition?	Yes	Yes
Were confounding factors identified?	Yes	Unclear
Were strategies to deal with confounding factors stated?	No	No
Were the outcomes measured in a valid and reliable way?	Yes	Yes
Was appropriate statistical analysis used?	Yes	Yes
Total Quality Score	7	6
Percentage	88%	75%

(Moola *et al.* 2020)

2.3 Results/Review of the findings

This synthesis involved the juxtaposition of findings from multiple studies, with some analysis of the common themes or findings across studies (Popay *et al. 20*06). Given the methodological and clinical heterogeneity of studies, a meta-analysis was not possible. It was not possible to conduct a statistical comparison between the studies using the mean differences and the standard deviations. Therefore, a narrative approach guided by Popay *et al.* (2006) was used to develop the review.

In regards to the studies that were selected the common factor in the population is that they were all adults and in acute hospitals. They differ in terms of age, diagnosis, morbidity and location in the hospitals i.e. some are in the ED and some in ward areas. Therefore, the population was heterogeneous.

Results from this systematic review were synthesised and it was found that the literature produced some common themes: (i) Five studies included the theme of education and training programmes and their effect on clinician behaviour and consequently patient outcomes, (ii) the effect of various versions of early warning scores and systems on mortality and morbidity of patients was studied in three papers (iii) the predictive nature of the EWS for early detection of patient deterioration was reviewed in one study (iv) One study looked at the reliability of NEWS as an instrument for predicting patient deterioration (V) and the effectiveness of electronic or automated versions of EWS was a theme in three studies. Similarly, measured outcomes were combined where appropriate.

2.3.1 Education and the EWSs/EWSS

The theme of education and training programmes in relation to the EWSs and EWSS and its impact on outcomes was evident in five of the studies reviewed.

Badr *et al.* (2021) evaluated the effect of the NEWS implementation in the identification of patients at risk of deterioration at an Emergency Hospital following a two-month education programme. The study found that the intervention had a statistically significant effect on cardiopulmonary arrest (p=0.03) total acute kidney injury (P=0.03) escalation plan (<0.001) and vital signs measurement (P<0.001). The quasi-experimental design can be used to answer implementation science questions in the absence of randomization. However, a limitation of this design is that it is especially vulnerable to threats to internal validity (Shadish *et al.*, 2002 cited in Miller 2020). Also, the majority of the consented patients were surgical and based in one geographical area of Egypt, therefore results may not be generalizable.

In Haegdorens *et al.* (2019), the implementation of an observation protocol using NEWS in combination with a pragmatic medical response strategy and the provision of education to ward nurses was investigated. There was no statistical difference in the percentage of patients without observations when comparing the control and intervention group, although there was an increase in the documentation of the vital signs. This study also performed post hoc analysis of data from another RCT. This type of analysis has been described as 'data dredging' or 'fishing' and is the weakest type of trial analysis (Friedman *et al.*1996 cited in Barnett and Pihlstrom (2012)). Computerised randomisation procedure and stepped wedges were used and these are studies in which all participants receive the intervention, but in a staggered fashion (Miller *et al. 202*0). This may affect the internal validity of the study i.e. how well a

causal relationship between intervention and outcome can be inferred from the findings (Juni *et al. 20*01 cited in Porritt *et al.* 2014). Also, stepped wedge cluster RCT take longer than similarly sized parallel group RCTs. This increases the chances that secular trends, policy changes, or other external forces impact study results. In addition, imbalanced site assignment can confound results (Miller *et al*. 2020). The resulting confounding between site assignment and time can threaten the internal validity of the study (Miller *et al.* 2020). The implementation of an ED Clinical Triggers program including a comprehensive education process for physicians and nurses and its effect on clinical outcomes was studied in Imperato *et al.* (2017). There was no statistically significant difference in median LOS 3.8 vs 4.0 (*p=0.21*) or time spent in the special care unit (5.0 vs 5.6 days, *p= 0.42*) or in-hospital mortality within 30 days of admission (6% v 5.6%, *p= 0.66*). However, this was a single site study, which limits generalisability, samples were underpowered and patient mortality was only tracked if patient death occurred within the facility. This could have led to an underestimation of the mortality data.

Pre and post intervention self-report questionnaires were completed by nursing respondents following the provision of a short- time nurse education on NEWS2 to facilitate nurse's use of it and the use of a checklist for score calculation in Hwang and Kim (2022). A pragmatic sample was used and such samples are designed to evaluate the effectiveness of interventions in real life routine practice conditions and show real world effectiveness with broader patient groups. Pragmatic trials produce results that can be generalised and applied in routine practice settings (Patsopoulos, 2011). There was a significant (< *p=0.05*) increase in handover quality, teamwork, safety climate, frequency of vital signs recordings and documentation of clinical concerns after NEWS2 use. There was no significant *(>p=0.05*) change: in nurses' patient safety

competency scores, length of stay, clinical deterioration or adverse events. Strengths of this study include the reliable instruments used, samples were powered, patient data was non-subjective, and there was a high response rate. The limitations included that the study was completed at a single site, and the self-report surveys may be subject to recall bias and social desirability bias. Recall bias is a systematic error that occurs when participants do not remember previous events or experiences accurately or omit details: the accuracy and volume of memories may be influenced by subsequent events and experiences (CEBM, 2017). Social desirability bias is the tendency to under report socially undesirable attitudes and behaviours and to over report more desirable attributes (Latkin *et al.* 2017). Also, the post intervention survey was completed directly after the intervention. In addition, there was a high respondent burden and funding was provided in the form of a voucher for each respondent, which might limit the replicability elsewhere.

Wu *et al.* (2021) looked at the effectiveness of the implementation of an electronic version of the NEWS (E-NEWS) including the provision of an education programme (ward by ward) on reducing unexpected clinical deterioration. This study found a significant decrease in adverse events (AEs) from 6.06% to 5.51% (p=0.001), a reduction in cardiac arrests at ward level (0.52% to 0.34% p=0.012) and a reduction in ICU patient transfers (3.63% to 3.49%, p=0.035). However, this data was collected immediately after the intervention period and the education continued during the intensive period, therefore a time series design may have been better for validity. Also, the majority of patients in this study had a diagnosis of cancer and this might limit generalisability.

2.3.2 Effects of the use of various versions of EWS on patient outcomes

The aim of Creutzburg *et al*. (2021) was to assess the incidence of IHCA before and after the implementation of the NEWS system in general hospital wards. This study found that NEWS did not decrease the incidence of IHCA. A strength of this study was that non-subjective patient data was used and missing data was minimised as it was obtained from DANARREST. A limitation was that the study was completed at a single site.

An investigation of the effect on clinical deterioration of the implementation of a regional EWS combined with skin observation, clinical concern and patients and relatives concern, pain, dyspnoea, and team risk assessment was the aim of Tygesen *et al.* (2021). Physicians and nurses were also given a one and half -hour introduction to the model in this study. The findings indicate that there was no statistically significant impact on mortality, ICU, readmissions, or in either 7 to 30 day MR *(>p=0.05*). Strengths of the study included the fact that the sample was powered with a significance level of 80%. It had two control and two interventional groups that strengthen generalisability and no patients were lost to follow up.

Ursolino (2019) sought to determine if the MEWS implementation would reduce the number of adverse outcomes. Although the results were not significant statistically, MEWS demonstrated a reduction in unplanned ICU admissions and unplanned surgery. The proportion of patients requiring a code blue activation significantly increased post the implementation of MEWS (0.98% vs 8.9%). Convenience sampling was used in this study, which limits external validity; however, it can be used when the research does not aim to generate results that will be used to create generalizations pertaining to the entire population (Etikan *et al.* 2016).

2.3.3 Predictive ability of the EWSs

Bedoya *et al.* (2019) determined the effectiveness of NEWS implementation on predicting and preventing patient deterioration in a clinical setting. The study found that NEWS made no difference to the outcomes measured, and that 'Best Practice Alerts' (BPAs) were ignored by nurses. A limitation was that the study population contained a large cohort of transplant patients that may impact on validity. In addition, the study was a retrospective cohort design and these studies lack the rigour of an RCT, however Black (1996) makes the argument that recognition needs to be given to observational quantitative, epidemiological research methods such as cohort and case control studies.

2.3.4 Reliability of NEWS as an instrument

Kostakis *et al.* (2021) looked at the ability of the NEWS or NEWS 2 to discriminate the outcomes of death or ICU admission within 24 hours of vital signs in COVID 19 positive patients. While NEWS2 is now recommended for use, there was no difference in how either one performs. The study investigated the instruments using Area Under the Receiver Operating Characteristic (AUROC) found that both versions performed well as AUROC values ranged between >0.842 to 0.894. A strength of this study was that the sample of patients were recruited consecutively and Blain *et al.* (2019) contends that these samples have the advantage of evaluating a real-world practice. The large dataset of subjective patient data (electronic data collection system) and the fact that all (Vital Pac) data was prospectively collected in a standardised manner were also strengths. Further, there was the use of the control groups for comparison purposes.

2.3.5 Electronic/Automated systems

Remote monitoring by nurses of the records of patients who had been identified as high risk via an automated early warning system, and who then communicated the findings to the RRTs within the hospital was the intervention studied in Escobar *et al.* (2020). Results indicated that in the intervention versus the comparison cohort that ICU admission percentage was 17.7% v 20.9%. The LOS (6.5 days vs. 7.2 days) and MR associated with 30 days after the event reaching the alert threshold was 15.8% versus 20.4%.and this was statistically significant ($p< 0.001$). A strength of this study was the large sample size drawn from 19 hospitals and that data collection was from an electronic health record (EHR), making it a non-subjective data source.

Heller *et al.* (2020) evaluated the effect of deploying an automated MEWS-based early warning system with paging functionality, including telemetry on an at risk population post complex surgical interventions recovering in wards outside the ICU. The results were statistically significant *($p<0.0001$)* for the rate of cardiac arrests dropping from 5.3 vs 2.1 per 1000 admissions. In addition, unplanned ICU admissions reduced from 3.6% to 3% (*$p< 0.001$*). There was no changes found in the MRs between the groups. However, the study used retrospective databases and these are designed to analyse pre-existing data, and are subject to numerous biases as a result(Nickson, 2020). Therefore, these studies are an inferior level of evidence compared with prospective studies (Nickson, 2020).

Kumar *et al.* (2020) studied the effect of an electronic warning system available via electronic medical records, and the introduction of the MEWS system on the early detection of patients who present with acute deterioration. This study indicated a misclassification rate of 0.29 (CI 0.24 to 0.35) with this association. The high

misclassification rate indicates MEWS did not provide discriminatory support for patients at risk for mortality. The results indicated that increasing MEWS were clinically, but not statistically associated with prognosis ($p = 0.0107$). Also, the misclassification rate of 29 suggested poor calibration using MEWS as a tool to predict mortality. A limitation of the study was that it was a single site using consecutive sample of patients, which may impact on generalisability.

This dissertation now moves onto the conclusion on the reviewed studies, relevance to quality improvement and implications for practice.

Chapter 3 Discussion /Summary of the findings

The purpose of this chapter is to provide the reader with a conclusion on the reviewed studies as well as discussing their relevance to quality improvement. Recommendations and application to practice are discussed as well as strengths and limitations of the review. It also points to where future work is required.

This systematic review aimed to synthesise evidence from 13 studies that assessed the effect of the interventions used to assist staff recognise patient deterioration in wards/ED units of acute hospital settings. The results of the review may be varied but in the main, there is a positive correlation with improved outcomes and the use of EWS/MEWS/NEWS/NEWS2. Since previous systematic reviews were completed, and after the first cases were identified in Wuhan (China) in December 2019, the novel coronavirus SARS-CoV-2 caused a pandemic of respiratory illness named COVID-19 (Covino *et al.* 2020). The pandemic has challenged and had an impact on healthcare settings worldwide. Globally, as of 17 June 2022, there have been 535,863,950 confirmed cases of COVID-19, including 6,314,972 deaths, reported to the World Health Organisation (WHO) (WHO, 2022). In this review, it was found that one study (Kostakis *et al.* 2021) had focused on the effectiveness of NEWS and NEWS2 in identifying patient deterioration in COVID Positive patients. The study investigated the instruments using AUROC found that both versions performed well in predicting patient deterioration.

Failure to recognise physiological deterioration, undertake prompt clinical assessment, and instigate timely intervention results in increased rates of cardiac arrest and unplanned intensive care admissions (Smith *et al.* cited in Credland *et al.* 2021). Early warning systems (EWSS) were developed, adopted and widely mandated to assist in

the detection of acute deterioration (Gerry *et al.* 2020). It has been demonstrated that high scores of NEWS/NEWS2 at admission are associated with deterioration of patients and poor clinical outcomes (Gidari *et al*. 2020). However, following decades of research on recognition and response to clinical deterioration, raised international awareness and implementation of new models of response, the problem of failure to rescue remains (Bucknall *et al.* 2022).

The overall benefit of EWS in these studies was mixed and in some instances conflicting. A number of studies found that NEWS did not have an effect on patient outcomes, e.g., Badr *et al* (2021), Creutzburg *et al.* (2021), Bedoya *et al.* (2019), Kumar *et al.* (2020), and Imperato *et al.* (2017). Further studies found that the implementation of EWSs did have a statistically significant effect on patient outcomes, e.g. Escobar *et al*. (2020), Heller *et al*. (2020) and Wu *et al.* (2021). The remaining studies showed mixed findings, e.g., Haegdorens *et al.* (2019), (Hwang and Kim 2022), and Tygesen *et al.* (2021) and Ursolino (2019).

Much of the studies had similar findings; all NEWS instruments/versions in the main did the same thing i.e. improved survival rates. Therefore, although the results of the studies were mixed, (as in McNeill and Bryden (2013), Alam *et al.* (2014), Smith *et al*. (2014), Jayasundera *et al*. (2018), Gerry *et al*. (2020), and Credland *et al*. (2020)) the majority of the studies indicated that there was a positive trend towards better clinical outcomes.

This systematic review concurs with previous literature that failure to recognise and respond to patient deterioration and escalate care led to an increased risk of adverse events (AEs) in hospitalized patients that may have been avoided if patient deterioration had been recognized and responded to earlier (Massey *et al.* 2014, cited in Massey *et al.* (2017). Recent research also suggests that early identification and

management of critically ill adult patients admitted to general hospital wards may prevent in-hospital mortality, unplanned intensive care unit (ICU) admission and decrease hospital length of stay (LOS) (Gielen *et al.* 2021). Rosero *et al.* (2021) contend that early recognition through bedside and remote monitoring is the first step toward prevention of "failure to rescue" followed by rapid response initiatives and timely escalation of care.

3.1 Strengths

This systematic review updates previous systematic reviews such as (McNeill and Bryden (2013), Alam *et al*. (2014), Smith *et al*. (2014), Jayasundera *et al.* (2018), Gerry *et al.* (2020), and Credland *et al.* (2020)). It comprehensively identifies methodological issues that may contribute to biases using the JBI Critical Appraisal checklist tool.

3.2 Limitations

This review is restricted by the limitation on language, which could potentially bias its publication. The fact that all studies were in the main performed in single sites and often-involved specific patient subgroups, means that the application of the findings may not be generalizable to the other acute care sectors or to the Irish acute hospital settings. Bedoya *et al.* (2019) Escobar *et al.* (2020) and Haegdorens *et al.* (2019) were performed at multiple sites and therefore may have better external validity. In addition, the potential contribution that the included non-randomised studies can make to the evaluation of the effectiveness of healthcare interventions has generated considerable debate as discussed in (Sedgwick, 2014). However, based on the results from the

individual studies, the use of EWSs and EWSS on clinical and safety grounds for improving responses to patient deterioration may be appropriate.

3.3 Recommendations

Future research may need to stop focusing on which EWS version is more effective, but focus more on how to educate future health professionals on using EWS or to establish why it is not proving effective in some instances/clinical settings. This research should capture whether the various EWSs and EWSS are being implemented as per the guidance protocols and that appropriate responses are being triggered. When this data is gathered, a review of reasons why non-adherence occurred should also be explored. The move towards electronic implementation of EWSs presents an opportunity to introduce better scoring systems, particularly with the increasing interest in modern model building approaches, such as machine learning and artificial intelligence (Gerry *et al.* 2020). Three of the studies in this systematic review described electronic monitoring systems with mixed results.

When this author completed an audit in the Irish Healthcare setting (HSE, 2018), a finding of non-compliance was found in relation to the 'recording, scoring and totalling of the seven patient observations on the NEWS chart in three of the eight hospitals audited'. This would point to the fact that the EWS was not being implemented as planned. This possibility of a difference between policy and practice is also alluded to in Credland *et al.* (2019). The literature indicates that although guidelines may be seen as important tools that support decision-making, in conjunction with clinical judgement and patient preference, that there is still a lack of adherence to guidelines worldwide across different conditions and levels of care

(Pereira *et al.* 2022). Furthermore, as unexpected cardiac pulmonary arrest is the ultimate deterioration, research on what has happened in the hours or period prior to the arrest as regards to adherence to EWSs and the EWSS guidance/protocols should be studied. Rapid response systems (RRS) consist of an afferent limb with a track-and-trigger system based on vital signs to identify deteriorating patients early and trigger a call to the efferent limb, usually a Medical Emergency Team (MET)(Sørensen and Petersen, 2015). Data on whether the EWSs were totalled accurately and completed within the agreed time frames for the patients acuity and where the scores are increasing, whether the patient care is being escalated appropriately and in a timely manner should be explored. Identification of the deteriorating patient, communication with a senior, and an adequate management plan are all elements on the chain of escalation that, if broken could lead to delays in the patient receiving appropriate care (Johnston *et al.* 2015). Further RCTs in this area might shed light on the nature of the lack of an optimal clinical response. While this review provides areas for improvement, this failure to respond to deterioration remains topical and future research should capture if EWSs and EWSS guidance and protocols are being adhered to as care of the deteriorating patient remains sub optimal.

In addition, the value of clinical audit of the deteriorating patient should be considered. Clinical audit is a clinically led quality improvement process that seeks to improve patient care and outcomes through systematic review of care against explicit criteria and acting to improve when standards are not met (NOCA, 2022). A recent deteriorating patient audit feasibility report (Kehoe *et al.* 2022) points out that the international literature recognises in-hospital cardiopulmonary arrest and unplanned admission to ICU as measures suitable for clinical audit for capturing and improving the clinically deteriorating patient pathway. It also clarifies that the UK and Northern

Ireland have national audits of in-hospital cardiac arrest. However, this data is not currently captured in the Irish healthcare setting. This represents an opportunity to adequately capture the scale of this issue in the acute healthcare setting in Ireland. As part of IHI's 100,000 Lives Campaign, some 1,500 hospitals are now actively using and/or implementing RRTs. Cardiac arrest rates, MRs, and lengths of stay in the intensive care unit (ICU) are dropping, and hospitals with RRTs are moving their cultures toward a team-based approach to clinically challenging situations (IHI, 2019). Therefore, research data of challenges and opportunities that might arise within team cultures when implementing EWSs and EWSS would also provide an opportunity to establish if this area can be improved.

3.4 Conclusion

The results of this review will help build on previous research and offer up to date evidence for policy development and healthcare professionals using and implementing EWSs/EWSS in the acute hospital setting. For improvements to be achieved in clinical practice, a continued need to support and educate healthcare staff on these systems remains a priority. This review indicated that there is conflicting evidence in relation to the use of EWSs and EWSS in assisting healthcare professionals in the early recognition of patient deterioration with the aim of improving patient outcomes.

This chapter provided the reader with a conclusion on the reviewed studies as well as discussing its relevance to quality improvement. Recommendations and application to practice were discussed as well as strengths and limitations of the review. It also points to where future work is required.

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Appendix I: Literature Searches

CINAHL Search
Completed 19/04/22

15	S8 AND S10	Limiters - Full Text; Published Date: 20170101-20221231; English Language; Peer Reviewed; Exclude Pre-CINAHL; Exclude MEDLINE records; Evidence-Based Practice; Age Related: All Adult: Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	32
S14	S8 AND S10	Limiters - Full Text; Published Date: 20170101-20221231; English Language; Peer Reviewed; Exclude MEDLINE records; Evidence-Based Practice Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	68
S13	S8 AND S10	Limiters - Published Date: 20170101-;20221231 English Language; Peer Reviewed; Exclude MEDLINE records; Evidence-Based Practice Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	71
S12	S8 AND S9	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	5
S11	S8 AND S10	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search	119

			Database - CINAHL Plus with Full Text;MEDLINE	
S10	hospitalisation OR inpatient*	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	562,851
S9	"randomised controlled trial*" OR RCT OR "interventional Stud*"	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	103,947
S8	S5 AND S6 AND S7	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	343
S7	S1 OR S2	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	7,054
S6	S3 OR S4	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	8,325
S5	AB (outcome* OR mortality) OR TI (outcome* OR mortality)	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	3,500,831
S4	AB ("patient deterioration" OR "clinical deterioration") OR TI ("patient deterioration" OR "clinical deterioration")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	7,778

S3	(MH "Clinical Deterioration")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	1,028
S2	AB ("early warning scor*" OR "early warning system" OR "track and Trigger*" OR EWS OR "Early Warning System*") OR TI ("early warning scor*" OR "early warning system" OR "track and Trigger*" OR EWS OR "Early Warning System*")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	6,997
S1	(MH "Early Warning Score")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL Plus with Full Text;MEDLINE	411

Medline Search
Completed 19.04.2022

S18	S13 OR S14	Limiters - Scholarly (Peer Reviewed) Journals; Date of Publication: 20170101-20221231 Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	69
S17	S13 OR S14	Limiters - Date of Publication: 20170101-20221231 Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	70
S16	S13 OR S14	Limiters - Date of Publication: 20170101-20221231 Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	70
S15	S13 OR S14	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	82
S14	S8 AND S11	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	28
S13	S7 AND S12	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	54
S12	S6 AND S11	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	249
S11	S5 OR S9 OR S10	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	4,693
S10	S3 OR S4	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,805

S9	S1 OR S2	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,295
S8	(MH "Mortality")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	48,759
S7	(MH "Heart Arrest") OR TI (ICU admission OR intensive care admission) OR AB (ICU admission OR intensive care admission)	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	62,135
S6	(MH "Treatment Outcome") OR "patient outcomes"	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,176,541
S5	AB (Early warning scor* OR EWS) OR TI (Early warning scor* OR EWS)	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	3,062
S4	"early warning system"	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,682
S3	"track and trigger"	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	138
S2	"early warning score"	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	1,295
S1	(MH "Early Warning Score")	Expanders - Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - MEDLINE	308

Cochrane Library Search

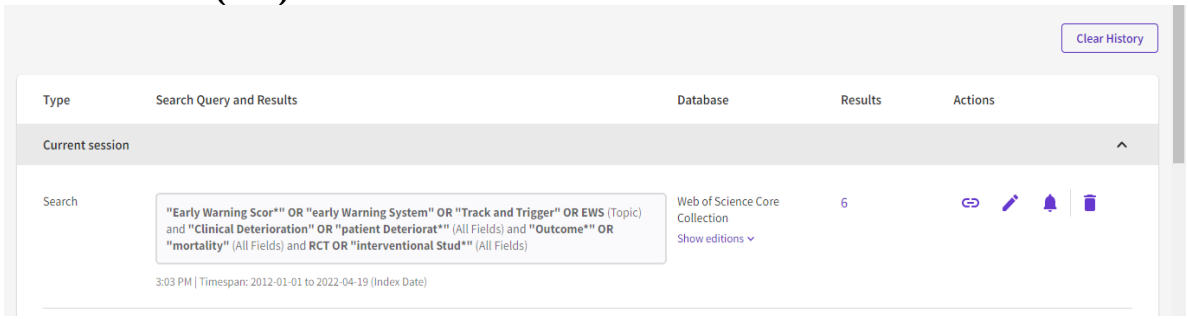
Search Name: EWS Cochrane search to April 2022
Date Run: 19/04/2022 13:22:49
Comment:

ID	Search	Hits
#1	(*early warning score):ti,ab,kw (Word variations have been searched)	273

Embase Search

#1('early warning scor*' OR 'early warning system*' OR 'track and trigger' OR ews OR 'patient deterioration':ti OR 'clinical deterioration':ab,ti) AND [2017-2022]/py 210

Web of Science (n=6)



Scopus

Search performed on 19th April 2022.

Both these searches identified papers that were added to Covidence as with the other databases.

Appendix II (Study Characteristics)

Table 5: (n=13)

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
1	Badr *et al*. 2021	To evaluate the effect of the NEWS implementation in patients at risk of deterioration.	Prospective, control/intervention groups, with quasi-experimental design. Randomisation of patient's to either group. Implementation of a nursing EWS. **Data collected** Socio-demographic, medical datasheet, observational checklist for patient outcomes & vital signs. Control group July 2018 to February 2019. Intervention between December 2018 and February 2019. All study patients followed to either discharge or death. Evidence of medical review by nurses following clinical deterioration and length of stay (LOS).	One study site: Inpatient unit in Emergency hospital in Egypt Sample 300 required by power analysis. N=364 adult. Randomly assigned to intervention group (N=174) and control group (N=190) **Inclusion:** consented adults; not a readmission, nurse patient ratio: 3/1.	**Dependent Variables**: Cardiopulmonary arrest, Unplanned ICU admissions Emergency surgery Unexpected death Acute kidney injury Escalation plan.	Patient's demographic and medical data sheet. NEWS scale per parameter. Respiratory rate (RR). Oxygen saturation. (O_2 Sats) Temperature (Temp). Systolic BP (SBP) Heart Rate (HR) Level of consciousness (LOC) Rated 0-3. Scores summed, used as a parameter of clinical risk for each patient **Low risk** 0-4. **Medium risk** >5 or 3 in one parameter. **High risk** >7, escalation protocol activated.	Descriptive analysis: Standard deviations, independent t-test, chi Square test. Significance was set at the 5% level (P = 0.05).	**Comparison between the control and study groups** **1.** Cardiopulmonary arrest (4.7% vs 1.1%, p = 0.046). 2. Emergency surgery (6.3% vs 0%, p=0.001). 3. Unplanned ICU admission (5.3% vs 1.7%, p= 0.049). 4. Acute kidney injury (6.8% vs 1.1%, p= 0.006). 5. Escalation Plan (3.2% vs 26.4%, p = <0.001). Logistic regression - intervention statistically significant effect on 1. Cardiopulmonary arrest (p=0.03), 2. Total AKI (p=0.03), 3. Escalation plan(<0.001), 4. Vital sign measurement (P<0.001).	**Generalisability of the findings:** *Strengths:* Reliable instruments used (tested for reliability utilizing inter rater-reliability with Krippendorff's alpha. Design q-experimental design *Limitations* Sampling: The majority of the consented patients were surgical and based in one geographical area of Egypt, therefore results may not be generalizable. *Usefulness to practice*: Could be replicated in an ED unit in similar hospital as tools could be used in other settings.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
2	Bedoya *et al*. 2019	To determine the effectiveness of NEWS on predicting and preventing patient deterioration in a clinical setting.	Retrospective cohort study (quasi-experimental study design). **Intervention:** Implementation of the NEWS with Electronic Health Record (EHR) and automated Best Practice Alert (BPA). **Data collection**: via the EHR at both sites. Both groups were followed to discharge/ICU transfer/ death. **Timelines:** pre-implementation of NEWS March 1, 2014 to February 28 2015. **Implementation of NEWS period:** August 1 2015 to July 31 2016.	Two sites USA 1) Academic hospital (2/3 of the study population) 2) Community hospital. N=85,322 **Pre implementation of NEWS - control** N=42,402. **Implementation of NEWS - study group** N=42,920. Patient's records reviewed using the EHR. **Inclusion:** Patients' ≥ 18 years hospitalised during the periods above.	**Dependent variables**: In-patient mortality Unanticipated transfer from ward to ICU before and after implementation of BPA Nurse response to the BPA Predictive performance of NEWS Association between NEWS and patient outcomes.	**NEWS parameters**: SBP RR HR Temperature, O2 Sats Supplemental oxygen LOC. A BPA when NEWS reached 7 threshold. Fine and Gray method to estimate sub distribution hazard ratio (HR). Predictive value of NEWS determined using the c statistic & calculated at discrete time periods, i.e. NEWS over 12 hour increments from admission to 7-day stay. Presence of an event over 48 hours was assessed and over discrete 4-hour increments.	R version 3.2.1. Stratified by hospital facility. Logistic regression model to test goodness of fit. HR - 95% CI, Chi square tests and Wilcoxon Rank Sum test used to calculate the differences between the patient characteristics during the pre/post periods. Unadjusted incident rates per 100 hospital days.	Stratified by hospital: NEWS made no difference to outcomes measured and BPAs ignored by nurses. 1. ICU transfer & death adjusted HRs of 0.94 (0.84, 1.05) 0.90 (0.77, 1.05) based on 95% CI. 2. 177,352 BPAs were made. BPAs were ignored 86% of the time & performed better at community hospital predicting an event within 12 hours. Patients at the academic centre more likely to have an event within 12 hours once nurses had accepted the BPA compared to when they were ignored with an odds ratio of 1.23. 3. NEWS predictive performance ranged 072-0.80 and 0.74 and 0.90 for the academic and community facility (based on c statistic).	**Generalisability of the findings:** *Strengths:* Large sample from two hospitals. Performed as part of EHR data collection, so non-subjective. *Limitations:* Retrospective cohort study lacked the rigour of an RCT. Population contained a large cohort of transplant patients that may impact on validity. *Usefulness to practice:* Study carried out using an EHR and could limit repetition.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
3	Creutzburg *et al.* 2021	To assess the incidence of in-hospital cardiac arrest (IHCA) before and after the implementation of NEWS.	Pre and post study conducted as a retrospective quality assurance study based on IHCA data pre 2017. 2012 IHCA data excluded to avoid bias. **Intervention:** implementation of NEWS and impact of CA.	One acute hospital in Denmark. Patients ≥18y N=938 patients **Pre EWS** 2006-2011 (N=444). **Post EWS** 2013-2018 (N=494). Followed up to death/discharge.	Implementation of the NEWS on general ward **Primary outcome** Incidence rate of IHCA **Secondary outcome:** Return of spontaneous circulation (ROSC).	Descriptive statistics: P-values at <0.05. Pre and post EWS compared by incidence rate ratio (IRR), reported as IHCA per 1000 admissions, 95% CI. NEWS vital signs: RR arterial O_2 saturation, HR SBP AVPU Temp.	R version 3.6.2 and Rstudio version 1.2.5033. Incidence rate ratio (IRR) Significance set at p-value <0.05.	NEWS did not decrease the incidence of IHCA in general wards 1. Rate of IHCA 1.13 vs 1.11. IIR between two groups 0.98 (95% CI [0.86 1.11], p=0.71) 2. ROSC 1.14(95% CI [0.88, 1.47], p=0.32). 3. 30 day MR 1.30 (95% CI [0.96, 1.75] P =0.09).	**Generalisability of the findings.** *Strengths:* Non-subjective patient data. Missing data minimised (4% of the registered IHCA had missing data). *Limitations:* One hospital site used limiting generalisability. *Usefulness to practice:* Study replication challenging unless hospitals had access to an IHCA registry.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
4	Escobar *et al.* 2020	To establish whether the outcomes of patients who reached an alert threshold were improved by the implementation, involving remote monitoring (Advance Alert Monitor) (AAM) by nurses who communicated findings to rapid response teams.	An interventional study: outcomes at sites with program operational (intervention population) was compared with outcomes at sites with no program. **Intervention**: Remote monitoring by nurses who reviewed patients identified as being at high risk via an automated EWS. **Data collection** via the EHR at all sites. Both groups followed up to ICU transfer, discharge or death.	N= 37,071 - 19 hospitals in the USA using the EPIC EHR system **Interventional cohort** N= 13, 274 patients ≥18 y. **Comparison cohort** n=23,797 Included patients admitted to any of the study hospitals in the year preceding the introduction of the intervention (historical controls). 548, 838 patients admitted to a ward or step down area, and 43,949 (7.1%) reached the alert threshold. **Study period** 1/08/2015 to 28/02/2019.	**Dependent Variable:** mortality within 30 days following an AAM at ward level. **Secondary outcomes** included, LOS, ICU admission, & favourable status at 30 days (patient alive, not in hospital, and not having been hospitalised) was analysed post hoc.	Rate of deaths expressed per 1000 patients. CI 95%. Binary outcomes: mortality, ICU admission & favourable status within 30 days using a Poisson distribution. Competing- risk Cox proportional hazards model to assess effect on LOS. Hazard rate refers to intervention instantaneous rate of discharge divided by the instantaneous rate of discharge in the comparison group. Models applied to 1000 bootstrap samples	R software, Version 3.5.2, and SAS software Version 9.4 (SAS Institute) Two sided P value 95% CI used	Intervention V comparison cohort: 1 ICU admission (17.7% v 20.9%). 2 LOS (6.5 days vs. 7.2 days). 3 MR associated with 30 days after event reaching alert threshold (15.8%vs 20.4%) (P< 0.001) & an absolute difference of 3.8 percentage points.	**Generalisability of the findings:** *Strengths:* Large sample size drawn from 19 hospitals. Data collection from EHR non-subjective & analysis adjusted for severity of illness. *Limitations:* Generalisability of cohort as the sample was insured patients only and may not be representative of general population. *Usefulness to practice* Large study involving 19 hospitals, plus two pilot sites and grant aid supported. Similar resources required to replicate study.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
5	Haegdorens *et al.* 2019	To investigate the impact of the NEWS on the frequency and quality of vital sign recording and the association between nursing compliance with NEWS and patient mortality	Post hoc analysis of data from a stepped wedge cluster RCT in 6 hospitals. 5 periods (each period 4 months, October 2013-May 2015). Phased introduction of the **intervention** – Standardised observation protocol based on NICE Guidelines using NEWS combined with a medical response strategy from the Royal College of Physicians. Observation protocol using NEWS in combination with a pragmatic medical response strategy at ward level. Hospitals integrated the NEWS into patient record Hospital management blinded for the intervention date. Ward staff made aware of inclusion 2 weeks prior to commencement of the intervention.	6 acute hospitals, Belgium. **Inclusion:** non-pregnant & ≥17 years admitted to 24 wards from October 2013 to May 2015 N = 60, 956, N= 32, 722 were in the intervention group. Cross sectional sample of patients sampled every 4 months for comorbidity scores (n= 3,600) and vital signs (n=2951). Block randomisation method. <u>Cross sectional sample</u> N= 2,951. Control, N= 1361. Cases N=1590 Up to 24 hr before SAE – **Control N=266** **Cases N=402.**	**Dependent variables:** Unexpected death, CA with CPR, Unplanned ICU Admissions, Registered vital signs, Comorbidity scores, Mean comorbidity index (CCI).	CCI, Temperature, SBP, HR, O2 , RR, LOC NEWS score, Supplemental oxygen.	SPSS Version 24 Patient outcome measure presented per 1000 patient admissions. Pearson's Chi squared test used to test all proportions between two or more groups. Linear regression used to show association between protocol compliance MR per 1000 admissions	1 Unexpected cardiac death rates 0.6 per 1000 admissions (0.451, p=0.027). 2 Unexpected CA with CPR rate 1.0 per 1000 admissions (P= 0.469). 3 Unplanned ICU admissions: rate 10.7 per 1000 admissions. 4 LOS: In the cross sectional, sample significantly shorter than intervention group 11.2 vs 14.4 days. Increase in LOS in patients in the intervention group up to 24h before SAE, 5 SAE occurred more frequently in interventional group. Significant negative association between percentage protocol compliance & combined MR, was 2.1 per 1000 admissions (p= 0.080). 6 No statistical difference in patients without observations when comparing the control and intervention groups. Increase in registration of all 6 vital signs and supplemental oxygen.	**Generalisability of the findings:** *Strengths:* *Sample* Computerised randomisation procedure used, treatment groups, and control groups chosen entirely by chance, therefore, good for generalisability. Data collection: non-subjective patient data used via the Standardised electronic checklist used to collect data. *Limitations:* Design: stepped wedge cluster RCT can take longer than similarly sized parallel group RCTs. Intervention patients younger than control group. *Usefulness to practice* Post hoc analysis of data and outcome measures limited applicability Study took considerable time.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
6	Heller *et al.* 2020	To evaluate the effect of deploying an automated MEWS with paging functionality, including telemetry on an at risk population post complex surgical interventions.	Interventional study: retrospective 12 month data review using 4 routine databases and measurement logs of the deployed system (intervention phase only) . **Intervention:** 1/07/2016 to 30/06/2017. **Control**: patients on the 4 databases before the deployment of the system Data from 01/01/2015 to 31/12/2015 followed to death/discharge.	One site Germany University Teaching Hospital. N=3827 patients from 2 surgical wards comprised of: N=1896 in control setting and N=1931 in interventional cohorts Two 12 month observation periods	**Independent Variables**: automated MEWS with paging functionality. **Dependent Variable**: rate of cardiac arrests per 100 admissions. Percentage of unplanned ICU admissions. Rate of notification of critical conditions to the ward surgeon.	RR, O2 sats, Supplemental oxygen, Temp, SBP HR, LOC Team concern. <u>MEWS scoring Sheet:</u> MEWS 1-4 nurses informed and next set of observations measurement scheduled for between 4-6 hours. MEWS 5 or 6: ward physician and nurse informed. MEWS ≥7 ward physician automatically paged to assess the patient.	SPSS version 24 used. P significance set at P<0.05. 2 tailed unpaired t tests performed for comparisons of interval scaled variables between the two observation periods. Mann-Whitney U test applied to non-parametric group testing Fisher exact test to nominal scaled data. X^2 test to nominal scaled data. Statistical comparison between the 2 observation periods was completed.	**1** Rate of cardiac arrests dropped: 5.3 vs 2.1 per 1000 admissions, (p<0.0001). **2** Unplanned ICU admissions 3.6% vs 3% (p< 0.001). **3** No changes found in the MRs between the groups. **4** German diagnosis related groups (DRG) case weight intervention were higher in the intervention period. Increase in notifications of critical conditions to surgeons (N=118).	**Generalisability of the findings:** *Strengths:* Non-subjective patient data used. *Limitations:* One site and retrospective data used. Patient characteristics differed between the two observation phases, which may threaten internal validity. *Usefulness to practice:* Data on LOS, ICU admissions, age, sex, survival G-DRG-codes and case weight from ORBIS hospital information system. Data on comorbidities extracted from anaesthesia information system. ICG database provided data on MEWS and physiological parameters. Study could be replicated elsewhere if similar databases in use.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
7	Hwang, and Kim, (2022)	To examine the impact of using an EWS for patient handover.	A before and after study. **Intervention**: provision of a short- time nurse education on NEWS2 to facilitate nurse use and use of a checklist for score calculation (June 4, 2019 to June 30 2019). **Pre-intervention**: self-report questionnaire survey conducted 09/05/2019-22/05/2019. **Post intervention** questionnaire conducted 25/06/2019-5/07/2019. Medical record randomly selected for review for the pre and post sample	One site: Seoul, South Korea. 128 patients needed to attain 80.0% power at a 5.0% level of significance. N = 388 patients enrolled from 3 general wards (188 before EWS and 200 after EWS. Nurses pre N=90/post N=89.	Patient safety competency Handover quality Teamwork (structure, leadership, communication, mutual support, situation monitoring), Safety climate Clinical judgment Patient deterioration NEWS2 score 2 at 24 hours post admission, NEWS2 score of 0 or 1 at admission, increased NEWS2 risk category of 1 at 24 hours after admission, Adverse events In-hospital mortality, Unplanned admission to ICU cardiopulmonary resuscitation (CPR).	Health Professional Education in Patient Safety Survey (H-PEPSS): 16 items: 5 point Likert scale. Patient handoff quality assessment tool: 12 items, 4 point scale. Teamwork Perceptions Questionnaire: 35 items, 5-point Likert scale. Safety Attitudes Questionnaire 5-point Likert scale. Clinical judgement scores based on changes in breathing, changes in circulation, rigors, changes in mentation, agitation, pain, no progress, patients' comments, subjective nurse observation. Clinical deterioration LOS, Discharge status, Adverse events.	SAS Version 9.4. used. Statistical significance set at P<.05. Independent t-tests to identify differences in frequencies of vital signs recording, clinical concerns and LOS. Chi-square tests for identification of differences in clinical deterioration, discharge status and adverse events.	1. Significant (< p=0.05) increase in handover quality, teamwork, safety climate, frequency of vital signs recordings and documentation of clinical concerns after NEWS2 use. 2. No significant (>p=0.05) change: in nurses' patient safety competency scores, LOS, clinical deterioration or adverse events.	**Generalisability of findings** *Strengths:* Reliable instruments used, samples were powered, non-subjective patient data and a high response rate. *Limitations:* One hospital site, self-report surveys may be subject to recall and social desirability bias. Post intervention survey completed after the intervention (time series design may have been stronger). *Usefulness to practice:* High respondent burden, funding for voucher for each respondent, similar resources may be required if replicating.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
8	Imperato *et al* 2017	To determine if a clinical triggers program with predetermined abnormal signs to activate a rapid assessment team had a measurable effect on clinical outcomes.	Retrospective pre and post intervention study. **Intervention:** implementation of an ED clinical triggers program including comprehensive education process for physicians & nurses (10/07/2011-10/07/2012) (pre-intervention period) 10/07/2012-9/07/2013 (post intervention period) All patients followed up to death or discharge	Powered sample. One site: N=73,965. Community teaching hospital, USA. Patients ≥18y presenting to the ED. N= 37,740 pre intervention – N=36,225 post intervention. Patients included major trauma, cardiac arrest, stroke, acute ST elevation.	**Dependent Variable:** inpatient days before and after implementation of the triggers programme. **Secondary outcomes**: days spent in special care unit. 30 day in hospital mortality Frequency of upgrade in level of care once admitted.	Trigger patients met the following criteria: HR<40 or>130 beats/minute, RR <8 or>30/minute SBP <90mmHg, O2 sats <90% on room air. Alert occurred if any patient met the specified vital sign criteria.	Descriptive analysis: Median inpatient days for all, unit & ward admissions compared before and after the intervention. Significance at the 5% level (p=0.05). Chi square test used to compare pre and post groups. Fishers exact test to measure the frequency of trigger criteria and patient variables The differences in MR Upgrades in levels of care compared with t-test.	No difference in: 1. Median LOS 3.8 vs 4.0 (P=0.21), 2. Median days spent in special care unit (5.0 vs 5.6 days, p= 0.42) 3. In-hospital mortality within 30 days of admission 96% v 5.6%, p= 0.66). There was a decreased rate of upgrade in level of care from the Step Down Unit to ICU within 24 hours of admission (4.9% vs. 4.5, p=0.52) or anytime during admission (10.1 % vs 6.2%, p =0.16), but this was not significant. Patients less frequently met trigger criteria in the post intervention period 3.1% vs. 3.7%).	**Generalisability of the findings:** *Strengths:* Non-subjective data used, patient data retrieved from hospitals health care analytic system so all patients captured. *Limitations:* Single site, samples were under powered, patient mortality only tracked if patient death occurred at site could lead to underestimation of the mortality data. *Usefulness to practice:* Data extracted from hospitals analytic system, similar resources may be required to replicate study.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
9	Kostakis *et al.* 2020	To evaluate the ability of the NEWS or NEWS2 to discriminate the outcomes of either death or ICU admission within 24 hrs of a vital sign set in 5 different patient cohorts including a COVID 19 positive cohort & 4 control cohorts.	Area under the receiver operating characteristic (AUROC) used to determine if there was a difference in how both instruments (NEWS and NEWS2) performed. **Intervention:** Implementation of NEWS2 in context of Covid NEWS2 implemented on 5 February 2019. All patients followed up to ICU admission/death.	One study site: Acute hospital, United Kingdom. N= 60, 436 Patients' ≥16y consecutively admitted between 01/01/2018 & 04/05/2020. COVID 19 positive cohort & 4 control cohorts (1 from 2018, 1 from 2019 and 2 from 2020).	**Dependent Variable**: Admission to ICU and mortality within 24h of a vital sign set, identified from the hospitals administration system & ICU admission database.	HR RR SBP Temp, Neurological status using either the AVPU S_pO_2,	R v 3.6.0 statistical computing. Descriptive statistics: means, medians (IQR, Q1-Q3) and proportions. Proportions compared using chi squared test. Mean values compared using one way ANOVA & Scheffe's tests and median values compared using Kruskall_Wallis & Dunn's test.	No discernible difference between NEWS & NEWS2 and no rationale for changing to NEWS2. 1. Both versions performed well (ranged between >0.842 to 0.894). **2.** Significantly lower AUROC value of 0.842 (0.829-0.855) between Control 2019 & Covid not tested group. Difference was attributed to the influence of differing pressures on clinical services & possibility of change from NEWS to NEWS2 from 06/02/2019.	**Generalisability of the findings:** *Strengths:* Large dataset of subjective patient data prospectively collected in a standardised manner. Use of the control groups for comparison. *Limitations:* Control group from 2019 may have had COVID 19 positive patients as uncertainty regarding the location and date of the index case of Covid. *Usefulness to Practice* Implementation of NEWS2 in context of Covid. Study could be completed/replicated at other sites with similar electronic vital sign data.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
10	Kumar *et al.* 2020	Evaluation of the MEWS scoring following the System wide implementation of the electronic warning system available via the Epic electronic medical record.	Retrospective study. Intervention: Evaluation of the MEWS scoring system used as part of a bedside evaluation for unplanned escalation of care in surgical patients using an EWS via the Epic electronic medical record.	Single site, Acute hospital, USA. N=263, Consecutive admissions from ward to the surgical intensive care unit (SICU) Inclusion: ≥ 18 y unplanned surgical admissions to the SICU 2016. Complete dataset as records electronic.	Dependent Variable: mortality following unplanned escalation of care in surgical patients.	Data set from the Epic electronic health record. Extraction of calculated MEWS values during bedside evaluation before unplanned SICU admission.	Descriptive analysis: JMP 13.2 SAS. Statistical program calculated that the optimum cut off point of the MEWS was 3. Logistic regression used for association of MEWS and mortality. Discriminatory ability was analysed with C-statistics. Predictive accuracy was analysed with misclassification rates. CIs of 95%. Significance set at P< 0.01. Chi squared tests Internal validation with bootstrapping to determine probable population values.	1. Increasing MEWS were clinically but not statistically associated with prognosis (P =0.0107) 2. Incidence of mortality was 29.3% (CI 24.1% to 35%) 3. Unadjusted odds ratio per unit of change of 1.2 (CI 1.1 to 1.5) & a satisfactory C-index value of 0.60 (CI 0.54 to 0.66). 4. Probability for MRs for the MEWS ranged from 22% to 57%. 5. Misclassification rate of 29 (CI 0.24 to 0.35) suggesting poor calibration using MEWS as a tool to predict mortality 6. Model sensitivity 0.984 (CI 0.97 to 0.996) specificity of 0.052 (CI 0.019 to 0.080). 7. Kappa Value 0.049 (CI-0.015 to 0.103). Youden J value 0.036 (CI 0.01 to 0.08)	Generalisability of the study *Strengths:* Non-subjective electronic patient data with a 100% dataset. Use of misclassification rates. Measures of effect size and C-statistic to indicate discriminative ability. Bootstrapping to determine probable population values. *Limitations:* single site using consecutive sample of patients may impact on generalisability. *Usefulness to Practice:* Similar study could be replicated if hospitals have access to a similar electronic record and dataset for EWS.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
11	Tygesen *et al.* 2021	To investigate the effect of a situational awareness (SA) model on clinical deterioration in ED patients including EWS with objective and subjective parameters.	Controlled pre and post study. **Intervention**: regional EWS combined with skin observation, clinical, patients and relatives concern, pain dyspnoea, and team risk assessment. Prior to the start nurses were given a 1 ½-hour introduction to the SA model, including the team risk assessment underpinning the process of deterioration. Physicians were given a ½-hour introduction. **Data collection:** retrospective data via the EHR. Prospective data collection completed using the Danish civil registration number. Mortality data from the Danish Civil Registration System.	One site, ED department, acute hospital, Denmark. 34,556 patients: N=16,392 patients in the pre period and 18,164 in the post period. N=4891 in each of the EDs (pre and post periods in the intervention & control groups). **Inclusion**: patient's ≥18 years with medical or surgical complaints admitted to the short stay unit at 4 regional EDs. July-December 2016 (pre-intervention period/control) November 2017-April 2018 (post intervention period. Two EDs to the intervention group and two to the control group.	**Primary outcome:** Clinical deterioration (CD) defined as a change in vital signs that required an increase in observations, i.e., increase in warning scores from 0 to 1 to score >2 or increase from score ≥2 and above. Composite CD: combination with death or ICU admission directly from ED. **Secondary outcomes**: proportion of 7 day & 30-day mortality, ICU admissions and readmissions.	RR, O_2 sats, SBP, Pulse, Temp LOC. Each parameter assigned 0-3 points, higher score indicating more severe deterioration. Score of 0-1 low risk (re-assess within 8 hours), 2 (re-assess within 1 hour). Score of 3-4 or single parameter score of 2 (physician assessment), ≥5 (senior physician assessment).	STATA Software Version 15.1. Descriptive statistics: difference in regression (the mean difference within groups compared with the groups intervention and control). Significance level set at 5% with a 95% CI. Logistic regression analysis used to adjust EWS for gender, admission and age.	1. CD: occurrence increased from the pre-group to the post-group (22%, CI 0.69; 0.89). There were significantly reduced odds of CD (p<0.001). 2. No significant impact on mortality, ICU or readmissions (>p=0.05). 3. No significant change in either 7 (p=0.967) or 30 (p = 0.170) day MRs. ICU admission (p= 0.049). Readmission rate (P = 0.202). ..	**Generalisability of the findings:** *Strengths:* Sample was powered with a significance level of 80%. Two control and two interventional groups strengthen generalisability. No persons were lost to follow up. *Limitations:* For patients with no registered EWS, (285 patients) all vital signs were registered except temperature. The data collection periods could be influenced by seasonal variations. *Usefulness to Practice* Study a collaboration between a research centre so support/collaboration of a similar source may be required to complete a study of this scale.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
12	Ursolino 2019	To determine if MEWS implementation reduced the number of adverse patient outcomes	Quasi-experimental study and retrospective chart review. **Intervention:** implementation of the MEWS online education program mandatory for surgical Nurses. Scoring system integrated into hospitals EMR and provided a total score when all vitals entered. Data collection: EHR and excel for analysis. Timelines: 01/06/2016-30/10/2016 (pre MEWS) and 01/06 2018-20/10/2018 (post MEWS). All cases followed up	One site: acute hospital, USA. Sample was powered N= 281 - 102 (pre NEWS), 179 (Post MEWS). Convenience sample of adult patients who had a code blue/rapid response team (RRT) activation. **Inclusion**: patients ≥ 18y admitted in medical surgical units who had RRT & code blue activation.	**Dependent variable:** RRT and code blue activations. *Adverse events*: CA, unexpected ICU admission & unplanned surgery.	Increasing number points awarded when measurements deviate outside established normal vital sign values for RR HR, SBP LOC Temp, O_2 sats Supplementary O_2.	Excel used - statistical software not specified. Bio statistical consultation to inform appropriate data analysis.	No significance 1. RRT activations increased 8.9 %(*p*=0.0074). 2. RRT upgraded to code blue (11%) (>p= 0.05). 3. Unexpected ICU admissions 47.06% vs. 37.43% (p= 0.1150). 4. CA 0.98% vs. 8.94 %(p=0.0072) designated as a 'failure to rescue'. 5. Unplanned surgery 0.985 vs. 0.56% p=0.6878). 6. Proportion of patients who remained in medical surgical units 50.98% vs 53.07% (p = 0.7363).	**Generalisability to practice;** *Strengths:* Non-subjective patient data used, all cases followed up and no missing data as EHR used. *Limitations:* One site, convenience sample. *Usefulness to practice:* EHR used for this study, researcher and assistant completed study so similar resources required to replicate.

N	First Author, year	Purpose of the study	Design/Method	Sample/Setting	Major Variables Studied (and their Definitions)	Measurement	Data Analysis	Findings	Appraisal: Worth to Practice
13	Wu *et al.* 2021	To evaluate the effectiveness of implementing an electronic-NEWS (E-NEWS) in reducing unexpected clinical deterioration	**Intervention**: E-NEWS introduced to clinical practice in 3 phases: (1) baseline 1/10/2018 to 28/02/2019 (N=23,543); (2) implementation phase 01/03/2019 to 31/08/2019 (N=30,035), consisted of educational program; (3) Intensive period 01/09/2019 to 31/12/2019(N=20,096), Education program continued, E- NEWS ≥7 text notification sent to mobile attending physicians. Nurses asked to check E-NEWS scores during shift and if score had increased or patient unstable, nurses required to inform the physicians on the ward and routine handover of documentation.	Medical tertiary centre, Taiwan, N=39,161. **Inclusion:** patients hospitalised in wards ≥ 24h & ≥20yrs. Prospective study of patients without an adverse event (AE) and with a scheduled admission to ICU following surgery & cardiac catheterisation allocated to control group also. **Data collection**: E-NEWS updated hourly in Health Information System (HIS) and Nurse Information System (NIS).	**Dependent Variable:** Rate of AEs, defined as patients who had received CPR, transferred to ICU due to unexpected deterioration or died. Number of CPRs at ward level. Number of patients transferred to ICU from wards with scores of E-NEWS ≥7 and a deterioration trend in E-NEWS.	Temp, RR, BP. Study did not have precise data on all patients SPO_2, alertness, confusion, voice, pain and unresponsiveness Patients were defined as alert if they had no Glasgow coma scale data or a motor response score of 6 (from the nursing notes). Oxygen therapy determined by presence of therapeutic orders (e.g., nasal cannula, mask, non-invasive positive pressure ventilation). Framework of E-NEWS dashboard - HIS for physicians and NIS for nursing staff.	SPSS version 22 and R software version 3.4.1. Statistical significance set at $p \leq 0.05$ two-tailed significance level. Multivariate analysis used to adjust confounding factors of demographic variables to examine effectiveness of intervention. Kruskal-Wallis test for continuous variables, chi square test for categorical data	1. Significant: decrease in AEs from 6.06% to 5.51% (p=0.001). 2. Reduction in CPRs at ward level (0.52% to 0.34% p=0.012). **3.** Reduction in ICU patient transfers (3.63% to 3.49%, p=0.035). Using multivariate analysis, intensive period showed reduced AEs (p=0.019).	**Generalisability of the findings:** *Strengths*: Non-subjective patient data. *Limitations*: One site, post intervention data collected immediately after the intervention, and education continued during the intensive period, (time series design may be stronger). Majority of patients had a diagnosis of cancer and this might limit generalisability. *Usefulness to practice:* Electronic expertise required to convert to E-NEWS. Education program resource intensive.