

**Electronically captured clinical observations, early  
warning scores and compliance: An integrative review.**

Lisa Campbell

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## **Abstract**

**Background:** Reducing the rates of serious adverse events associated with acute in-patient deterioration is a worldwide health priority. To date systematic reviews have failed to unequivocally demonstrate that early warning systems (EWSs) reduce the incidence of in-patient cardiac arrests, unanticipated intensive care unit admissions or mortality rates. Currently there are several hundred EWSs in use which vary in how they facilitate the recognition, activation and response to acutely deteriorating patients. With new innovations in health and computer technology, electronic EWSs are increasingly being employed to address shortfalls and challenges associated with both the detection and response arms of paper-based EWSs.

**Aim:** The primary aim of this integrative review was to determine if electronically captured clinical observations with/without automated alert systems improve compliance with physiological early warning system (EWS) protocols and improve patient outcomes.

**Methodology/Methods:** An integrative review was chosen as the methodology of choice as it allows one to combine diverse methodologies to fully understand a phenomenon. The following electronic databases were searched: Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase (Ovid), Web of Science, The Cochrane Library, Joanna Briggs Institute (JBI) and Scopus. Unpublished or grey literature was also sought to avoid publication bias. Included studies were critically appraised using JBI's 2014 critical appraisal tools and data was extracted and synthesised using Braun and Clarke's (2006) six phases of thematic analysis which identified four main themes and eight subthemes which were presented in a narrative format.

**Results:** This review identified that most electronic EWSs improve the detection of deteriorating patients in hospital by improving the accuracy of vital signs and early warning scores. This finding was prevalent with systems that allow documentation of vital signs at the point of care and the automated transfer of vital signs to the electronic health record. The frequency of vital sign measurement and escalation of care for deteriorating patients remained variable. This review found that the

technology and hardware used in electronic EWSs enhanced the accessibility and visibility of vital signs and aggregate early warning scores. This enhanced accessibility and visibility supports proactive and remote management and response to deteriorating patients. The electronic systems included in this review utilised numerous methods of escalating care for deteriorating patients such as automated alerts, onscreen prompts and visible electronic dashboards. Improvements in patient outcomes were not conclusively demonstrated by this review.

**Conclusion:** Electronic EWSs facilitated the detection of deteriorating patients by improving the accuracy and accessibility of patient's vital signs and early warning scores. Future research is required to determine the optimal method of escalating care in electronic EWSs. Once an alert of patient deterioration is raised, challenges remain. There remains a need to ensure an appropriate, timely and adequately resourced response to deteriorating in-patients in an attempt to demonstrate improved patient outcomes.

## **Preface**

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**List of abbreviations**

ACSQHC	- Australian Commission on Safety and Quality in Healthcare
CDHB	- Canterbury District Health Board
CINAHL	- Cumulative Index to Nursing and Allied Health Literature
CNM	- Charge Nurse Manager
DHBs	- District Health Boards
EHR	- Electronic Health Record
EWS/s	- Early Warning System/s
HCA/s	- Health Care Assistants
HDC	- Health and Disability Commissioner
HQSC	- Health Quality and Safety Commission
ICU	- Intensive Care Unit
IT	- Information Technology
JBI	- Joanna Briggs Institute
MAStARI	- Meta-Analysis of Statistics Assessment and Review Instrument
MeSH	- Medical Subject Headings
NEWS	- National Early Warning Score
NHS	- National Health Service
NICE	- National Institute for Health and Clinical Excellence
NOTARI	- Narrative, Opinion and Text Assessment and Review Instrument
NZ	- New Zealand
NZEWS	- New Zealand Early Warning Score
PDA	- Personal Digital Assistant
QARI	- Qualitative Assessment and Review Instrument
RRT/s	- Rapid Response Team/s
SUMARI	- System for Unified Management, Assessment and Review of Information
UK	- United Kingdom
USA	- United States of America
ViEWS	- Vitalpac Early Warning Scores

## **Glossary of terms**

**Early warning systems:** These are clinical prediction models using vital signs measured during a patient's hospital stay to monitor their health and identify physiological signs of deterioration which could lead to death, an increased length of hospital stay or unplanned admission to an intensive care unit.

**New Zealand Early Warning Score:** The New Zealand Early Warning Score (NZEWS) is a physiological early warning system implemented in all New Zealand hospitals. The score is calculated from routine vital sign measurements and increases as vital signs become increasingly abnormal. The early warning score triggers a clinical response which escalates according to the degree of deviation from normal, so that clinicians with the right skills can intervene and manage the patient's deterioration.

**Detection arm:** Early warning systems traditionally consist of two arms: a detection arm and a response arm. The detection arm uses vital signs and early warning scores to identify and trigger a response to patients who are deteriorating clinically.

**Response arm:** The response arm specifies the appropriate and expected response to patient deterioration, either from ward staff, or nurse-and/or doctor-led rapid response teams.

**District Health Board:** Is an organisation established within a defined geographical area of New Zealand by the New Zealand Public Health and Disability Act 2000 to ensure the provision of primary, secondary and tertiary health and disability services in that area.

**Integrative literature review:** A review method that allows one to combine diverse methodologies to fully understand a phenomenon.

**Intensive Care Unit:** Is a separate, self-contained area of a hospital with specially trained staff equipped to manage patients with life-threatening or potentially life-threatening conditions.

**Health Care Assistant:** Is a non-regulated health professional who works under the direction and delegation of a registered health professional.

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## **Chapter One: Introduction and background**

### 1.1 Introduction

#### 1.1.1 Overview

In this chapter an overview of the concept, history and efficacy of early warning systems (EWSs) is presented and the New Zealand Early Warning Score (NZEWS) and its components are introduced. Other aspects included in this chapter are a personal statement from the researcher, the research aim and objectives and an overview of the focus and structure of the integrative review. Challenges associated with the detection and response arms of paper-based EWSs are highlighted and technological advancements associated with the use of EWSs identified. The rationale for undertaking research on the efficacy of electronic EWSs in facilitating the identification and activation of a timely response and management for deteriorating in-patients is discussed.

#### 1.1.2 Early warning systems

Nationally and internationally, the need to identify and treat patients who deteriorate acutely when nursed on general hospital wards resulted in the development of EWSs, also known as track or trigger systems or rapid response systems (Moore & Poynton, 2015). These umbrella terms describe the entire system; however, EWSs traditionally consist of two arms: a detection arm and a response arm. The detection arm uses vital signs and early warning scores to identify and trigger a response to patients who are deteriorating clinically. The response arm specifies the appropriate and expected response to patient deterioration, either from ward staff, or nurse-and/or doctor-led rapid response teams (RRTs) (Moore & Poynton, 2015). Ideally, the response arm should be resourced 24 hours a day, seven days a week, by appropriately trained personnel external to the ward. These personnel should be resourced to respond to deteriorating patients in a timely manner when their needs exceed ward based resources (Health, Quality and Safety Commission, 2016b).

Theoretically, the use of EWSs should reduce the rates of serious adverse events associated with in-patient deterioration; however, three systematic reviews have failed to unequivocally show that EWSs reduce the incidence of in-patient cardiac arrests, unanticipated intensive care unit (ICU) admissions or mortality rates (Alam et al., 2014; McGaughey et al., 2007; National Institute for Health and Clinical Excellence, 2007). This inability to demonstrate improved patient outcomes may be associated with challenges encountered in both the detection and response arms of paper-based EWSs (McGaughey, O'Halloran, Porter, Trinder, & Blackwood, 2017b).

### 1.1.3 Personal statement

In New Zealand (NZ) the Canterbury District Health Board (CDHB) and the West Coast District Health Board, formally implemented the NZEWS on the 19<sup>th</sup> September 2017 after participating in a six-hospital trial. At the same time an electronic observation chart, called Patientrack, was implemented with a view to improve compliance with EWS protocols and optimise the outcomes of deteriorating patients. As a nurse educator who was involved with the implementation and education of the NZEWS and Patientrack in a small, rural CDHB hospital, the researcher has a particular interest in electronic EWSs and their potential to improve the clinical outcomes of deteriorating in-patients. The researcher is also a member of the CDHB NZEWS Working Group implemented to regularly monitor the utilisation, efficacy and ongoing development of the NZEWS and its electronic platform, Patientrack, to improve the detection and response to patients who deteriorate acutely in NZ hospitals.

### 1.1.4 Focus of this integrative review

This integrative review explores the presence of shortfalls in current paper-based EWSs and investigates what the available literature says about the growing use of electronic EWSs and their potential to address these issues. Studies which investigate if the electronic documentation of vital signs improves the accuracy of vital signs and early warning scores, reduces the time taken to document vital

signs and subsequent vital sign measurements, are included. The perceptions of key stakeholders in electronic EWSs are considered and the strengths and limitations of the hardware and technology used in these systems are addressed. Studies exploring the use of electronic EWSs to escalate care for deteriorating patients and the impact on patient outcomes are also included. This information can then be used to inform future practice and development in this area.

#### 1.1.5 Research aim and objectives

The primary aim of this integrative literature review was to determine if electronically captured clinical observations with/without automated alert systems improve compliance with physiological early warning system (EWS) protocols. Research objectives were to identify:

- the effect of electronically captured observations and early warning scores with/without automated alert systems on clinical outcomes of deteriorating adult in-patients;
- if electronically captured clinical observations improved the reliability and accessibility of patients' vital signs and the accuracy of calculating early warning score totals;
- if electronically captured clinical observations reduced the time required to measure and document patients' vital signs and/or increased the frequency of vital sign recordings in deteriorating patients;
- the benefits and limitations of electronically captured clinical observations with/without automated alert systems.

#### 1.1.6 Integrative review structure

This integrative review consists of four chapters:

Chapter one introduces the concept, history and efficacy of EWSs. An explanation of the NZEWS and its components is provided. Challenges associated with the detection and response arms of paper-based EWSs are highlighted and technological advancements associated with the use of EWSs discussed.

Chapter two describes the chosen methodology and the rationale for selecting an integrative review as the methodology of choice. The literature review research

method is presented and includes the research aim and objectives, the search strategy used, inclusion and exclusion criteria applied, critical appraisal of the literature and strategies used to extract and analyse the data.

Chapter three presents the results of the literature search strategy and outcomes of quality appraisal of the literature. A table of the included studies is provided and themes and subthemes derived from the thematic analysis are presented.

Chapter four summarises and critically analyses and interprets the findings from the included studies. The strengths and limitations of this integrative review are presented and implications for practice and opportunities for future research are addressed.

## 1.2 Background

### 1.2.1 The composition and history of EWSs

Internationally there are now several hundred EWSs in use employing a variety of vital sign parameters and thresholds to trigger an appropriate response to in-patient deterioration. Some systems use single vital sign parameter abnormalities to trigger a response, while others use aggregate scores of multiple vital sign parameter abnormalities (Psirides, Hill, & Hurford, 2013). Combination systems use both single and aggregate scoring systems to trigger an escalation of care. The response to vital sign abnormalities is usually graded and specifies maximum response times depending on the degree of deviation from the norm (Psirides et al., 2013). A low-level response may only require increasing the frequency of observations and alerting the nurse in charge. A medium-level response may require review by the doctor/s assigned to the ward. A high-level response, indicating severe physiological abnormality, may elicit a full emergency response from a team with advanced life support training (McGaughey, O'Halloran, Porter, & Blackwood, 2017a).

Morgan, Williams and Wright (1997) first developed the concept of an EWS based on weighted scores assigned to key vital sign parameters to aid the early detection of developing critical vital sign parameters. The use of EWSs became more widespread after 2004 when the Institute for Healthcare Improvement launched its 100,000 Lives Campaign (Berwick, Calkins, McCannon, & Hackbarth, 2006). This campaign proposed that United States of America (USA) hospitals implement six interventions, which they considered highly achievable, to reduce hospital morbidity and mortality. One of the six interventions was the institution of RRTs to ensure deteriorating patients have the best chance of improved outcomes (Berwick et al., 2006).

Early warning systems have evolved since their inception two decades ago to the point where standardisation of EWSs is being requested by governing bodies in implementing countries in an attempt to improve clinical outcomes for deteriorating in-patients. Consequently, numerous centralised bodies, such as the

National Institute for Health and Clinical Excellence (NICE) in the United Kingdom (UK) and the Australian Commission on Safety and Quality in Healthcare (ACSQHC) have called for standardisation of both recognition and response systems in their respective countries (ACSQHC, 2012; NICE, 2007).

### 1.2.2 EWSs in New Zealand

In NZ in 2004 a Health and Disability Commissioner (HDC) inquiry investigating a case of <sup>1</sup>failure to rescue a deteriorating patient in a large urban hospital, prompted a recommendation that District Health Boards (DHBs) implement EWSs (Seddon, 2007). A NZ study by Quirke (2011) identified that factors associated with suboptimal care of deteriorating patients included excessive workloads and staff shortages, ineffective teamwork and use of the shift co-ordinator role, poor communication and unclear implementation and evaluation strategies for new service delivery changes. The healthcare organisations attempted to reduce clinical risk by implementing service delivery changes such as colour coded observation charts, EWSs and critical care outreach services (Quirke, 2011). Over time all the DHBs responded to the HDC's recommendation and a variety of EWSs were implemented nationwide. The EWSs vary in how they facilitate the process of recognition, activation and response to acutely deteriorating in-patients. By December 2012, 21 different EWSs were being used across NZ's 20 DHBs (Psirides et al., 2013). In December 2014 the NZ Health, Quality and Safety Commission (HQSC) began an exploration into the implementation of a national programme for detecting and responding to clinical deterioration in non-pregnant, acutely hospitalised adult patients (HQSC, 2016a). The HQSC gave DHBs until the 30<sup>th</sup> June 2018 to prepare for and implement the national detection and response system (HQSC, 2017b). The aim of a standardised approach was the minimisation of adverse patient outcomes from failure to recognise and respond appropriately to patients who deteriorate acutely (HQSC, 2016a).

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<sup>1</sup> Unrecognised patient deterioration that is not acted upon may delay treatment, management and diagnosis of acutely unwell patients with potentially catastrophic outcomes, including unplanned admission to an ICU, cardiac arrest or unexpected death.

The Sapere Research Group, commissioned by the HQSC, predicted that standardising and improving EWSs nationally would improve the early recognition of deteriorating patients by at least five percent (Moore & Poynton, 2015). Benefits of a single standardised system include the ability to teach the system at the undergraduate level, eliminate retraining when moving between hospitals, simplify data collection and reporting and allow nationwide promotion of the system and comparisons of outcomes (Psirides et al., 2013). The NZEWS is based on the National Early Warning Score (NEWS) used by the National Health Service (NHS) in the UK (HQSC, 2016a). The NEWS has been found superior to other published EWSs tested in predicting patients at risk of unplanned ICU admissions, cardiac arrest and death within 24 hours of an elevated NEWS value (Smith, Prytherch, Meredith, Schmidt, & Featherstone, 2013).

The detection arm of the NZEWS has been standardised and nationally mandated. The escalation pathway for each level of clinical risk has not. There is significant variation in the response arm of EWSs in NZ. Moore and Poynton (2015) reported that five of the 15 regional hospitals and four of the five tertiary hospitals had formal RRTs dedicated to responding to deteriorating patients. The HQSC (2017b) acknowledged that situational variety makes it very difficult to be too directive when considering a response framework. Response teams were likely to be unique to each hospital setting, depending on the hospital size, availability of resources and staff (HQSC, 2017b; Moore & Poynton, 2015). Although the response arm of the NZEWS may be unique to different hospitals, standardisation of the detection arm will facilitate a nationwide understanding among health professionals when communicating the components of the NZEWS (HQSC, 2017b).

### 1.2.3 The composition of the NZEWS

Seven core vital sign parameters form the basis for the NZEWS, with a score and zone colour allocated to each abnormal parameter (table 1). The more abnormal the vital sign, the higher the score allocated to that vital sign. The sum of the individual scores for each parameter determines the aggregate early warning score

and the required clinical zone response as determined by an escalation pathway. Single vital sign parameters can also trigger an escalation response if they fall in the red or blue zones, regardless of the aggregate early warning score. The NZEWS permits senior medical staff to appropriately modify single or multiple vital sign parameters ensuring patients with chronic disease, or known abnormal vital signs, do not inappropriately trigger a clinical response. Clinicians can also escalate care, regardless of the NZEWS, based on their clinical judgment (HQSC, 2017a).

Table 1 NZEWS vital sign parameters and scoring

New Zealand Early Warning Score									
	10+	3	2	1	0	1	2	3	10+
	Single trigger	Single trigger						Single trigger	Single trigger
Resp rate	≤ 4	5-8		9-11	12-20		21-24	25-35	≥ 36
SpO2		≤ 91	92-93	94-95	≥ 96				
Supplemental O2			YES		NO				
Temp			≤ 34.9	35.0-35.9	36.0-37.9	38.0-38.9	≥ 39.0		
Sys BP	≤ 69	70-89	90-99	100-109	110-219			≥ 220	
Heart rate	≤ 39		40-49		50-89	90-110	111-129	130-139	≥ 140
Level of consciousness					Alert			Voice or Pain	Unresponsive or fitting
<b>Total EWS Score Zone</b> Add up score from table above	<b>EWS 1-5</b>		<b>EWS 6-7</b> <i>Acute illness or unstable chronic disease</i>			<b>EWS 8-9</b> or any vital sign in <b>RED ZONE</b> <i>Likely to deteriorate rapidly</i>		<b>EWS 10+</b> or any vital sign in <b>BLUE ZONE</b> <i>Immediately life threatening critical illness</i>	

Ref: CDHB-23-9115 Authorised by: Quality and Safety Director, Quality Aug 2017

#### 1.2.4 Efficacy of EWSs

The risk of preventable harm from failure to recognise and respond to clinical deterioration may increase as procedures become increasingly complex and the population ages (Moore & Poynton, 2015). Research suggests that clinical deterioration frequently occurs up to 24 hours before a critical event (McGaughey et al., 2007). If hospital staff are able to recognise the early signs associated with clinical deterioration they have a window of opportunity to intervene in order to optimise patient outcomes (McGaughey et al., 2007). Despite the lack of

quantitative evidence demonstrating that EWSs improved patient outcomes, a scoping review by La Lagadec and Dwyer (2017) concluded that there was strong anecdotal evidence that EWSs enhanced the ability of clinical staff to identify and respond to patient deterioration. Early warning systems were shown to improve identification of deteriorating patients and prompt earlier calls for help (Fox & Elliot, 2015). Frost et al. (2015) found an increase in RRT call rates with the implementation of standardised processes and procedures which specified the level of physiological abnormality requiring a clinical review or RRT call. Research has found EWSs improved communication by nurses enabling them to relay objective, quantifiable evidence when making a call for help, allowing the doctors to prioritise their workload (Andrews & Waterman, 2005). The use of objective criteria to escalate care facilitates evidence based, clinical decision making (McCaughey et al., 2017b). This is particularly useful for less experienced staff, junior staff and staff who lack self-efficacy, as opposed to senior staff who additionally use clinical judgment and intuition to recognise deterioration and escalate care (Moore & Poynton, 2015). Despite the benefits associated with the use of EWSs, challenges are encountered in both the detection and response arms of EWSs.

#### 1.2.5 The detection arm of EWSs

Deteriorating patients are not always identified and escalated as they should be due to shortfalls in the implementation of the detection arm of EWSs. Although the implementation of EWSs has resulted in improved monitoring of vital signs, especially respiratory rate, (McBride, Knight, Piper, & Smith, 2005) the user dependent nature of recording vital signs means they are frequently incomplete, or not taken when due (Simmes, Schoonhoven, Mintjes, Fikkers, & van der Hoeven, 2012). Pressure to complete observations at certain times and competing ward priorities may contribute to inaccurately completed early warning score charts (McCaughey et al., 2017b). A complete set of vital signs is required to inform most early warning scores, so incomplete observation sets may result in missed alerts for physiologically unstable patients. In a study of paper-based early warning scores by Clifton et al. (2015) only 65.5% of 16,795 observation sets were fully completed and had an accurately calculated total score. Even when a

complete set of observations were recorded the weights assigned to vital signs and the aggregate scores were frequently incorrect. Other research identified that when aggregate scores were erroneously calculated they were 11 times more likely to be underscored than over-scored (Austen et al., 2012). When an observation set was incorrectly calculated it was often followed by another incorrectly calculated observation set. It appears the preceding scores predicted the outcome of subsequent observations sets (Clifton et al., 2015). The risk is that the first sign of instability may be missed if vital signs indicative of early signs of deterioration were preceded by a stable sequence of normal scores. Potentially, an electronic system that only allows clinicians to see the prior vital signs after entering all the vital signs, may address this issue (Clifton et al., 2015).

Close monitoring of physiologically unstable patients by increasing the frequency of observations beyond routine monitoring was recommended to identify advancing instability or improvement (DeVita et al., 2006). This vital requirement of the detection arm of EWSs was often not adhered to. A possible explanation may be that nursing staff had become desensitised to frequently occurring triggers, especially in EWSs where single parameters can generate a trigger (Smith & Aitken, 2015). Lack of education and knowledge regarding monitoring and interpretation of vital signs amongst nursing staff may be another possible explanation for failure to increase the frequency of observations when prompted (Odell, Victor, & Oliver, 2009). Competing clinical priorities, inadequate staffing and unavailability of monitoring equipment have been identified as factors contributing in failure to follow up with timely repeat assessments (Hands et al., 2013; McGaughey et al., 2017b). Ward factors such as strong, visible management, adequate staffing and a commitment to education have the potential to address this (Smith & Aitken, 2015).

The taking of routine observations can be viewed as a ritualistic task frequently delegated to health care assistants (HCAs) or student nurses to alleviate the workload of registered nurses (McGaughey et al., 2017b; Wheatley, 2006). This practice was commonly driven by excessive workloads, increasing time pressures and low levels of qualified staff (McGaughey et al., 2017b). Student nurses and

HCAAs may not have the necessary qualifications and/or experience to recognise deteriorating patients and if they do, they frequently failed to communicate abnormal findings (Odell et al., 2009; Wheatley, 2006). McCaughey et al. (2017b) found when registered nurses delegated the recording of routine observations to less experienced or unqualified staff there was limited interpretation of clinical observations and holistic patient assessment.

Intuition and experience were the most common method for detecting patient deterioration and a descriptive exploratory study conducted by Cioffi (2000) over 12 months, found experienced nurses escalated care 18 percent of the time, because “they were seriously worried about the patient” (p. 265). Yet, concern was seldom included as a parameter in early warning scores (Gao et al., 2007). Intuition was most effective when the patient was well known to the nurse enabling him/her to detect changes in behaviour or physical signs. An experienced, intuitive nurse may identify deterioration through pattern recognition, where deviation from the expected clinical course occurs. This prompts the nurse to further assess the patient by monitoring vital signs to confirm his/her suspicions (Odell et al., 2009). Patients who are effectively compensating may have vital signs within normal limits, or only marginally changed prior to a severe and rapid deterioration associated with decompensation (Cioffi, 2000). Experienced nurses are generally more confident to escalate care based on subjective cues, (McGaughey et al., 2017) while junior nurses tend to be more rigid in their application of EWS protocols and may not have the knowledge or past experience to detect subtle signs of deterioration (Cioffi, 2000; Odell et al., 2009).

The barriers cited above, which contribute to failures in the detection arm may be why studies have failed to categorically prove the efficacy of RRT’s within the response arm (Alam et al., 2014; Hillman et al., 2005; McGaughey et al., 2007). The following section explores what works well within the response arm and the issues and gaps present.

### 1.2.6 The response arm of EWSs

Standardised referral protocols form the basis of the response arm of EWSs. These protocols empower nurses to utilise the trigger score to communicate concern and mobilise an early, bedside response from staff with the appropriate skills (McGaughey et al., 2017a). The composition of RRTs and the available levels of response are determined by the type and size of the hospital. For example, a large hospital may have more than one type of response team, available 24 hours a day, responding to different levels of deterioration. In contrast, the response team of a small rural hospital may consist of only one person, on-site during the day, with virtual support from a larger hospital available after hours. The standard principle of providing an appropriate and timely response, however, should apply irrespectively (Moore & Poynton, 2015).

The success of EWSs largely depends on the timely escalation of care associated with reporting abnormal scores. In a Danish cross-sectional study abnormal early warning scores were escalated by nursing staff 38% of the time (Niegsch, Fabritius, & Anhøj, 2013). Shearer et al. (2012) found that despite their organisation having a well embedded EWS and associated educational support, on 42% of instances the RRT was not activated for patients who fulfilled activation criteria. A number of sociocultural factors contribute to failure to activate the RRT. In this study, interviews with staff who failed to activate the RRT revealed that they chose to implement alternative actions to manage patients, although they were concerned about the patients and knew they fulfilled activation criteria. It was reported that 13% of nurses and 26% of doctors feared that activating the RRT would elicit a negative or hostile reaction from colleagues (Shearer et al., 2012).

Another reason identified for failing to activate the RRT was bedside clinical staff feeling that they had the required skill and experience to manage the patient themselves (McCaughy et al., 2017b; Shearer et al., 2012). Even when deteriorating patients met the criteria for RRT activation, 62% of ward nurses tended to call the doctor overseeing the ward, instead of the RRT (Azzopardi,

Kinney, Moulden, & Tibballs, 2011; Radeschi et al., 2015). Prior involvement of the critical care team, but an unavailability of ICU beds resulted in a reluctance to re-contact the RRT when required (Shearer et al., 2012). Poor interdisciplinary communication and inconsistent use of a formal communication tool also contributed to escalation failure (McCaughey et al., 2017b). There was also a reluctance to activate the RRT when clinical investigations or reviews were pending (Shearer et al., 2012). Experienced nurses viewed the referral protocol as a guideline which could be superseded by clinical judgement, particularly at lower trigger scores. A lack of confidence on the part of junior nurses, reluctance to report a single deranged parameter and an inclination to recheck observations were other factors associated with referral delays to the RRT (McCaughey et al., 2017b). In some hospitals a traditional hierarchical referral culture meant junior doctors felt they needed to assess, manage and re-evaluate deteriorating patients before calling for senior help (Azzopardi et al., 2011; McCaughey et al., 2017b). In most cases failure of junior doctors to call for senior support was an appropriate and informed decision based on the practitioner's clinical judgment. Occasionally, failure to recognise an underlying problem or to re-evaluate a patient resulted in a failure to rescue (McCaughey et al., 2017b; Shearer et al., 2012).

Both doctors and nurses displayed some degree of protocol deviation. In one large survey study conducted by Fox and Elliot (2015), 85% of nurse respondents reported doctors did not review patients within the recommended time guidelines. Doctors' workload, particularly when busy, out of hours, or at night was perceived by nurses as one reason for the delayed response times (Fox & Elliot, 2015). Fox and Elliot (2015) also found a lack of knowledge of the EWS among some doctors was perceived by the nurses as contributing to a delayed response. Some doctors failed to realise the significance of a trigger score, the required response times as per the escalation procedure or when to contact senior medical staff (Fox & Elliot, 2015; Niegsch et al., 2013). Although doctors and nurses frequently receive the same initial EWS training at the commencement of employment, the influence of clinical nurse educators and senior nurses facilitated the integration of the system into nursing practice. In contrast, the doctors' role in the EWS was seldom subject to evaluation and the absence of ongoing support and training may have

influenced adherence to EWS protocols (Rihari-Thomas, DiGiacomo, Phillips, Newton, & Davidson, 2017).

Most EWSs have a modification section which allows specified clinicians to modify one or more parameters for individual patients, when clinically appropriate to do so. For example, a patient with chronic obstructive pulmonary disease may have a chronically elevated respiratory rate, which is normal for that patient rather than an indication of deterioration. If the respiratory parameter is not modified for the patient the “abnormal” respiratory rate will repeatedly generate an alert. Focus groups conducted by Elliot et al. (2015) reported that in practice doctors were frequently reluctant to, or omitted to complete the modification section. Failure to justifiably modify parameters resulted in inappropriate alerts being sent to members of a RRT (Fox & Elliot, 2015). Failure to review the modification for continued appropriateness, within the recommended time frame, was another issue identified by nurses. Failure to appropriately modify parameters or review modifications put pressure on nurses who felt responsible for ensuring the modification section on observation charts was completed appropriately (Elliot et al., 2015). Inappropriate RRT activations may be minimised through the early identification of those patients for whom invasive procedures or resuscitation attempts would reasonably expect to be futile. This should prompt a discussion and decision about palliative care options (McGaughey et al., 2017b). This ensures that audits reviewing missed or late observation sets are not picking up appropriately missed observations for palliative patients.

### 1.2.7 Electronic EWSs

There is a growing trend towards the use of systems that automate the measurement of vital signs, assign electronic weightings to individual vital signs and automatically calculate the total early warning score (Clifton et al., 2015). Technological innovations allow for the automatic activation of the RRT and documentation of clinical events and management plans. The ability of systems to allow integration of this information into various parts of the patient’s electronic health record (EHR) supports improved documentation, quality and access

(Rihari-Thomas et al., 2017). The incorporation of EWSs into an institution's electronic system has the potential to make reports available that can be used for shift handovers to enable rapid identification and prioritisation of high-risk patients (Mapp, Davis, & Krowchuk, 2013; Rihari-Thomas et al., 2017). The ability to retrieve data which is captured electronically will also make an evaluation of adherence to EWS protocols more effective and allow data extraction to test the sensitivity and specificity of an EWS (HQSC, 2016a).

### 1.2.8 Summary

This first chapter presented an overview of widely used EWSs to detect acute, adult in-patient deterioration and the components of both the detection and response arms of EWSs were discussed. The researcher's personal statement, the research aim and objectives and the focus and structure of the integrative review were included. The history of NZ and international EWSs was provided to give EWSs a context in time, but the efficacy of current EWSs remains unproven due to factors contributing to failure in the detection and response arms. Finally, an overview of innovations, such as the use of electronic EWSs to improve the accuracy and accessibility of patient information and the escalation of care, was provided.

## **Chapter Two: Methodology and Research Method**

### 2.1 Introduction

This chapter presents the chosen methodology and the rationale for selecting an integrative review as the methodology of choice. The process for the literature research method is also presented.

### 2.2 Methodology

With the growing body of literature increasingly emphasising the need to use evidence to inform a variety of practice decisions, there is a need to search and evaluate available research when seeking to answer a clinical question (Aveyard, 2010). Systematic reviews, integrative reviews, meta-analysis and meta-synthesis are all types of literature reviews used to locate and synthesise large volumes of information related to a question of interest (Schneider & Elliot, 2003). An integrative review using a systematic process was the methodological approach applied to this study and therefore a discussion on systematic reviews is included.

#### 2.2.1 Systematic review

A systematic review enables practitioners to comprehensively identify all available literature on a topic and then critically appraise and synthesise carefully selected studies, from a large body of evidence, to answer a well-defined clinical question (Aveyard, 2010; Cook, Mulroy, & Haynes, 1997). Internationally, the most well-known organisation for providing guidance on conducting systematic reviews is the Cochrane Collaboration (Schneider & Whitehead, 2013), which produces independent systematic reviews of high quality, evidence-based resources on the effectiveness of healthcare interventions (Aveyard, 2010). Other organisations which use the systematic review process are NICE and the Joanna Briggs Institute (JBI). A systematic review requires adherence to a strict protocol to limit bias and ensure the reproducibility of the review and rigor of the process. After formulating a clear and unambiguous research question, inclusion and exclusion criteria are developed and used to determine the relevance of literature

to the research question for incorporation into the review. Reviewers are required to develop and conduct a comprehensive and exhaustive search strategy for relevant primary studies. To avoid publication bias, published and unpublished literature on the topic is searched for. Selected papers and their research methodologies are then critically appraised according to predetermined criteria in order to assess their quality and validity. Only high-quality papers that meet the inclusion criteria are included in the review. Finally, selected studies are synthesised and interpreted using a systematic approach (Aveyard, 2010; Cook et al., 1997; Thomas & Hodges; 2010).

Many systematic reviews include only quantitative studies, particularly randomised controlled trials. When the results of several primary studies are quantitatively combined a meta-analysis is undertaken where several statistical results are pooled to provide an overall summary (Thomas & Hodges, 2010). This allows more “precise, powerful and convincing conclusions” to be drawn from the collective body of papers (Cook et al., 1997, p.378). Meta-synthesis and meta-ethnography are two methods that can be used to combine the results of qualitative primary studies (Aveyard, 2010; Thomas & Hodges, 2010; Whitemore & Knafl, 2005). More recently mixed methods systematic reviews, combining both quantitative and qualitative studies, are being used to provide a holistic overview of the evidence and a coherent narrative that is more likely to produce informative conclusions, relevant to policymakers and practitioners, than single method reviews (JBI, 2014).

### 2.2.2 Integrative review

The only review method that allows one to combine diverse methodologies to fully understand a phenomenon is an integrative review. It is the most comprehensive review method as it allows the inclusion of both experimental and non-experimental research. An integrative review also combines theoretical and empirical literature to enhance evidence-based practice by including all types of research (De Souza, Da Silva, & De Carvalho, 2010; Whitemore & Knafl, 2005). Integrative reviews address multiple purposes including defining concepts, reviewing theories and evidence and analysing methodological problems related to

a particular topic (Broome, as cited in Whitemore & Knafl, 2005). The purpose of this integrative review was to review available literature on the topic to answer a specific research question. A neutral perspective was taken to review and discuss the literature (Torraco, 2016). In order to conduct a thorough and rigorous integrative review the literature search needs to be broad and diverse to identify all eligible primary studies, including unpublished material, if appropriate to the review purpose (De Souza et al., 2010). Effectively combining diverse methodologies is challenging and particular consideration needs to be given to the method of analysing, synthesising and conclusion drawing in order to protect against bias and inaccurate inferences (Whitemore & Knafl, 2005). In order to address the challenges associated with combining diverse methodologies this current review was guided by Braun and Clarke's (2006) six step data analysis framework to systematically interpret and synthesise the data.

## 2.3 Research method

### 2.3.1 Research aim

The primary aim of this integrative literature review was to determine if electronically captured clinical observations with/without automated alert systems improve compliance with physiological EWS protocols. Research objectives were to identify:

- the effect of electronically captured observations and early warning scores with/without automated alert systems on clinical outcomes of deteriorating adult in-patients;
- if electronically captured clinical observations improve the reliability and accessibility of patients' vital signs and the accuracy of calculating early warning score totals;
- if electronically captured clinical observations reduces the time required to measure and document patients' vital signs and increases the frequency of vital sign recordings in deteriorating patients;
- the benefits and shortfalls of electronically captured clinical observations with/without automated alert systems.

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) checklist was used to demonstrate that a systematic approach was applied to the identification, selection and critical appraisal of relevant research. Furthermore, the PRISMA checklist recommends the use of the mnemonic PICO (population, intervention, comparator and outcome) to formulate and refine the research question (Moher, Liberati, Tetzlaff, Altman, & Prisma Group, 2009).

Population – acutely admitted adult in-patients

Interventions – use of electronically captured clinical observations with/without automated alert systems

Comparator – use of traditional paper-based EWSs

Outcome – improved compliance with EWS protocols and clinical outcomes of deteriorating adult in-patients.

### 2.3.2 Inclusion and exclusion criteria

The following inclusion criteria applied:

- primary research related to the utilisation of electronic EWSs to identify and escalate care for deteriorating adult in-patients (aged 18 years and above);
- English language only publications;
- studies published from 2008 to 2018;
- peer-reviewed articles

The following exclusion criteria applied:

- disease-specific electronic alert systems, for example, sepsis alert systems;
- automated electronic health records which predict clinical deterioration by combining various factors in addition to clinical observations, for example, laboratory results;
- electronic EWSs for obstetric or paediatric patient groups;
- non English language publications;
- studies preceding 2008

The search was limited to the last decade as computer technology changes rapidly. The findings related to recent electronic EWSs may not be comparable to a system utilising older technology.

### 2.3.3 Search strategy

#### 2.3.3.1 Databases searched

An initial, broad search for literature was undertaken in Google Scholar and other electronic databases to determine if prior literature reviews had been conducted on the chosen topic. With none identified the assistance of the University's Librarian was sought to undertake a comprehensive, computer-assisted search of the following relevant electronic databases: Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase (Ovid), Web of Science, The Cochrane Library, JBI and Scopus. The search was conducted using keywords and subject headings derived from the research question (Schneider & Whitehead, 2013). Unpublished or grey literature was also searched to avoid publication bias, as journals tend to only publish research that demonstrates interventions of a positive nature, as opposed to research that identifies a negative or ineffectual result (Aveyard, 2010). Grey literature databases searched were ProQuest Dissertations and Theses, Open Grey, TRIP Database and Google Scholar (Ebling Library, 2017).

#### 2.3.3.2 Keywords and literature search

The search terms used were: early warning score, track and trigger, rapid response, EWS, e-trigger, electronic observation, automated, electronic, real-time alert. The right keywords or terms were identified by using medical subject headings (MeSH) and the "explode" feature where appropriate (Schneider & Elliot, 2003). The appropriate truncation symbols were used when entering keywords into each database to ensure that a single search retrieved all root word variations. For instance automat\* reveals the following literature title variants: automatic, automatically, automated. Where required key search terms, consisting of two or more words, were grouped together so that individual words did not yield a result (Aveyard, 2010). For example, in CINAHL the search term track and trigger was placed within inverted commas to avoid these words being searched individually and irrelevant studies been identified. To further limit the search to articles that met the predetermined inclusion criteria, database limits

were imposed by ticking the following check boxes: published date range 2008 – 2018, English language and peer-reviewed articles. A step-wise search of each database was conducted using the identified keywords/terms. Boolean operators (“AND”, “OR”) were used to combine and narrow the search results to potentially relevant studies only (Schneider & Whitehead, 2013). In order to comply with the PRISMA guidelines a full search strategy for at least one database, including any limitations imposed, is included (Moher et al., 2009).

#### Appendix A. Literature search of the CINAHL database

##### 2.3.4 Article review

The titles and abstracts of the articles retrieved from the various databases were reviewed to determine if they met the study’s inclusion criteria. When the relevance of the title and abstract was unclear the full article was accessed and read. Preference was not given to one study over another, but the most robust form of evidence that addressed the research question was sought (Aveyard, 2010). Articles failing to meet the review’s inclusion criteria were eliminated. The remaining articles underwent full-text review and the reference lists of all relevant articles were hand searched to identify other potentially relevant studies that may have been missed during the database searches (Schneider & Whitehead, 2013). This resulted in 20 articles meeting the review’s inclusion criteria.

##### 2.3.5 Critical appraisal

Each article was critically appraised to determine whether it should be included in the literature review based on its methodological strengths and limitations and overall quality (Aveyard, 2010; Whitemore & Knafl, 2005). The JBI’s 2014 standard critical appraisal instruments for specific study designs were used to evaluate the literature. The rationale for choosing the JBI was that it is one of the organisations devoted to evidence-based practice and it provides tools for the evaluation of varied data sources, including qualitative, quantitative, economic research, text and opinion based evidence (JBI, 2014; Schneider & Elliot, 2003). The selected studies were grouped together according to study type. The

methodological quality, validity and applicability of each study considered for inclusion were appraised using the JBI critical appraisal tools from the System for Unified Management, Assessment and Review of Information (SUMARI). The JBI SUMARI appraisal tools use a checklist approach for reviewing the literature and a scoring system based on yes/no/unclear/not applicable. Each piece of literature was initially appraised by the student researcher and a second appraisal was independently conducted by the researcher's two academic supervisors. The JBI appraisal tools allow for the calculation of confidence intervals that can be used to set parameters for inclusion. Individual studies were only included if a confidence interval and cut off point of 70% was achieved (JBI, 2014). There was no discrepancy regarding the appraisal tool scores; therefore, a third independent reviewer was not required.

## Appendix B. JBI critical appraisal tools

### 2.3.5.1. Assessment of quantitative studies

The JBI MASTARI (Meta-Analysis of Statistics Assessment and Review Instrument) was used to assess the quantitative studies, which included only quasi-experimental (non-randomised experimental) studies. Critical appraisal of quantitative studies is related to determining the validity and quality of the chosen methodology and possibility of bias in every stage of the review (JBI, 2014).

### 2.3.5.2. Assessment of qualitative studies

The JBI QARI (Qualitative Assessment and Review Instrument) was used to assess the three included qualitative studies. The tool consists of ten questions used to determine the nature and appropriateness of the utilised methodology and methods, as well as the meanings ascribed to the words of study participants (JBI, 2014).

### 2.3.5.3. Assessment of text and opinion articles

The text and opinion article was assessed using the JBI NOTARI (Narrative, Opinion and Text Assessment and Review Instrument) tool. This is a six-question tool which focusses on the authenticity of the author's opinion, the source, possible factors motivating the opinion and how alternative opinions are dealt with (JBI, 2014).

### 2.3.6 Data extraction

Key data was extracted from studies utilising the applicable JBI data extraction tools as a guide for each study type: quantitative, qualitative, text and expert opinion methodology, ensuring appropriate data related to the research question was extracted from each study type (JBI, 2014). The extracted data for each study type was collated into a data extraction table designed by the researcher. The process of data extraction facilitated a thorough understanding of the data, which is necessary before the data can be analysed and one study compared with another (Aveyard, 2010).

### Appendix C. Data extraction table

### 2.3.7 Data analysis

Thematic analysis was the method used to analyse the data. This involved "identifying, analysing, interpreting and reporting patterns (themes) within data" (Braun & Clarke, 2006, p. 79). Braun and Clarke's (2006) six phases of thematic analysis were used to analyse and synthesise data into themes and sub-themes, which were then presented in a narrative format. Before analysing the data selected studies were classified according to their methodologies. Methodologically similar studies were then analysed chronologically from oldest to latest (Whittemore & Knafl, 2005). The initial stage of data familiarisation involved reading and re-reading the selected literature to determine its content and systematically identify and extract initial codes of meaningful data of interest from all the studies. Similar codes were then collated using different colours to start

identifying potential themes. Coded data extracts allocated to each potential theme were reviewed to ensure the data was cohesive within each theme and that individual themes worked across the entire data set. Thematic maps were useful for reviewing, refining and ultimately naming and defining the themes (Braun & Clarke, 2006). Although this method of data analysis is typically applied to mixed-methods and qualitative designs, it is also applicable to the analysis of data for integrative reviews as it supports the synthesis of varied data from diverse methodologies (Whittemore & Knafl, 2005).

*Table 2 Phases of thematic analysis (Braun & Clarke, 2006)*

<b>Phase</b>	<b>Description of the process</b>
1. Familiarising yourself with the data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2. Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code
3. Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4. Reviewing themes:	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (level 2), generating a thematic “map” of the analysis
5. Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6. Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature,

	producing a scholarly report of the analysis
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#### 2.4 Ethical considerations

While undertaking an integrative review does not require ethical approval, there are several ethical considerations that need to occur before undertaking one. Firstly, it is ethical practice to determine if a literature review has already been conducted that answers the research question, as it would be unethical to conduct the research again. It is also important to ensure the findings of studies included in the review are represented accurately and fairly and that only ethically sound studies are included in the review. It would also be unethical to present participants' data from included studies in a way that they may not have agreed to when consent was obtained for the primary study (Body et al., 2010). The researcher believes that the research has merit in that it addresses a health phenomenon, which with advances in technology will become increasingly important in the future. The researcher made every attempt to apply a robust methodology to the research to ensure an integrative review of high quality was produced.

## **Chapter Three: Results**

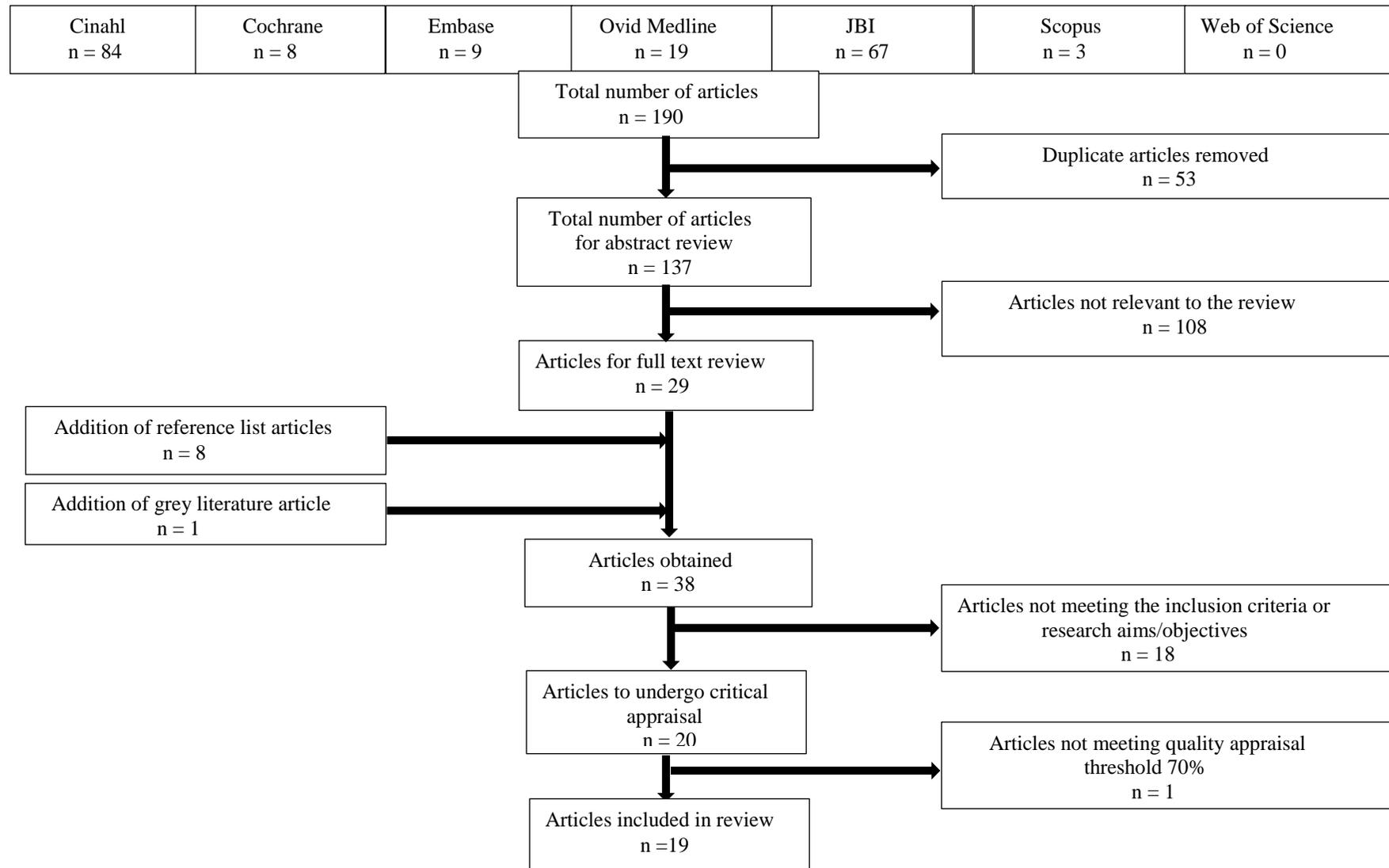
### 3.1 Introduction

The key elements presented in this chapter include the results of the literature search strategy and outcomes of critical appraisal of the literature. A table of the included studies is provided and themes and subthemes derived from the thematic analysis are presented.

### 3.2 Results of search strategy

In order to locate literature relevant to the review a comprehensive, logical and systematic search strategy was undertaken (Aveyard, 2010). In the first instance primary literature was sought to answer the research question. The initial keyword search in the seven identified databases yielded 190 potential articles. After removing 53 duplicates 137 articles remained. After reviewing the articles' associated abstracts against the research aims and objectives and criteria for inclusion and exclusion, a further 108 articles were eliminated. The remaining 29 articles were retrieved for full text review. Scrutiny of the reference lists of these articles identified a further eight potentially suitable papers for full text review. The search of grey literature yielded one further article for review. From these 38 articles 18 were excluded as they did not meet the research aim/objectives and inclusion criteria, leaving a total of 20 articles for critical appraisal.

Figure 1 Flow diagram of literature research



### 3.3 Outcomes of critical appraisal of the literature

The articles included in this integrative review were critically appraised using the JBI critical appraisal tools. Of the 20 articles that were quality appraised, 16 were quasi-experimental (non-randomised experimental) studies and were critically appraised using the JBI MAStARI quasi-experimental study tool (JBI, 2014). Two of these studies attempted to utilise some form of control group or blinding; however, they did not meet the criteria to be classified as randomised-controlled trials, as they did not have an independent, separate control group and the influence of potential confounders or bias could not be ruled out (Fletcher, Aaronson, White, & Julka, 2018; Heal, Silvest-Guerrero, & Kohtz, 2017).

Twelve studies used a single group pre-test post-test design (Bellomo et al., 2012; Evans et al., 2014; Guay, Murphree, & Steele-Moses, 2011; Jones et al., 2011; Kollef et al., 2017; Meccariello, Perkins, Quigley, Rock, & Qiu, 2010; Mwulu, Westwood, Edwards, Kelliher, & Coleman, 2012; Pullinger et al., 2017; Schmidt et al., 2015; Smith, Banner, Lozano, Olney, & Friedman, 2009; Wager et al., 2010; Wong et al., 2017). Two studies were retrospective audits of electronic EWSs utilising large datasets (Hands et al., 2013; Pederson et al., 2018). In one of the quasi-experimental studies follow up was not complete due to concerns regarding the delay in getting vital signs entered into the patient record (Wager et al., 2010). In six of the studies it was unclear if participants included in any comparisons were exposed to other treatment or care other than the intervention of interest (Guay et al., 2011; Kollef et al., 2017; Meccariello et al., 2010; Pullinger et al., 2017; Schmidt et al., 2015; Smith et al., 2009). In two of the studies it was unclear if the participants included in any comparisons were similar (Guay et al., 2011; Jones et al., 2011). In one study multiple measurements of the outcome both pre and post exposure were difficult with the repeated treatment design used in the study (Fletcher et al., 2018). Except for the study by Guay et al. (2011) all the quasi-experimental studies met the critical appraisal threshold of 70%. The study by Guay et al. (2011) was excluded from the review after discussion with the secondary researchers.

The three qualitative studies were assessed using the JBI QARI tool. Although the articles met the appraisal threshold of 70%, none addressed the influence of the researcher on the research, or visa versa. The relationship between the researcher and the study participants was also not addressed (Lang, Pinchin, Brown, & Sharples, 2016; Mackintosh, Rainey, & Sandall, 2011; Yeung, Lapinsky, Granton, Doran, & Cafazzo, 2012). Two of the studies did not declare the researchers' values, beliefs or theoretical orientation, so it was not possible to identify if these potentially influenced the study (Lang et al., 2016; Yeung et al., 2012).

The one expert opinion piece was assessed using the JBI NOTARI assessment tool. This study met all six the quality appraisal questions and was included in the review (Wong et al., 2015). A total of 19 articles were included in the integrative review consisting of 15 quasi-experimental studies, three qualitative studies and one expert opinion piece. The studies included in this integrative review obtained consent from participants' when this was required for the study type.

Table 3 Table of included studies

Authors and Year	Title	Study Type	Sample size/setting	Key findings
Smith, L.B., Banner, L. Lozano, D., Olney, C.M. & Friedman, B. (2009)	Connected Care – Reducing Errors Through Automated Vital Signs Upload	Post-implementation study	Step-down cardiac ward. 20 beds. Pepin Heart Hospital in Tampa, Florida.	There was a reduction in omission, transcription and transmission errors with an automated system which automatically transfers vital signs from the observation machine to a PDA and finally the EHR.
Wager, K.A., Schaffner, M.J., Foulis, B., Kazley, A.B., Parker, C. & Walo, H. (2010)	Comparison of the Quality and Timeliness of Vital Signs Data Using Three Different Data-Entry Devices	An observational study	Four medical/surgical wards at a South Carolina Hospital.	Transcription errors reduced and there was faster documentation of vital signs when vital signs were entered at the point of care, directly from the observation machine into an electronic tablet attached to the observation machine
Meccariello, M. Perkins, D., Quigley, L.G., Rock, A. & Qiu, J. (2010)	Vital Time Savings Evaluating the Use of an Automated Vital Signs Documentation System on a Medical/Surgical Unit	A quasi-experimental design	An acute care medical/surgical ward at a medium sized hospital in the US.	The use of an automated documentation system as opposed to a manual documentation system (Observations entered into a bedside computer) reduced documentation errors by 75%. An average time saving of 96.19 second was achieved using the vital sign acquisition/automated documentation method compared to the vital sign acquisition/manual documentation method.
Jones, S., Mullally, M., Ingleby, S., Buist, M., Bailey, M. & Eddleston, J.M. (2011)	Bedside electronic capture of clinical observations and automated clinical alerts to improve compliance with an Early Warning Score protocol	Historically controlled study	This study was conducted on a medical assessment unit and a general medical ward at the Manchester Royal Infirmary.	Real-time clinical deterioration alerts to a doctor's pager resulted in a reduction in the patient's length of stay from 9.7 days to 6.9 days and the clinical response to patient deterioration increased from 29% to 78%. Critical care admissions and the length of stay in ICU reduced after real-time clinical deterioration alerts were implemented. Reductions in cardiac arrest incidence and mortality did not reach clinical significance.

<p>Bellomo, R., Ackerman, M., Bailey, M., Beale, R., Clancy, G., Danesh, V., Hvarfner, A., Jimenez, E., Konrad, D., Lecardo, M., Pattee, K.S., Ritchie, J., Sherman, K., &amp; Tangkau, P. (2012)</p>	<p>A controlled trial of electronic automated advisory vital signs monitoring in general hospital wards</p>	<p>Before-and-after controlled trial</p>	<p>18305 patients constituted the study cohort. Patients included from ten hospitals in the US, Europe and Australia on 12 general wards and a total of 349 beds.</p>	<p>In this study the time required to complete and record a set of vital signs and automatically calculate the early warning score reduced from an average of 4.1 minutes to 2.5 minutes after an automated documentation system was introduced (vital signs transferred automatically to advisory bedside patient monitors). The advisory bedside monitors prompted earlier calls for help and when a RRT call was made, in-hospital and 90 day survival rates increased from 86%-92% and cardiac arrest rates decreased.</p>
<p>Mwulu, U., Westwood, D., Edwards, D., Kelliher, F. &amp; Coleman, J.J. (2012)</p>	<p>Adoption of an Electronic Observation Chart with an Integrated Early Warning Scoring System on Pilot Wards</p>	<p>Early phase review</p>	<p>Patients from about 1200 inpatient beds and six pilot wards (a plastics/burns ward, three neuroscience wards and two medical wards) at a large university hospital in England were included.</p>	<p>In this study where vital signs were captured electronically from an observation machine to the EHR via a bedside computer, traditional gaps in vitals sign recordings were still found for vital signs that needed to be entered manually, for example respiratory rates. 80.5% of the observation sets were fully completed and produced an early warning score.</p>
<p>Hands, C., Reid, E., Meredith, P., Smith, G.B., Prytherch, D. R., Schmidt, P.E. &amp; Featherstone, P.I. (2013)</p>	<p>Patterns in the recording of vital signs and early warning scores: compliance with a clinical escalation protocol</p>	<p>Evaluation Study</p>	<p>A total of 950 043 observation sets were included in the evaluation study from a NHS District General Hospital on the South Coast of England.</p>	<p>On screen prompts, which included instructions on when vital signs should be rechecked as determined by the ViEWS value, did not improve the timeliness of rechecking vital signs and compliance was poorer overnight compared to the day. Sicker patients were more likely to have their vital signs recorded overnight. There were large peaks in vital sign recordings between 06:00 – 06:59 and 21:00 and 21:59. For patients on continuous electronic monitoring it was mandatory for staff to document the vital signs on VitalPac as frequently as required according to the hospital's clinical escalation protocol. Compliance with regards documentation of vital signs was also poor.</p>

<p>Evans, R.S., Kuttler, K.G., Simpson, K.J., Howe, S., Crossno, P.F., Johnson, K.V., Schreiner, M.N., Lloyd, J.F., Tettelbach, W.H., Keddington, R.K., Tanner, A., Wilde, C. &amp; Clemmer, T.P. (2014)</p>	<p>Automated detection of physiologic deterioration in hospitalized patients</p>	<p>Prospective Observational Study</p>	<p>All patients admitted to a 33-bed medical/oncology ward and a 33-bed surgical trauma ward at a hospital in Salt Lake City, were monitored.</p>	<p>In this study patients were continuously monitored and vital signs were transferred automatically to a bedside computer and the EHR every five minutes. Real time clinical alerts were then sent to the CNM's pager. The positive predictive value of the alerts as perceived by nurses was 91%-100%. More RRT calls were made (60 vs 29 pre-intervention) and significantly fewer patients died (2.6% vs 3.7%) compared to the pre-intervention year. In the one intervention ward where patients were older with more co-morbidities there was a reduction in mortality, the length of stay increased and more patients were transferred to ICU compared to the pre-intervention year.</p>
<p>Schmidt, P.E., Meredith, P., Prytherch, D.R., Watson, D., Watson, V., Killen, R.M., Greengross, P., Mohammed, M.A., &amp; Smith, G.B. (2015)</p>	<p>Impact of introducing an electronic physiological surveillance system on hospital mortality</p>	<p>Retrospective, observational study</p>	<p>The electronic system was deployed in three wards in two large (&gt;1000 bed) acute general hospitals approximately 240km apart in England.</p>	<p>After introducing an electronic early warning system crude mortality fell from 7.75% to 6.42% at one hospital and from 7.57% to 6.15% at a second hospital. Year on year statistics at both hospitals showed abrupt and sustained reductions in mortality, in all specialities, which coincided with the implementation of the electronic EWS.</p>
<p>Kollef, M.H., Heard, K., Chen, Y., Lu, C., Martin, N. &amp; Bailey, T. (2017)</p>	<p>Mortality and Length of Stay Trends Following Implementation of a Rapid Response System and Real-Time Automated Clinical Deterioration Alerts</p>	<p>Retrospective analysis</p>	<p>The retrospective analysis utilised data obtained from eight general medical wards of a 1250-bed academic medical centre in St Louis, Missouri over 12 years.</p>	<p>Real time clinical deterioration alerts generated by the electronic EWS were sent to a RRT nurse's mobile device. The RRT nurse responded to alerts within 10 minutes. There was a reduction in mortality rates, cardio-pulmonary arrest rates and length of hospital stay after the EWS with real time clinical deterioration alerts were introduced. There was a statistically significant year-to-year increase in RRT activations that was inversely correlated with the occurrence of cardio-pulmonary arrests.</p>

Wong, D., Bonnici, T., Knight, J., Gerry, S., Turton, J. & Watkinson, P. (2017)	A ward-based time study of paper and electronic documentation for recording vital sign observations	Before- and- after observational study.	577 nurse observation taking events were observed (281 paper and 296 electronic system) on three medical wards in two university teaching hospitals in the UK.	It took 215 seconds to record a complete set of vital signs and calculate the early warning score on paper compared to 150 seconds on the electronic system.
Pullinger, R., Wilson, S., Way, R., Santos, M., Wong, D., Clifton, D., Birks, J. & Tarassenko, L. (2017)	Implementing an electronic observation and early warning score chart in the emergency department: a feasibility study.	Before and after study	The study enrolled approximately 3000 subjects before and 3000 subjects after implementation of the automated system in a high acuity area of an emergency department in the UK.	Pre-implementation of the electronic EWS 52.7% of subjects had an accurately calculated early warning score compared to 92.9% after implementation. In stage one (vital signs captured directly onto paper) only 66% of the subjects had full EWS documentation that was available for review. In stage two 93% of subjects had full documentation available for review. There were no statistically significant differences between mortality rates, cardiac arrest rates, transfers to the resuscitation room or ICU and length of stay.
Pedersen, N.E., Rasmussen,L.S., Petersen, J.S., Gerds,T.A., Østergaard, D. & Lippert, A. (2018)	A critical assessment of early warning score records in 168,000 Patients	Observational Study of NZEWS data	A total of 2,835,331 NEWS records were included in the study from patients admitted to public hospitals in Denmark.	Of 2,835,331 NEWS records reviewed 10% were incomplete with one or more vital signs missing and 0.2% of the captured vital signs were implausible values. Digit preferences for even numbers were found and there was an unusually high recording of heart rate records just below 91 beats per minute which could indicate bias towards a value that does not generate a NEWS point.
Heal, M., Silvest-Guerrero, S., & Kohtz, C. (2018)	Design and Development of a Proactive Rapid Response System	Quasi-experimental	The study was conducted on two medical-surgical wards at a 600-bed hospital located in the Midwest.	In this study on the intervention ward a dedicated crisis nurse was required to check the early warning score on the EHR to detect deteriorating patients. On 132 occasions the RRT was activated on the intervention ward. On the control ward staff activated the RRT 110 times. The use of an electronic alert responded to by a crisis nurse reduced the reliance on the bedside nurse to recognise subtle signs of patient deterioration and activate the RRT.

Fletcher, G.S., Aaronson, B.A., White, A.A. & Julka, R. (2018)	Effect of a Real-Time Electronic Dashboard on a Rapid Response System	Repeated treatment design	The study took place on the general medical-surgical wards at a teaching hospital in Washington with 413 beds and about 19000 admissions a year.	The use of a real-time electronic dashboard which increased the visibility of early warning scores to the entire care team, including the RRT, did not significantly reduce overall RRT activations, Cardiopulmonary arrests, unexpected ICU admissions and mortality. There was a 20% increase in first RRT activations, but overall RRT activations did not increase. The dashboard encouraged a proactive, rather than reactive approach to monitoring and reviewing patients at risk, mitigating the risk of the bedside nurse not calling for help.
Mackintosh, N., Rainey, H. & Sandall, J. (2011)	Understanding how rapid response systems may improve safety for the acutely ill patient: learning from the frontline	Ethnographic study	The study was conducted at two tertiary UK NHS teaching hospitals. The Acute medical wards of each hospital admit approximately 15000 – 20000 patients annually. Semi-structured, individual interviews were conducted with 35 clinicians in person.	After the electronic early warning system was introduced the percentage of vital signs recorded late still ranged from 30% - 70%. Nurses reported that the electronic dashboard of patients and their early warning scores assisted them with sharing information, planning and allocating workloads by glancing at the dashboard. The ability to access the EWS remotely allowed clinicians to keep an eye on deteriorating patients without being physically present on the ward. Nurses expressed concern regarding an over-reliance on the EWS and the loss of experiential-intuitive knowledge due to the prescriptive nature of the electronic EWS.
Yeung, M.S., Lapinsky, S.E., Granton, J.T., Doran, D.M., Cafazzo, J.T. (2012)	Examining nursing vital signs documentation workflow: barriers and opportunities in general internal medicine units	Qualitative ethnographic analyses and quantitative time-motion study were conducted	The study was conducted in five general medical wards at three tertiary hospitals in Toronto, Ontario.	If the electronic EWS does not support the documentation of vital signs at the point of care it could take longer document vital signs. In this study it took a nurse an average of 17.2 minutes to document vital signs using the paper-based system. At the hospital using the electronic system it took an average of 53.2 minutes before vital signs were documented. Transcription was common at the hospital using the electronic EWS which increased the risk of transcription errors and delayed the documentation of critical patient information.

<p>Lang, A., Pinchin, J., Brown, M &amp; Sharples, S. (2016)</p>	<p>Report: Handheld Technologies in the Ward.</p>	<p>Evaluation using observation and interviews/focus groups</p>	<p>The study was carried out in 19 wards in two hospitals in the UK. It included more than eighty five hours of observing staff directly, interviews with forty staff and four focus groups.</p>	<p>After the electronic EWS was introduced clinicians spent more time interacting with patients and colleagues. The time doctors spent with patients more than doubled (2.9% - 7.3%). Interview data revealed that the electronic system improved accessibility to patient information and improved team, patient and relative communication. The ability to easily and remotely access patient data provided clinical reassurance. The handheld mobile devices used to document vital signs on were like personal tools which allowed nurses to manage workloads and improved situational awareness. Some negatives reported with the electronic system were alert fatigue, disempowerment of nurses, restrictions in terms of access and permission and lack of senior medical staff engagement.</p>
<p>Wong, D., Bonnici, T., Knight, J., Morgan, L., Coombes, P. &amp; Watkinson, P. (2015)</p>	<p>SEND: a system for electronic notification and documentation of vital sign observations</p>	<p>Post-implementation assessment</p>	<p>The SEND system was deployed on a short-stay ward, an oncology ward and a respiratory ward within University Hospitals in Oxford. These wards contained a total of 59 beds.</p>	<p>A patient overview screen was viewed as useful during doctors' ward rounds and nurses' handovers and assisted with the immediate recognition of patients with abnormal vital signs. User acceptability of the system was high. The System Usability Scale score was 77.8 (all scores above 68 are considered above average). 95.2% of users said the training received it was "just right." The SEND system appears to be well accepted by staff with system usability scores ranging from 3.9/5 to 4.3/5.</p>

## Appendix D. Table of excluded studies

### 3.4 Themes and subthemes

Thirteen of the studies investigated either the accuracy of vital signs, time taken to document vital signs and/or timeliness of rechecking vital signs. Accurately recorded and documented vital signs and correctly calculated early warning scores forms the basis of the detection arm of EWSs and facilitates the detection of deteriorating in-patients. These studies used a variety of methods and tools to record and document the vital signs to the EHR. An explanation of the different tools and methods; therefore, needed to be provided when reporting the findings of collated data for the first theme to give the results a context.

Four studies investigated the perceptions of doctors and nurses using electronic EWSs, which meant a heavy reliance on coded data from a few studies for this theme. Human factors are a major factor in evaluating health information systems and compliance with EWSs (Andargoli, Scheepers, Rajendran, & Sohal, 2017). This knowledge strengthened the decision to assign this collated data to a main theme.

Ten of the included studies addressed the benefits and shortfalls of the electronic EWS technology, the hardware utilised in practice and the visibility and accessibility of data in electronic EWSs. This information formed the third theme, which focused on technology and its contribution to patient safety.

Thirteen of the studies focused on the response arm of electronic EWSs. The included studies used various methods to escalate care once patient deterioration was identified and a variety of individuals or teams were tasked with reviewing the deteriorating patient. Once again, when reporting the results of collated data for this theme, variations across studies required explanation to allow the reader to interpret the findings in context. Numerous studies investigated the impact of electronic EWSs on patient outcomes, but a number of different outcome measures were used across the various studies.

After coding the data four potential themes and 12 potential subthemes were identified. The researcher discussed the suggested themes and subthemes with the secondary reviewers. After a constructive discussion the 12 subthemes were condensed into eight subthemes and consensus was reached on the four main themes. A brief description of each theme and their associated subthemes are presented below. Overall findings from the 19 included studies are then reported and related to the four main themes and eight subthemes.

#### 3.4.1 Theme One: The detection arm of patient deterioration in electronic EWSs

The components of the detection arm of EWSs facilitate the detection of in-patient deterioration and the following three subthemes were identified within this theme:

- **Accuracy of vital signs in electronic EWSs:** Accurately recorded and documented vital signs form the basis of the detection arm of EWSs. These components are required to generate an accurately calculated early warning score to facilitate the detection of deteriorating patients.
- **Faster documentation of vital signs:** Delayed documentation of recorded vital signs increases the potential for documentation errors and hinders access to important information required to assess the patient's condition.
- **Timeliness of rechecking vital signs:** Physiologically unstable patients should be closely monitored by increasing the frequency of observations beyond routine monitoring.

#### 3.4.2. Theme two: Human factors associated with the use of electronic EWSs

This theme addresses the perceptions of stakeholders in electronic EWSs and forms the basis of the second theme. One subtheme was identified within this theme:

- **User acceptability of electronic EWSs:** The needs, expectations and perceptions of key stakeholders must be identified and addressed in electronic EWSs.

### 3.4.3 Theme three: Technology and its contribution to patient safety

Electronic EWS technology, the hardware utilised in practice and the visibility and accessibility of data in electronic EWSs were addressed in the third theme. The following two subthemes were identified:

- **Strengths and limitations of the technology and hardware used in electronic EWSs:** The technology, hardware and clinical environment should support the electronic EWS in use, or it could delay the documentation of vital signs, potentially impacting patient safety.
- **Visibility and accessibility of data in electronic EWSs:** When vital signs and early warning scores were readily accessible and easily visible they facilitated the recognition of patient deterioration.

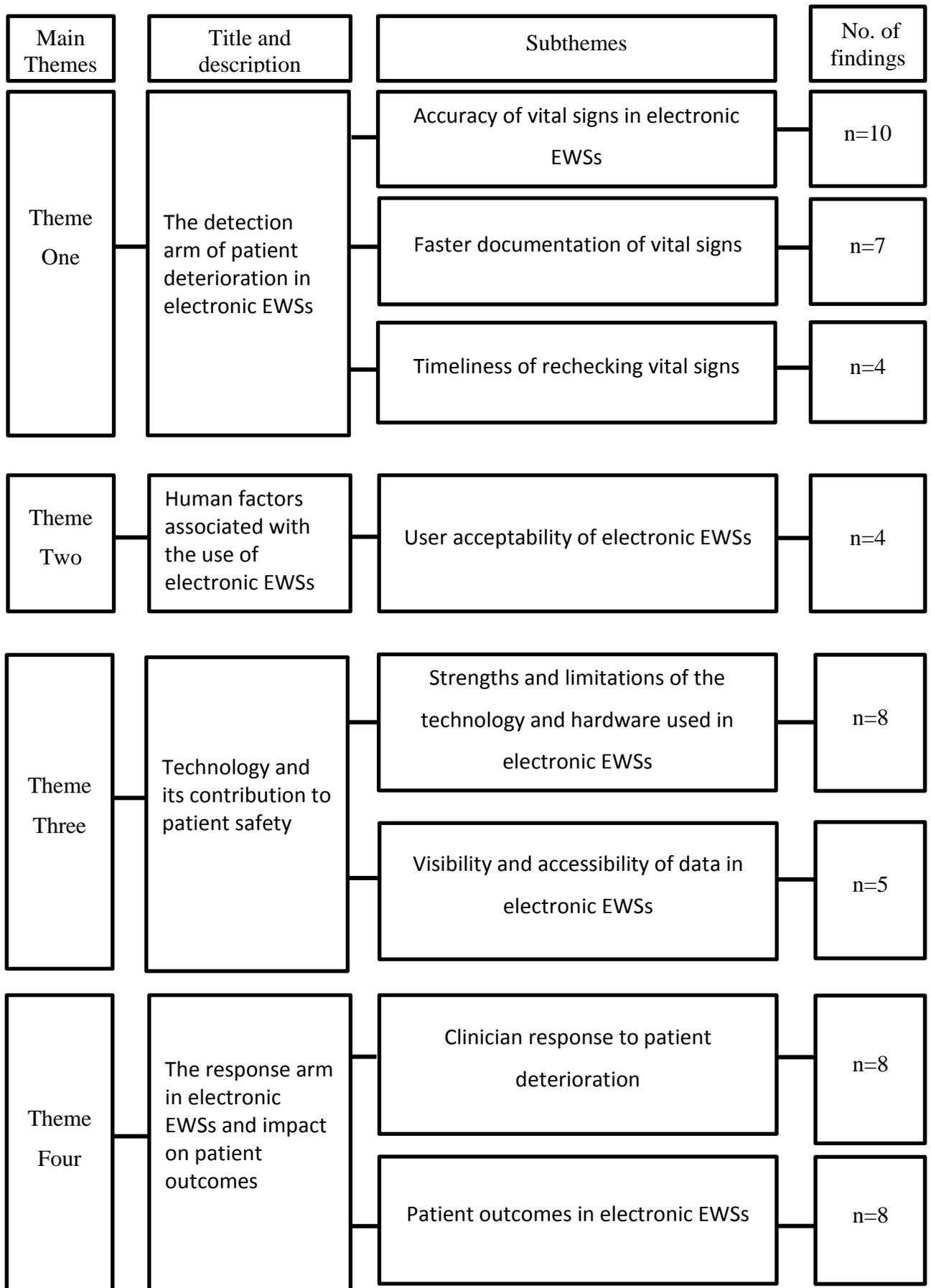
### 3.4.4. Theme four: The response arm in electronic EWSs and impact on patient outcomes

The response arm facilitated the escalation of care for deteriorating in-patients to individuals or teams, within specified timeframes, to ensure the best clinical outcomes for deteriorating patients. The following two subthemes were identified within this theme:

- **Clinician response to patient deterioration:** Electronic EWSs utilise various methods to escalate care and/or activate the RRT to ensure appropriate and timely care to the deteriorating patient.
- **Patient outcomes in electronic EWSs:** Ultimately all physiological EWSs were designed and implemented to positively impact the outcomes of deteriorating patients.

A flow diagram delineating the four themes, eight subthemes and the number of articles representing each subtheme follows (Figure 2).

Figure 2 Flow diagram of themes and subthemes



### 3.5 Theme one: The detection arm of patient deterioration in electronic EWSs

This theme is comprised of the following three subthemes: Accuracy of vital signs in electronic EWSs, faster documentation of vital signs and timeliness of rechecking vital signs.

#### 3.5.1 Subtheme one: Accuracy of vital signs in electronic EWSs

The first section of this subtheme refers to studies using automated vital sign documentation systems and their contribution to the accuracy of vital signs in electronic EWSs. One study used a system to automatically transfer vital signs from the observation machine to the patient's EHR. This system utilised infrared technology to automatically transfer vital signs from an observation machine to a personal digital assistant (PDA). The registered nurse or nurse technician then confirmed the display of vital signs on the PDA by pushing a button which automatically transferred the vital signs to the patient's EHR and to a vital sign sheet. In this study the nurse was required to review and validate the vital signs within the EHR before they became a permanent part of the EHR. Respiratory rates needed to be entered manually as the observation machine did not measure respiratory rates (Smith et al., 2009).

In the automated system utilised by Meccariello et al. (2010) vital signs were captured automatically from the observation machine directly to the EHR after confirming the vital signs on the observation machine. The use of this automated documentation system, as opposed to a manual documentation system, reduced documentation errors by 75%. Of the 92 sets of vital signs done utilising the automated documentation system, there was a reported error rate of 3.3%. The three errors that occurred were difficulty scanning the patient's identification bar-code, one typographic error (typing the manually entered respiratory rate or pain score into the computer incorrectly) and one omission error for failing to enter a result that required manual entry (Meccariello et al., 2010).

Within the automated system utilising infrared technology there were 60 errors in total, representing an error rate of 0.66%. There were 53 errors of omission (non-entry of a vital sign or non-validation of the EHR) accounting for 0.58% of the total

recorded vital signs. Twenty respiratory rates were missing which may have been due to the requirement to enter the respiratory rate manually into the PDA or EHR. Three complete sets of vital signs were missing because the nurse did not review and validate the vital signs within the EHR. Sixteen oxygen saturation values and five pulse rate values were missing. In 13 cases the nurse removed the saturation probe from the patient's finger before the data was transmitted from the observation machine to the PDA. There were seven transcription errors (applying to manually entered values), accounting for 0.08% of the total recorded vital signs. In one case the respiratory rate was erroneously entered into the saturation parameter. In a second case the nurse manually entered an entire set of six vital signs directly into the EHR for the wrong patient, rather than reviewing and validating the vital signs from the PDA. There were no transmission errors associated with the automated transfer of vital signs (Smith et al., 2009). A limitation of these studies is that neither identified who made the errors, registered nurses or nurse technicians, or if accuracy was influenced by other factors such as the experience level of staff, patient load or patient acuity (Meccariello et al., 2010; Smith et al., 2009).

A number of the studies included in this integrative review required the manual entry of vital signs into the patient's EHR (Hands et al., 2013; Jones et al., 2011; Mackintosh et al., 2011; Meccariello et al., 2010; Mwulu et al., 2012; Pederson et al., 2018; Pullinger et al., 2017; Schmidt et al., 2015; Wager et al., 2010; Wong et al., 2017; Yeung et al., 2012). When vital signs were entered manually at the point of care, documentation errors were reduced. In one study the manual transcription of vital signs from a piece of paper to a computer-on-wheels or workstation kept outside the patient's room, resulted in a transcription error rate of 15.2%. When vital signs were manually entered at the point of care, directly from the observation machine to an electronic tablet attached to the machine, transcription errors reduced to 5.6% (Wager et al., 2010). In this study vital signs were recorded by nurse technicians (nursing assistants) rather than registered nurses. Accuracy results between studies using nurse technicians to enter vital signs, rather than registered nurses, may not be directly comparable.

Similar findings were reported by Yeung et al. (2012) where they found hospitals using electronic EWSs did not accommodate vital sign documentation at the point of care. Consequently, transcription from paper to computer was common and increased the risk of transcription errors and contributed to gaps in the recorded data. In contrast, fewer transcription errors were found at the paper-based hospitals in their study where vital sign charts were conveniently located at the patient's bedside (Yeung et al., 2012). In the manual documentation period of their study, Meccariello et al. (2010) reported a combined error rate of 13.5% from 52 sets of vital signs. In this study vital signs were either captured from the observation machine into the EHR via a bedside computer, or onto a piece of paper before entering into a computer outside the patient's room (Meccariello et al., 2010). Conversely, Jones et al. (2011) reported 100% accuracy with the manual entry of vital signs from the observation machine directly to the EHR via a PDA.

Electronic EWSs automatically and accurately calculate an early warning score once all the physiological variables are entered. Electronic EWSs that allow for the partial entry of vital signs are more likely to have incomplete sets of vital signs (Mwulu et al., 2012; Pederson et al., 2018). If all the required vital signs are not entered an early warning score cannot be calculated as identified by Mwulu et al. (2012) where only 80.5% of the observation sets produced an early warning score. The wards included in this study had levels of completeness of observation sets ranging from 69% to 92% (Mwulu et al., 2012).

In a large observational study of 2,835,331 NEWS records the electronic system automatically calculated the early warning score if all seven vital signs comprising the NEWS were entered. In this study 271,103 (10%) of the NEWS records had one or more missing vital signs and implausible values were found in 0.2% of the records. Some of these erroneous or extreme values may have been eliminated if the system was programmed to identify erroneous records at the point of entry. Due to the limited knowledge the researchers had on the data collection practices in the different hospitals, potential sources of error or extraneous variables could not be identified (Pederson et al., 2018). The EWS in the study by Mackintosh et al. (2011) had inbuilt safety prompts advising when an incomplete set or "unlikely" vital signs were entered.

These prompts, together with a record of who entered the vital signs, improved the completeness of vital signs (Mackintosh et al., 2011).

Schmidt et al. (2015) found that in both study sites where the EWS required users to enter a full set of vital signs on each occasion of taking routine observations, a complete set of vital signs was completed 98% of the time. Pullinger et al. (2017) had similar findings where 92.9% of their subjects had an accurately calculated early warning score after implementation of the electronic EWS. Pre-implementation vital signs were captured on paper and the early warning score was calculated manually with an accuracy rate of 52.7% (Pullinger et al., 2017).

Mwulu et al. (2012) found traditional gaps in vital sign recordings, like the recording of respiratory rate. The researchers acknowledge that expecting a complete set of observations to be recorded on every occasion of vital sign monitoring is unrealistic (Mwulu et al., 2012). An incomplete set of vital signs may be entered due to protocol non-adherence (Pederson et al., 2018), but occasionally if there is clinical concern around only one or two vital signs some researchers suggest it is appropriate to only monitor the pertinent vital signs more frequently (Mwulu et al., 2012; Pederson et al., 2018). Pederson et al. (2018) found that a large percentage of partially entered vital signs were followed by complete records shortly after.

When reporting on the accuracy of vital signs it is worth noting that staff practice may have an influence on recorded vital sign values. In a study by Pederson et al. (2018), which had access to NEWS data from a public hospital system covering 1.7 million people and the ability to merge data from multiple hospitals, digit preferences for even numbers were found for respiratory rates, oxygen flow rates, heart rate and systolic blood pressure. In addition, the authors postulated that distribution anomalies like scoring heart rate records just below 91 beats per minutes could indicate bias towards a value that does not generate a NEWS point. This finding suggests that manually entered data may not always be a true and accurate representation of recorded vital signs (Pederson et al., 2018). The accurate capture of a complete set of vital signs is important, as is the timely documentation of the captured vital signs.

### 3.5.2 Subtheme two: Faster documentation of vital signs

Timely documentation of vital signs is important so that early warning scores can be determined and provided to clinicians. The literature highlights the need for the clinical environment to support the documentation method utilised. Vital sign documentation into the medical record occurs more promptly when the patient's chart or documentation tool is located in a convenient location for the nurse (Yeung et al., 2012). Wager et al. (2010) found that it took an average of nine minutes 15 seconds to input vital signs from paper into computers outside the patient's room as computers were often occupied by other clinicians. This delay in inputting the vital signs into the patient's medical record caused such grave concerns among medical staff that this stage of the study was cut short. When vital signs were entered directly into an electronic tablet affixed to the observation machine, imputation took 35 seconds (Wager et al., 2010).

Nurses in a study by Wong et al. (2017) also entered vital signs directly into a tablet mounted alongside the observation machine. Introduction of their electronic observation system resulted in a statistically significant reduction in the time taken to record and document vital signs compared to paper. The geometric mean time to record and document a set of vital signs was 215 seconds on paper, compared to 150 seconds on the electronic system. This reduction was significant even after allowing for differences between wards, nursing levels, individual nursing behaviour and encountered interruptions. The time reduction; however, was only clinically significant in one of the three wards studied and the sample size was smallest for this ward (Wong et al., 2017). The reason for the large time saving in one ward, compared to less significant time savings in the other two, was not addressed by the researchers.

Yeung et al. (2012) found that in their study's electronic-based hospital it took an average of 53.2 minutes before vital signs were documented, as their electronic documentation system was not conducive to vital sign documentation at the point of care. At the hospital using an electronic documentation system vital signs were always transcribed onto interim paper notes before being documented electronically. In comparison in their paper-based hospitals, where vital signs were documented onto paper charts, it took an average of 17.2 minutes to document vital signs. In this study it

was also found that 53% of the patients' vital signs were memorised for more than one minute before documenting on any medium, namely a paper chart, electronic record or interim paper notes. Vital signs were memorised for the longest period before documentation in the hospital where vital signs were documented electronically. This delayed the communication of potentially critical patient information and contributed to additional errors and compromised data (Yeung et al., 2012).

Automated documentation systems automatically transfer the vital signs to the patient's EHR thus eliminating manual documentation (Bellamo et al., 2012; Meccariello et al., 2010; Smith et al., 2009). In the study by Meccariello et al. (2010) it took an average of 107.5 seconds to acquire and document the vital signs using an automated documentation system. The acquisition and documentation of vital signs took 203.69 seconds where vital signs were recorded on paper and then entered into a computer in the hallway and 131.63 seconds when vital signs were acquired and manually documented to a bedside computer. An average time saving of 96.19 seconds was achieved when using the vital sign acquisition/automated documentation method compared to the vital sign acquisition/manual documentation method to a remote computer. This equated to almost 120 hours a month for a 36 bed unit where vital signs were recorded on average four times a day. This study did not measure the time lag between acquiring and documenting the vital signs into a computer outside the patient's room, so it may have taken even longer before the vital signs were available to clinicians in the EHR (Meccariello et al., 2010).

The automated documentation system utilised by Bellamo et al. (2012) decreased the average time required to acquire, document and calculate the early warning score from 4.1 minutes to 2.5 minutes. This resulted in a time saving of about 1750 nursing hours per ward per year (Bellamo et al., 2012). In this study the documentation method used pre-implementation of the automated documentation system was unclear, as was the explanation of how this time difference was measured.

In the paper phase of the study by Pullinger et al. (2017) the full EWS documentation was only available for review in 66% of the subjects. The principle reason for lack of available EWS chart was that 24% of subjects had vital signs written in their notes, but not on the EWS chart. In contrast, when the electronic EWS was implemented 93% of

the subjects had full documentation available for review. In this before and after design other variables may have contributed to this improvement in documentation between the two study stages, as quality initiatives were implemented and improvements were made in staff training and workflow (Pullinger et al., 2017). In addition to ensuring recorded vital signs are documented in a timely manner they must also be rechecked at regular, protocol-driven intervals to facilitate the detection of trends towards physiological deterioration.

### 3.5.3 Subtheme three: Timeliness of rechecking vital signs

Although many of the EWSs included in this review provided prompts regarding the frequency of subsequent vital signs based on the early warning score and the EWS protocol, (Bellamo et al., 2012; Jones et al., 2011; Meccariello et al., 2010; Pederson et al., 2018; Pullinger et al., 2017; Schmidt et al., 2015) these prompts were not always responded to. Electronic systems did not improve the timeliness of rechecking observations in a study by Jones et al. (2011). Compliance with rechecking observations according to the recommended timeframe for deteriorating patients did not change significantly between the baseline phase when vital signs were captured on paper and the alert phase with electronic capture. The percentage of vital signs recorded late still ranged from 30% to 70% (Jones et al., 2011). A similar finding was reported by Mackintosh et al. (2011) who found compliance to protocol in terms of rechecking observations remained variable after implementation of the electronic system. In contrast, a retrospective analysis of vital signs by Pullinger et al. (2017) revealed that with the electronic system vital signs were recorded more frequently for patients with a high early warning score, than with the paper-based system. This was attributed to an increased awareness of patient deterioration over time and to the automated prompts given by the electronic system to increase the frequency of vital sign monitoring in deteriorating patients (Pullinger et al., 2017).

In the study of 950 043 observation sets it was found that irrespective of the Vitalpac Early Warning Score (ViEWS) value, adherence to protocol was always greater in the day than at night. During the day-time for patients with a ViEWS of 3-6, it took 5.64 hours to document their next set of observations, 4.91 hours for patients with a ViEWS of 7-8 and 4.22 hours for patients with a ViEWS  $\geq 9$ . At night-time it took 7.88 hours

(ViEWS: 3–6), 6.59 hours (ViEWS: 7–8) and 5.17 hours (ViEWS:  $\geq 9$ ), respectively. These vital signs should have been documented at four hours (ViEWS: 3–6), one hour (ViEWS: 7–8) and 30 minutes (ViEWS:  $\geq 9$ ). Only 12.81% of the daily vital signs were recorded between the hours of 23:00 and 05:59. This increased to 23.84% for patients with a ViEWS score  $\geq 9$ , indicating that deteriorating patients were monitored more frequently during these hours. Despite the finding that there was less variability in the frequency of vital sign recording among sicker patients, 47.42% of patients with a recorded ViEWS of 7-8 and 31.22% of patients with a recorded ViEWS value  $\geq 9$ , between 20:00 – 23:59, did not have their vital signs rechecked in the next six hour period. There were also two large peaks in vital sign recording between 06:00-06:59 and 21:00-21:59 and the RRT was more frequently activated during peak times of vital sign recording than at night. Failure to check observations may miss early patient deterioration and undermine the effectiveness of any EWS (Hands et al., 2013).

#### 3.5.4 Summary of theme one

This theme reported on the accuracy of vital signs and aggregate early warning scores, documentation of vital signs and timeliness of rechecking vital signs in electronic EWSs. These components form the basis of the detection arm of EWSs. The evidence in this theme demonstrated that electronic EWSs improve the accuracy of vital signs and aggregate early warning scores, providing the available technology and clinical environment supports the documentation of a complete set of vital signs at the point of care. Compliance to a pre-determined protocol with regards the timeliness of subsequent vital signs measurements did not generally improve in electronic EWSs. The second theme considers human factors associated with the use of electronic EWSs described by four of the included studies.

#### 3.6 Theme two: Human factors associated with the use of electronic EWSs

This theme is comprised of the following subtheme: User acceptability of electronic EWSs.

### 3.6.1 Subtheme one: User acceptability of electronic EWSs

Nurses were noted as being anxious initially when it came to using electronic charts (Lang et al., 2016; Mwulu et al., 2012). They feared the use of new technology and that increased monitoring would increase their workload. After a period of adjustment, nurses engagement with the electronic chart was, however, generally positive (Mwulu et al., 2012). Lang et al. (2016) found nurses reported the technology increased their workload and stress. The stress was reported as sustained due to staff feeling unsupported by the information technology (IT) help service and the absence of a sustainable procedure to provide feedback to IT.

In the post-implementation assessment of one electronic EWS, Wong et al. (2015) reported that qualitative acceptance of the electronic EWS was high as indicated by the system usability scale score of 77.8 (all scores above 68 were considered above average). Clinical users' perception of the training received prior to the implementation of the EWS application was high with 95.3% (62 of 65 users) indicating that they had been taught how to use the system. Four point eight percent of those said the training was "not enough", 95.2% said it was "just right" and no-one said it was "too much". This particular EWS appeared to be well accepted by staff with system usability scores ranging from 3.9/5 to 4.3/5 (Wong et al., 2015).

Senior nurses expressed concern that nurses may become over reliant on the electronic EWS and lose the ability to detect patient deterioration through clinical assessment (Lang et al., 2011; Mackintosh et al., 2011). Intuitive-experiential knowledge was acknowledged by a number of senior nursing and medical staff to be a valid element in detecting early deterioration (Mackintosh et al., 2011). Mackintosh et al. (2011) found that the PDA used to record vital signs directed the users to follow a routine with every instance of vital sign recording. On some occasions junior staff and HCA's in particular were so focused on adhering to the routine that they lost sight of other subtle or significant signs of deterioration, such as increased restlessness (Mackintosh et al., 2011).

Two of the included qualitative studies sought the doctors' perspectives on electronic EWS (Lang et al., 2011; Mackintosh et al., 2011). Doctors expressed frustrations

about policies which restricted their access and permissions in the electronic EWS causing disruptions to working practices. For example, some electronic EWSs only allow consultant physicians to modify parameters, although registrars work independently within the system and only access advice from consultants when required. Both nursing and medical staff expressed frustration about the lack of senior medical staff engagement with the new electronic system and this was perceived as hindering team communication round the use of the system. This lack of buy in was perceived as limiting the system in terms of realising its potential benefits in practice. Both doctors and nurses spent more time with patients after the electronic system was introduced and in the case of doctors this time more than doubled (2.9% to 7.3%). These findings were confirmed by interview data where medical staff expressed that it appeared the electronic system and handheld devices assisted with task and time management and reduced the time spent searching for people and information (Lang et al., 2011).

### 3.6.2 Summary of theme two

This theme focused on the views and experiences of users and stakeholders in electronic EWSs. After a period of adjustment and engagement system usability scores were high. The following factors were identified as contributors to users' acceptance of electronic EWSs: adequate initial training, on-going IT support, recognition of the value of intuitive-experiential knowledge apart from the electronic EWSs and time savings. Access restrictions and disengagement of senior medical staff were frustrations associated with the use of electronic EWSs. The third theme focusses on the technology used in electronic EWSs and its contribution to patient safety.

### 3.7 Theme three: Technology and its contribution to patient safety

This theme is comprised of the following two subthemes: Strengths and limitations of the technology and hardware used in electronic EWSs and visibility and accessibility of data in electronic EWSs.

### 3.7.1 Subtheme one: Strengths and limitations of the technology and hardware used in electronic EWSs

To ensure recorded vital signs were assigned to the correct patient a number of the electronic EWSs required nurses to scan the bar-code on the patient's wristband to determine the patient's identification (Meccariello et al., 2010; Smith et al., 2009; Wong et al., 2015; Wong et al., 2017). Two systems also required the clinician's identification badge barcode to be scanned in order to access the vital signs screen (Meccariello et al., 2010; Wong et al., 2015).

In the study conducted by Wager et al. (2010) the size of the computer on wheels meant that technicians could not enter the vital signs at the point of care as it was too difficult to manoeuvre the computer and observation machine into the patient's room. The resulting delay in documenting vital signs had implications for patient safety, especially in the acute ward setting. The electronic EWS utilised by Yeung et al. (2012) required an extensive amount of additional mandatory data to be entered. The time required to do so deterred nurses from documenting directly into the bedside or hallway computers where the ergonomics were unfavourable. For security purposes the computers were locked in cabinets, which needed to be unlocked before nurses could access them and launch the vital sign application. Computers at the central nursing stations were also frequently occupied. As a result of these challenges, nurses in this study frequently deferred the documentation of vital signs in favour of more imminent clinical tasks, or until the end of their shifts. This documentation delay meant that patient information was frequently not available for clinical decision support and there was an increased risk of transcription errors, potentially impacting patient safety (Yeung et al., 2012). In the qualitative study by Lang et al. (2016) the nurses expressed concern about the reliance on the electronic EWS, which may be problematic if the technology infrastructure fails, or if there are insufficient devices to accommodate casual nurses and student nurses.

None of the included studies using handheld PDA's to document vital signs at the point of care reported any significant issues related to the technology or the PDA's themselves (Hands et al., 2013; Jones et al., 2011; Lang et al., 2016; Mackintosh et al., 2011; Pullinger et al., 2017; Schmidt et al., 2015). In one phase of the study by

Meccariello et al. (2010) PDA's were also available to record vital signs, but were not preferred by technicians, so only one set of vital signs was completed with this device. The reason for preferring to use alternative options available, namely bedside computers or remote computers was not mentioned by the researchers in this study.

Very few technical problems were encountered when electronic EWSs automatically transferred vital signs to the patient's EHR (Bellamo et al., 2012; Evans et al., 2014; Meccariello et al., 2010; Smith et al., 2009). In the study by Smith et al. (2009) the requirement for the nurse to confirm the display of vital signs on two occasions before they became a permanent part of the EHR resulted in three missing sets of vital signs, because the nurse failed to do so. The study did not identify if this requirement added any value, or if it was an additional step which could have affected outcomes. No errors occurred with the automated transmission of vital signs from the observation machine to the PDA, or from the PDA to the EHR (Smith et al., 2009). There was one instance of inability to scan the patient's identification bar-code in the automated documentation system utilised in the study by Meccariello et al. (2010). The strengths and limitations of the different hardware and technology in electronic EWSs contribute to their success or failure, as does the visibility and accessibility of vital signs and early warning scores.

### 3.7.2 Subtheme two: Visibility and accessibility of data in electronic EWSs.

All the electronic devices in the included studies automatically and wirelessly transferred the recorded vital sign data to the patient's EHR. This enabled vital signs to be viewed from any device linked to the hospital's intranet with required access rights (Evans et al., 2014; Hand et al., 2013; Jones et al., 2011; Lang et al., 2016; Mackintosh et al., 2011; Pullinger et al., 2017; Schmidt et al., 2015). The ability to access the observation data from the EHR remotely, along with other clinical data such as blood results, enabled doctors to better understand the deteriorating patient picture and "keep an eye" on patients at risk, without being physically present on the ward (Lang et al., 2016; Mackintosh et al., 2011). In the study by Lang et al. (2016) medical staff reported regularly accessing the system to monitor the progress of patients they had treated. While this was done for personal and clinical reassurance it may be problematic if this practice interferes with work life balance (Lang et al., 2016). Some

nurses reported that the ability to view a patient's status was compromised by the fact that during busy periods, computers on wheels were not readily available to log in and view the electronic vital signs (Mackintosh et al., 2011).

In contrast, interview data with staff in the study by Lang et al. (2016) revealed various benefits associated with the accessibility of data in the electronic system. Staff reported that the electronic system and the ability to view patient observations on handheld mobile devices improved accessibility to patient observations and improved team communication by fast tracking discussions about the care of deteriorating patients. The nurses also reported the accessibility of information provided them with reassurance concerning the patient's state of health and facilitated communication with patients and their relatives, as requests for information could be responded to without having to locate colleagues or paper charts (Lang et al., 2016). Finally, the ability to access data from an electronic EWS facilitated the collection of data for analysis and benchmarking performance, such as completeness and timeliness of observations and adherence to escalation protocol (Mackintosh et al., 2011).

When vital signs and or early warning scores were readily visible to clinicians the ability to identify trends and quickly evaluate the patient's condition was supported (Evans et al., 2014; Fletcher et al., 2018). In the study by Evans et al. (2014) patients were continuously monitored and vital signs were transferred automatically to a bedside computer and the EHR every five minutes. The vital signs were graphically displayed on the bedside computer which helped overcome the barrier of insufficient patient visualization and failure to recognise physiologic deterioration (Evans et al., 2014). Real time electronic dashboards or patient overview screens, ranking all patients according to their early warning score, facilitated rapid assessment of the status of all acute patients and deterioration trends over time (Fletcher et al., 2018; Mackintosh et al., 2011; Wong et al., 2015). Additional benefits associated with patient overview screens or dashboards included assisting clinicians with information sharing, planning and allocating workloads by glancing at the dashboard (Mackintosh et al., 2011; Wong et al., 2015).

### 3.7.3 Summary of theme three

This theme highlighted the importance of technology and hardware to be fit for purpose in the implemented clinical environment and for vital signs to be visible and accessible. Technology is constantly changing and developments in technology should always be evaluated to ensure they support, rather than hinder health care quality and patient safety. The final theme considers the response arm of electronic EWS and impact on patient outcomes.

### 3.8 Theme four: The response arm in electronic EWSs and impact on patient outcomes

This theme is comprised of the following two subthemes: Clinical response to deteriorating patients and patient outcomes in electronic EWSs.

#### 3.8.1 Subtheme one: Clinical response to deteriorating patients

During the automated alert phase of the study by Jones et al. (2011) when real-time clinical alerts were sent to doctors' pagers the clinical response to patient deterioration increased from 29% to 78%. Patients with the highest early warning score ( $> 5$ ) were responded to on 67% of deterioration instances in the baseline, paper-based EWS phase; compared to 96% during the electronic EWS with automated alert phase. In this study the EWS used not only issued alerts, but reissued reminders if clinicians did not attend the patient within the EWS protocol time. If the reminders failed an alert was sent to more senior doctors, for example, a registrar or consultant, until the alert was attended to and acknowledged. Compliance with the EWS protocol in terms of response times during the baseline phase was not reported on due to poor documentation of attendance times in the paper record. Although the electronic EWS automatically documented the time of clinical response after acknowledging the alert, the opportunity to report on response times with the electronic EWS was missed in this study (Jones et al., 2011).

When an automated alert signalling clinical patient deterioration was sent to the CNM's pager the nurses on both study units called the physician on 51% (unit A) and

44% (unit B) of occasions following review and discussion with the CNM (Evans et al., 2014). The positive predictive value of the alerts as perceived by the nurses was 91%-100%. The nurses' acceptance and approval of the system meant that their evaluations may have been biased and swayed towards a higher positive predictive value (Evans et al., 2014).

In the study by Kollef et al. (2017) when real time clinical deterioration alerts were sent to the RRT nurse's mobile device, internal audits showed that in 95% of cases the RRT nurse responded to alerts within 10 minutes. The study found that the use of an electronic EWS and real-time clinical deterioration alerts, in addition to nursing assessments, ensured rapid activations of the RRT and minimised delays often associated with a non-automated system. There was a statistically significant year-to-year increase in the number of RRT activations that was inversely correlated with the occurrence of cardiac arrests. The correlation between increased numbers of RRT activations and decreased cardio-pulmonary arrests gives merit to the clinical findings of this study as outlined above (Kollef et al., 2017).

Only two of the studies displaying onscreen prompts with actions required to be taken by the nurse according to the hospital's escalation protocol, reported on how the prompts contributed to protocol adherence in terms of response to patient deterioration (Bellamo et al., 2012; Mackintosh et al., 2012). In the study by Bellamo et al. (2012) a similar number of RRT calls were made during the intervention and control periods. However, RRT calls made for abnormal respiratory rates increased by 52% during the intervention period, as the bedside advisory monitors forced the nurses to manually enter the respiratory rates to calculate the early warning score. It was also found that patients had fewer physiological abnormalities at the time of the RRT call, indicating that the advisory monitors encouraged and prompted earlier calls for help (Bellamo et al., 2012). Mackintosh et al. (2011) reported that compliance to protocol greatly increased with prompts for escalating care provided by the electronic system. There were some disadvantages reported with the use of onscreen alerts like reducing potentially beneficial dialogue between staff regarding patient deterioration (Mackintosh et al., 2012). Another disadvantage associated with onscreen alerts was reported in the qualitative study by Lang et al. (2016) where the nurses reported that

onscreen alerts created alarm fatigue and cognitive overload, resulting in work arounds to turn alarms off.

Two of the included studies looked at the benefit of not having to rely only on the bedside nurse to activate the RRT for deteriorating patients (Fletcher et al., 2018; Heal et al., 2018). In the study by Fletcher et al. (2018) an electronic dashboard ranking all patients according to their aggregate early warning score enabled the entire care team, including the RRT, to rapidly identify patients with abnormal vital signs who could trigger the RRT. The study used a repeated treatment design where the dashboard was turned on for a week and then off for a week. On weeks where the dashboard was turned on it could be used to activate the RRT, in addition to the traditional method of the RRT being activated by the bedside nurse. With the use of the dashboard there was a 20% increase in first RRT activations, which was statistically significant, but overall RRT activations did not increase. It was reported that the dashboard may have alerted the RRT to patients who met activation criteria, but were not escalated. The dashboard also displayed patients from high to low early warning scores and the RRT may have responded to deteriorating patients with raised early warning scores below the usual level for activation. The activation threshold may have been lowered for the initial RRT review, but the subsequent RRT thresholds were maintained. A strength associated with the repeated treatment design is that it enabled the examination of the effect of the dashboard on RRT activation in a real life setting with a comparable control group. This type of study has greater internal validity than a pre-post study design as the influence of cofounders is less likely. To compensate for spill-over effects with this randomisation approach the analysis was based on the first alert. A limitation of this study is that it did not specify if the RRT was activated as a result of viewing the dashboard, or if bedside nurses activated the RRT independently of the dashboard. Staff were not blinded to the use of the dashboard and knowing that they were being observed may have prompted them to activate the RRT without viewing the dashboard scores (Fletcher et al., 2018).

Bedside nurses on both the intervention and control wards in a study by Heal et al. (2018) were unaware of the vital sign parameters and aggregate early warning scores that would trigger a response, as a new EWS was implemented on both wards without education. On the intervention ward a dedicated crisis nurse was required to check the

EHR and respond to any early warning score of three or more, every four hours. This reduced the reliance on the bedside nurse to recognise subtle signs of patient deterioration and activate the RRT. On the control ward the bedside nurses activated the RRT 110 times based on their perception of a patient's need. In comparison, the crisis nurse on the intervention ward activated the RRT 132 times. A limitation of this study is that the crisis nurse only reviewed the EHR for trigger activation every four hours, so further deterioration may have been missed during this period (Heal et al., 2018). In addition, had the bedside nurses been made aware of the EWS parameters that should trigger a response, they may have activated the RRT more frequently. Both these studies encouraged a proactive approach to the timely identification of patient deterioration and did not rely solely on the bedside nurse to activate the RRT (Fletcher et al., 2018; Heal et al., 2018). The various methods used in electronic EWSs to trigger a protocolled response to patient deterioration from staff with the appropriate skills may have an impact on patient outcomes in electronic EWSs.

### 3.8.2 Subtheme two: Patient outcomes in electronic EWSs

Four of the studies included in this integrative review automatically generated real-time clinical alerts if the early warning score triggered signs of physiologic patient deterioration. These automated alerts were sent to doctors' pagers (Jones et al., 2011), the CNM's pagers (Evans et al., 2014), a dedicated RRT nurse's mobile phone (Kollef et al., 2017) and email alerts via a mobile device to the critical care outreach team (Mwulu et al., 2012).

In a study by Jones et al. (2011) patient bedside vital signs were taken manually and the results were entered into a PDA. Real-time clinical deterioration alerts were then sent to a duty doctor's pager. During the baseline phase traditional systems were used to alert doctors to deteriorating patients. These included calls from nurses, pagers sent by switchboard or personal notifications. Following the introduction of real-time clinical deterioration alerts a significant reduction in the patient's length of stay from 9.7 days to 6.9 days was reported. During the baseline phase 14 patients were admitted to ICU and their combined length of stay in ICU was 51 bed-days. When automated alerts were sent five patients were admitted to ICU and their combined length of stay

in ICU was 26 bed-days. Reductions in cardiac arrest incidence and mortality did not reach clinical significance (Jones et al, 2011).

The opposite was found in a study by Evans et al. (2014) where during the intervention year automated clinical deterioration alerts were sent to the CNM's pager. The alerted patients on one of their study units had a significantly longer hospital stay during the intervention year compared to the pre-intervention year. This may be because the alerted patients generated more RRT calls, had more interventions or were transferred to ICU early enough to increase their chances of survival to discharge. During the intervention year in one of their two study units more patients were transferred to ICU (5.1% vs 4.1%), but fewer patients died (2.6% vs 3.7%) compared to the pre-intervention year. In their second study unit no significant differences were found in length of stay, ICU admissions or mortality after implementing automated alerts to the CNM's pager. The patients in the study unit where differences were observed were much older and had many more co-morbidities compared to the patients on the unit that did not demonstrate these findings. Consequently, they were more prone to physiologic deterioration as evidenced by the higher number of deterioration alerts generated (17% vs 9%). Based on these results it appears that the benefits associated with an EWS may be higher for older patients with multiple co-morbidities (Evans et al., 2014).

Starting in 2009 in the study by Kollef et al. (2017) real time clinical deterioration alerts were sent to the mobile phone of a RRT nurse. Statistically significant year-to-year decreases in mortality, cardio-pulmonary arrests and median lengths of stay were observed for the study years 2003 to 2014. In the study by Mwulu et al. (2012) for patients with the highest early warning scores email alerts were sent via a mobile device to the critical care outreach team. On average only two early warning scores produced a red alert (indicating severe deterioration) per day resulting in an email been sent to the outreach team (Mwulu et al., 2012). Unfortunately, this study did not evaluate the impact of an electronic EWS and automated alerts on patient outcomes, so it did not add much to the other studies reviewed.

A number of the included studies did not send automated real-time deterioration alerts, but displayed onscreen prompts with actions required to be taken by the nurse

according to the hospital's escalation protocol (Bellamo et al., 2012; Hands et al., 2013; Lang et al., 2016; Mackintosh et al., 2011; Mwulu et al., 2012; Schmidt et al., 2015; Wong et al., 2015). Bellamo et al. (2012) reported that the electronic EWS in their study resulted in increased calls for abnormal respiratory parameters and an earlier response to patient deterioration resulting in less need for mechanical ventilation, reduced arterial line insertion and vasopressor use. Rather, general medical interventions to address deterioration more than tripled, with more deteriorating patients transferred to high acuity areas with increased monitoring. This finding was only significant in the US hospitals involved in the study. Deteriorating patients for whom RRT activations were made also had improved in-hospital and 90 day survival rates (86%-92%). It was calculated that approximately 12 lives were saved by implementing the advisory monitors. Cardiac arrest rates also decreased from 34 during the control period to 24 during the intervention periods. The use of the advisory monitors was also associated with an overall decreased length of hospital stay (3.4-3.0 days). Once again this finding only reached significance in US hospitals.

Schmidt et al. (2015) also reported that year on year statistics at both their study hospitals showed abrupt and sustained reductions in mortality after the electronic EWS with onscreen advisory warnings was implemented. Crude mortality fell from 7.75% to 6.42%, equating to 397 fewer deaths in one hospital and from 7.57% to 6.15%, equating to 372 fewer deaths at the second hospital (Schmidt et al., 2015). Mwulu et al. (2012) reported that a daily average of 74 early warning scores, from 419 fully completed observation sets, produced onscreen alerts to clinical staff. Unfortunately, this study did not identify how many of these onscreen alerts resulted in an escalation of care or what the subsequent clinical outcomes of patients were.

The use of an electronic dashboard which enabled the entire care team, including the RRT, to rapidly identify patients with abnormal vital signs who could trigger a RRT did not significantly reduce cardiopulmonary arrests, unexpected ICU admissions or mortality. However, due to the infrequent nature of these events the study was not powered sufficiently to determine these outcomes. Length or cost of hospital stay may have been a better outcome measure (Fletcher et al., 2018). In a study where only a dedicated crisis nurse was made aware of the aggregate early warning score and response protocol, the difference in cardiac arrest rates between the intervention and

control wards did not reach clinical significance. This study missed the opportunity to determine how proactive rounding by a dedicated crisis nurse affects the length of stay after the RRT is activated (Heal et al., 2018).

### 3.8.3 Summary of theme four

This final theme showed that automated alerts, onscreen prompts and visible electronic dashboards generally improved medical attendance to the deteriorating patient, although onscreen prompts were associated with alert fatigue and a reduction in meaningful dialogue between staff. The included studies were not able to unequivocally demonstrate improved patient outcomes.

### 3.9 Chapter summary

Compared to paper-based EWSs, electronic EWSs reduced documentation errors and accurately calculated the aggregate early warning score. Systems which automatically transferred vital signs to the EHR or allowed manual entry of vital signs at the point of care were associated with greater accuracy and faster documentation of vital signs. The timeliness of repeating vital signs for deteriorating patients did not generally improve with electronic EWSs. User acceptability of electronic EWSs was high provided nurses were adequately trained and had ongoing support if problems were encountered. Concerns were expressed that the prescriptive nature of some electronic EWSs may dissuade the use of clinical assessment, experiential knowledge and intuition. Both doctors and nurses reported that electronic EWSs allowed them to spend more time with patients. The ability to identify patient deterioration was facilitated in electronic EWSs when the available technology and clinical environment supported point of care documentation and subsequent accessibility and visibility of vital signs. The use of automated real-time clinical deterioration alerts and widely visible electronic dashboards reduced the total reliance on bedside nurses to escalate care and minimised delays in care for deteriorating patients. Whether onscreen prompts improved compliance to protocol in terms of escalation of care was inconclusive and may have contributed to alert fatigue. Some of the studies included in this integrative review demonstrated improved patient outcomes with the use of electronic EWSs, others did not.

## **Chapter four: Discussion**

This final chapter discusses the findings from the literature included in the review. A critical analysis and interpretation of the findings is presented and related to each theme. The strengths and limitations of this integrative review are presented and implications for practice and opportunities for future research are addressed.

### 4.1 The detection arm of patient deterioration in electronic EWSs

Previous studies of paper-based EWSs proposed that EWSs may have been ineffective because vital signs were omitted, weightings were incorrectly assigned to vital sign parameters, early warning scores were incorrectly calculated and care was not escalated according to protocol (Clifton et al., 2014; Prytherch et al., 2006). In response to these deficits electronic EWSs have been implemented world-wide to support the accurate identification of deteriorating patients on general hospital wards and to aid timely interventions to improve their outcomes (Kollef et al., 2014). Accuracy of vital signs and aggregate early warning scores, documentation of vital signs and timeliness of rechecking vital signs forms the basis of the detection arm in both paper-based and electronic EWSs. Strategies to improve the documentation process of vital signs in electronic systems included the integration of monitors or observation machines that automatically and wirelessly transmitted recorded vital signs to the EHR, significantly reducing the risk of documentation errors (Meccariello et al., 2010; Smith et al., 2009). The requirement to manually enter some vital signs, such as respiratory rates and pain scores, meant some transcription and omission errors persisted in automated systems (Smith et al., 2009). The continuous recording and graphical display of vital signs, with intermittent measurements such as blood pressure triggered according to pre-set intervals, was an alternative strategy to improve the detection of deteriorating patients (Bonnici, Tarassenko, Clifton, & Watkinson, 2013; Evans et al., 2014). In theory, continuous monitoring should allow for the immediate detection of abnormal physiology and ensure vital signs are repeated in a timely manner (Bonnici et al., 2013). In practice, however, ambulant patients frequently fail to remain connected to conventional bedside monitors, questioning the place of these systems outside of high dependency areas (Watkinson et al., 2006).

Most of the included studies required the manual entry of vital signs into the patient's EHR (Hands et al., 2013; Jones et al., 2011; Mackintosh et al., 2011; Meccariello et al., 2010; Mwulu et al., 2012; Pederson et al., 2018; Pullinger et al., 2017; Schmidt et al., 2015; Wager et al., 2010; Wong et al., 2017; Yeung et al., 2012). Vital signs entered directly into the EHR at the point of care, without transcribing from one medium to another, were associated with greater accuracy and faster documentation of vital signs (Meccariello et al., 2010; Wager et al., 2010; Yeung et al., 2012). Integrating a tablet computer with an observation machine, (Bonnici, Gerry, Wong, Knight, & Watkinson, 2015; Wager et al., 2010) or the use of PDA's, facilitated the manual entry of vital signs at the point of care, reducing transcription errors and documentation delays (Hands et al., 2013; Jones et al., 2011; Lang et al., 2016; Mackintosh et al., 2011; Pullinger et al., 2017; Schmidt et al., 2015).

Electronic EWSs accurately calculated the early warning score provided all the required vital signs were entered. Electronic EWSs that required users to enter a full set of vital signs, or issued warnings if improbably values were entered, were more likely to have complete sets of vital signs and accurate early warning scores (Mackintosh et al., 2011; Mwulu et al., 2012; Pederson et al., 2018; Pullinger et al., 2017; Smith et al., 2015). Occasionally it may be clinically appropriate to allow the partial entry of vital signs (Mwulu et al., 2012; Pederson et al., 2018). To ensure all clinically required vital signs are entered the electronic EWS platform, Patientrack, used in the CDHB allows users to select between doing a full or partial set of vital signs. If the full set tab is selected the system will "force" users to enter a full set of vital signs, so that the early warning score can be calculated and displayed. Patientrack is also designed not to show the preceding set of vital signs when entering a new set. Only after entering the vital signs is a full observation chart with all the entries displayed allowing clinicians to identify trends towards deterioration or improvement. This prevents the occurrence of preceding scores predicting the outcome of subsequent observations (Clifton et al., 2015).

The need for the clinical environment to support the documentation method used was evident in the literature. Prior to implementing a clinical information system it is important to understand the workflow associated with patient care and to involve clinicians in the early stage of design (Stevenson, Israelsson, Nilsson, Petersson, &

Bath, 2016). If the technology is too cumbersome, or interferes with the delivery of care, workarounds need to be developed. Ideally recorded vital signs should be documented at the point of care, as delays in entering vital signs into the patient's EHR increased the risks of errors and delayed the access to potentially critical patient information (Wager et al., 2010; Wong et al., 2017; Yeung et al., 2012). Transcription still occurred in electronic systems when vital signs were documented to remote computers, rather than at the point of care (Yeung et al., 2012). The transcription of vital signs from paper to the EHR was a driver of errors, omissions and data delays in the EHR. Documentation delays also occurred if clinicians did not ensure electronic equipment was charged and ready for use, or if problems were not immediately reported for repair (Wager et al., 2010). Automated documentation systems, which automatically transferred vital signs to the patient's EHR, eliminated potential delays associated with manual documentation. As a consequence the accuracy of documented vital signs improved and clinician access to vital signs was not delayed (Bellamo et al., 2012; Meccariello et al., 2010; Smith et al., 2009).

The early detection of patient deterioration is facilitated by close monitoring of easily measured physiological variables like blood pressure, pulse, respiratory rate, temperature, oxygen saturations and level of consciousness (Smith et al., 2008). When an early warning score deviates from normal, EWSs require ward staff to increase the frequency of observations according to the degree of deviation from normal and a predefined protocol (McGaughey et al., 2017b; Odell et al., 2014). Despite electronic systems displaying prompts regarding the frequency of required vital signs, compliance with rechecking vital signs according to a pre-determined protocol did not generally improve in electronic EWSs (Jones et al., 2011; Mackintosh et al., 2011). The timeliness of rechecking vital signs was better for patients with a high early warning score (Pullinger et al., 2017), but remained poor overnight for all patients (Hands et al., 2013). Factors influencing the lack of compliance with regards the timeliness of subsequent vital signs were not addressed in the included studies, but it is probable that the reasons for non-compliance in paper-based and electronic systems are similar. Explanations offered for non-compliance in paper-based systems include nursing staff becoming desensitised to frequently occurring triggers (Smith & Aitken, 2015), competing clinical priorities, inadequate staffing, lack of available equipment (Hands et al., 2013; McGaughey et al., 2017b) and lack of knowledge regarding the

monitoring and interpretation of vital signs (Odell et al., 2009). The clinical impact of improving the components of the detection arm in electronic EWSs is yet to be determined.

#### 4.2 Human factors associated with the use of electronic EWSs

An electronic EWS may fail to realise its potential in the clinical setting if the needs, training requirements, expectations and perceptions of key stakeholders are not considered (Andargoli et al., 2017). Studies showed that user acceptance of electronic EWSs largely depended on the quality of their implementation and the organisational and cultural factors supporting their use (Bonnici et al., 2013; Lang et al., 2016; Wong et al., 2015). Nurses were initially anxious about using an electronic chart (Mwulu et al., 2012; Lang et al., 2016), but after a period of adjustment and engagement system usability scores were high (Mwulu et al., 2016, Wong et al., 2015). Pre-implementation training (Wong et al., 2015) and ongoing IT support contributed to acceptance of electronic EWSs (Lang et al., 2016).

Ideally, electronic EWSs ought to support and improve clinical decision making. This improvement included facilitating standardisation of care, thereby reducing disparities in care (Black et al., 2011). There is a risk that prescriptive algorithms associated with electronic EWSs may discourage critical thinking and decision making, integral components of effective nursing assessments (Ansell, Meyer, & Thompson, 2015). Senior nurses expressed concern that electronic EWSs may discourage the detection of patient deterioration through clinical assessment, clinical expertise and intuition (Lang et al., 2011; Mackintosh et al., 2011). Intuitive-experiential knowledge was occasionally used by senior nursing staff to detect early patient deterioration (Mackintosh et al., 2011), yet many of the widely used EWSs did not assign a weight to clinician concern. Escalating care for a patient with a physiologically “normal” early warning score can be challenging; therefore, there may be merit in considering the incorporation of a weighted parameter associated with clinician concern (Clifton et al., 2018). Nurses need to be empowered to escalate care when there is a discrepancy between the early warning score and staff concern based on clinical expertise and judgement (Lang et al., 2016). In the paper-based systems the recording of routine vital signs was frequently allocated to HCA’s and student nurses (McGaughey et al.,

2017b; Wheatley, 2006) and they may not have the intuitive-experiential knowledge to recognise subtle signs of patient deterioration (Odell et al., 2009, McGaughey et al., 2017b). In some of the electronic EWSs vital signs were also recorded by HCA's, but the studies did not specify if documentation errors were more likely to be made by HCA's, or if signs of deterioration were missed with this practice (Meccariello et al., 2010; Smith et al., 2009).

In the electronic systems junior doctors expressed frustration about not having the access or permission to modify patient parameters when appropriate. A previous study of a paper-based system, however, identified that in practice doctors were frequently reluctant to, or omitted to complete the modification section (Elliot et al., 2015) resulting in the generation of inappropriate alerts (Fox & Elliot, 2015). In the CDHB Patientrack also restricts the modification of vital sign parameters to senior medical staff and depending on their workload and availability, appropriate modifications may be delayed. Lack of senior medical staff engagement with the electronic EWSs created frustration amongst doctors and nurses, but both groups appreciated that electronic EWSs allowed more time to spend with patients (Lang et al., 2011).

#### 4.3 Technology and its contribution to patient safety

There were strengths and limitations associated with the hardware and technology used in the included studies. Documentation delays occurred when computers on wheels were too large to manoeuvre into rooms (Wager et al., 2010), when remote computers were unavailable (Yeung et al., 2012) or when there were insufficient devices for clinical staff (Lang et al., 2016). No significant issues were encountered with the use of handheld PDA's or systems which automatically transferred vital signs to the EHR (Bellamo et al., 2012; Evans et al., 2014; Hands et al., 2013; Jones et al., 2011; Lang et al., 2016; Mackintosh et al., 2011; Meccariello et al., 2010; Pullinger et al., 2017; Schmidt et al., 2015; Smith et al., 2009). Technology that required clinicians to scan their identification badge barcode and the bar-code on the patient's wristband ensured vital signs were assigned to the correct patient (Meccariello et al., 2010; Smith et al., 2009; Wong et al., 2015; Wong et al., 2017) and produced a record of who entered the vital signs (Mackintosh et al., 2011).

Vital signs and early warning scores need to be readily accessible and easily visible to facilitate recognition of patient deterioration. The automatic and wireless transfer of documented vital sign data to the patient's EHR allowed this data to be accessed remotely. Provided electronic devices were readily available for clinicians to access vital sign data (Mackintosh et al., 2011), this accessibility facilitated communication with colleagues, patients and relatives (Lang et al., 2016) and allowed doctors to monitor deteriorating patients without being physically present on the ward (Lang et al., 2016; Mackintosh et al., 2011). When vital signs were readily visible and easily accessible the ability to identify trends and quickly evaluate the patient's condition was supported (Evans et al., 2014; Fletcher et al., 2018). Real time electronic dashboards and patient overview screens allowed rapid assessment of patients' status and assisted with allocation of workloads (Fletcher et al., 2018; Mackintosh et al., 2011; Wong et al., 2015). Central dashboards displaying the most recent early warning scores enabled clinicians to rapidly assess the status of patients and encouraged the ward care team and RRT to take a proactive approach to prioritising patient care. The ability to monitor the electronic dashboard remotely could also be used by a person or team dedicated to identify patients who are deteriorating, reducing the total reliance on the bedside nurse to escalate care (Bonnici et al., 2013; Fletcher et al., 2018).

#### 4.4 The response arm in electronic EWSs and patient outcomes

Previous reviews have failed to establish the ability of EWSs to improve outcomes for patients whose clinical condition deteriorates as an inpatient (Alam et al., 2007; Gao et al., 2007; McGaughey et al., 2007; Nice, 2007). Anecdotal evidence, however, suggested that EWSs enhanced the ability of clinical staff to identify and respond to patient deterioration in a timely manner (La Lagadec & Dwyer, 2017). Bonnici et al. (2016) suggested that how nurses and doctors responded to patient deterioration, the presence of resourced escalation pathways and organisational facilities to care for deteriorating patients may contribute to improved outcomes. Electronic EWSs with automated, real-time clinical deterioration alerts to a doctor, CNM or RRT nurse minimised delays often associated with a non-automated system and improved medical attendance to the deteriorating patient (Evans et al., 2014; Jones et al., 2011; Kollef et al., 2017). If an abnormal score was not responded to within a specified timeframe a system may be programmed to generate sequential alerts to various

clinical team members until the alert is acknowledged (Jones et al., 2011). Automated alerts may mitigate the risk of the bedside nurse not calling for help due to sociocultural factors, such as fear that activating the RRT would elicit a negative or hostile reaction from colleagues (Shearer et al., 2012). None of the included studies reported on the timeframe to medical review after an alert or call for help was generated. This was a missed opportunity as previous studies demonstrated that doctors did not always review patients within the recommended time guidelines (Fox & Elliot, 2015).

The electronic system used by the CDHB currently does not generate any alerts and relies on the bedside nurse to know the escalation pathway that applies to the degree of deviation from normal and respond appropriately. In one study onscreen prompts with actions required to be taken by the nurse according to a hospital's escalation protocol found that a similar number of RRT calls were made during the intervention and control periods, but calls for help were made earlier and calls made for abnormal respiratory parameters increased (Bellamo et al., 2012). Another study reported that compliance to protocol, in terms of escalating care, greatly increased with onscreen prompts (Mackintosh et al., 2012). Disadvantages associated with onscreen prompts were alert fatigue (Lang et al., 2016) and a reduction in potentially beneficial dialogue between staff regarding patient deterioration (Mackintosh et al., 2012). The EWS in use needed to be sufficiently sensitive and specific to accurately detect patients who were deteriorating, but not too sensitive that staff experienced alert fatigue (Bonnici et al., 2013). The use of an electronic dashboard visible to the entire care team encouraged a proactive approach to the timely identification of patient deterioration and reduced the total reliance on the bedside nurse for RRT activation (Fletcher et al., 2018).

In terms of patient outcomes associated with the use of electronic EWSs the results were variable. Only eight of the included studies investigated whether electronic EWSs improve patient outcomes. In addition, these eight studies did not all use the same outcome measures or endpoints, further limiting the ability to draw conclusions. Outcome measures examined such as length of stay, unplanned ICU admissions and mortality were also influenced by a number of external factors that could lead to erroneous inferences about the effectiveness of electronic EWSs. An increased

admission rate to ICU may be due to an increased incidence of deteriorating patients or lower thresholds for ICU admission. Factors such as insufficient ICU beds may inhibit admission resulting in lower ICU admission rates (Bonnici et al., 2016).

The studies included in this review demonstrated that the implementation of real-time clinical deterioration alerts resulted in a reduction in length of stay and ICU admissions in one study (Jones et al., 2011) and an increased length of stay and ICU admissions in another, but fewer patient deaths (Evans et al., 2014). The conflicting results between these two studies using automated alert systems may have been influenced by significant design limitations associated with the study undertaken by Jones et al. (2011). Firstly, external factors may have had an influence on length of stay, particularly the influence of seasonal illness, as the study phases were conducted in different seasons with the automated alert phase occurring during summer. Secondly, the median age in the baseline phase was 70, compared to 65 in the alert phase and the difference in patient acuity was not determined. The inability to guarantee a homogenous patient group was a significant limitation, especially when length of stay was the focus. Thirdly, when the hospital introduced the electronic system they conducted additional deteriorating patient education with the nurses in the implementation wards, which may have resulted in improved clinical outcomes during the alert phase (Jones et al., 2011). Finally, there may have been a commercial conflict as one of the researchers was a founding director and shareholder of the Patienttrack system used in this study.

A retrospective study by Kollef et al. (2014) over a number of years (2003 to 2014) reported that real-time clinical deterioration alerts sent to the mobile phone of a RRT nurse resulted in statistically significant year-to-year decreases in mortality, cardio-pulmonary arrest and median lengths of stay. Given the retrospective nature of this study over a number of years the reductions in mortality, cardio-pulmonary arrests and hospital stay could not be definitively attributed to the introduction of the electronic EWS and real-time clinical deterioration alerts. In addition, the study results may have been influenced by the implementation of a dedicated RRT nurse position during the study allowing dedicated time to assess and pre-emptively identify deteriorating patients (Kollef et al., 2014).

The use of onscreen advisory warnings in the study by Bellamo et al. (2012) resulted in improved survival rates, reduced cardiac arrest rates and decreased length of stay for patients for whom RRT activations were made. The before-and-after study design meant that the three month intervention period occurred during a different season to the three month control period and this could potentially have affected patient cohort characteristics and outcomes. Another limitation of this study was that during the intervention period more RRT calls were made for less acutely unwell patients, possibly over-triaging, which may have been responsible for improved patient outcomes during the intervention period (Bellamo et al., 2012).

Another study also found that crude mortality fell after the implementation of the electronic EWS with onscreen advisory warnings (Schmidt et al., 2015). These findings were credible as these consistent results followed the electronic EWS implementation at different hospitals, across different specialities, at different times, suggesting the findings were generalisable and reproducible based on a plausible cause and effect relationship. Prior studies were smaller implementation studies limited to specific patient groups or focusing on process measures (Schmidt et al., 2015). The use of a visible electronic dashboard allowing activation of the RRT by the entire care team had no effect on cardiopulmonary arrests, unexpected ICU admissions or mortality (Fletcher et al., 2018).

The introduction of any EWS without ensuring there was an adequate clinical response specified by a predetermined, realistic and resourced escalation pathway was associated with the risk of alerts being ignored (Bonnici et al., 2013). As previously mentioned the NZEWS is based on the NEWS used by the NHS in the UK (HQSC, 2016a). The NZEWS is yet to be fully validated in the NZ setting with local population groups. Until the impact of implementing a standardized national EWS on staff and patients in NZ is determined, it is unlikely that electronic systems will be programmed to issue automated alerts.

Electronic EWSs offer theoretical benefits compared to paper-based EWSs, but existing literature has shown inconsistent results. Currently there is no conclusive evidence that EWSs (electronic or paper-based) improve patient outcomes (Alam et al., 2014; Gao et al., 2007; McGaughey et al., 2007; Nice, 2007). With the growing

use of electronic EWSs the potential to improve patient care, and potentially patient outcomes, may be in the ability to process and analyse large volumes of readily accessible electronic vital sign data. This data can be used to drive improvements by addressing identified flaws like delays in calling for help. In the future computerised algorithms using additional components of the EHR such as demographic data, laboratory results and medication usage may be used to enhance existing early warning scores (Bonnici et al., 2013).

#### 4.5 Strengths and limitations

This integrative review has several important strengths and limitations that need consideration when interpreting the results of this review.

##### 4.5.1 Strengths

To ensure the reproducibility of the review and rigour of the process a systematic approach was applied to this integrative review. A clear and unambiguous research question was formulated and inclusion and exclusion criteria were developed to guide a search for appropriate literature. The assistance of the University's Librarian was sought to conduct a comprehensive and exhaustive search strategy of relevant databases. To avoid publication bias, published and unpublished literature was sought. Selected studies and their research methodologies were critically appraised using JBI's 2014 critical appraisal tools and only studies meeting the 70% appraisal threshold and inclusion criteria were included in the review. Data from selected studies was analysed and synthesised into themes and subthemes using Braun and Clarke's (2006) six phases of thematic analysis and presented in a narrative format.

Most of the studies included in this review originated from the US and the UK. Although the findings cannot be directly extrapolated to the NZ context these countries do share similarities in terms of their EWSs components and availability of resources to respond to deteriorating patients. Although the results of individual studies may not be generalisable to other locations, this review allows organisations wanting to implement an electronic EWS to consider the strengths and limitations

associated with the different systems before investing valuable resources in designing or purchasing a system.

The electronic data in the included studies allowed the researchers to manipulate, analyse and synthesise large sets of data, which would not be possible with paper-based systems. This ability contributed to the credibility and reliability of reported results in the studies included in this review.

#### 4.5.2 Limitations

The heterogeneity of the studies included in the review made drawing conclusions challenging. While many of the studies focused on one or more of the research objectives, no study answered all the research objectives. The fact that the search was limited to English-language databases meant that some relevant literature may have been missed.

Twelve of the included studies used a quasi-experimental study design. This before-and-after study design cannot eliminate potential confounders such as seasonal influences or changes implemented in the clinical environment during the course of the study. The various studies used different ward settings and patient groups, so it is unknown if the results would be generalisable to, or reproducible in other locations with other patient groups, or in different clinical settings. Electronic EWSs are still in their infancy stage in NZ and the absence of NZ research impacts on the generalisability of this review to the NZ setting.

#### 4.6 Implications for practice

A number of implications for practice were identified from the findings of this integrative review. Firstly, it is essential that the NZEWS is fully validated in the NZ setting with local population groups to determine if it is sufficiently sensitive and specific to accurately detect deteriorating in-patients. Until this is done it may be challenging to evaluate the true impact of electronic EWSs in NZ. For example, in the CDHB where the NZEWS was implemented a year ago there has been an increased

incidence of single parameter triggers. This has led to an increase in referrals for deteriorating patients which risks overloading clinical services.

It is important for organisations considering the implementation of an electronic EWS to evaluate not only the technology itself, but the usability of the system for clinicians and how well the system would integrate into the organisation (Andargoli et al., 2017). Organisations need to ensure that the clinical environment supports the documentation of vital signs at the point of care, that users are adequately trained and that there are enough devices for clinicians to use without delay. The electronic EWS needs to integrate seamlessly with the rest of the EHR, so that vital signs and early warning scores are remotely and widely accessible. Finally, organisations need to ensure that electronic EWSs are effectively and regularly evaluated using a multidisciplinary approach, with results clearly communicated to staff and used to inform continuous quality improvement of the system (Black et al., 2011).

#### 4.7 Opportunities for future research

There were only three qualitative studies investigating the training requirements, expectations and perceptions of key stakeholders using electronic EWSs; therefore, there is an opportunity for further research in this area. Qualitative studies help to understand the socio-cultural factors that affect compliance with protocols (Shearer et al., 2012). Qualitative studies may help to determine why the timeliness of subsequent vital signs measurements did not improve with electronic systems, or why bedside nurses failed to escalate care despite the electronic system prompting them to do so.

The inability of the available literature to conclusively demonstrate the effect of electronically captured clinical observations with/without automated alerts on clinical outcomes of deteriorating adult in-patients highlights the need for further research in this area. Ideally RCTs are needed to establish the impact of electronic EWSs, but as EWSs are already widely implemented the ability to do so is potentially limited. Given the complexities associated with conducting RCTs and eliminating extraneous variables that could affect patient outcomes, perhaps the focus of future research needs to change. Instead of attempting to demonstrate improved patient outcomes with EWSs, studies should focus on determining the optimal use of technology and EWSs

to identify and respond appropriately to deteriorating patients, as these factors may positively influence patient outcomes. As technology in healthcare continues to develop there may be opportunities to implement systems which use both real-time EWS data and additional data from the EHR to predict clinical deterioration and potentially intervene to improve patient outcomes.

#### 4.8 Conclusion

Electronic EWSs have the potential to facilitate the recognition, activation and response to acutely deteriorating hospital in-patients. The review clearly identified improvements in the detection arm of EWSs with the use of electronic EWSs. Electronically captured clinical observations improved the reliability and accessibility of patients' vital signs and the accuracy of aggregate early warning scores. Numerous technological developments and hardware options were identified to ensure point of care documentation and the automated, wireless transfer of vital signs to the EHR. Compliance to protocol in terms of frequency of vital sign measurement and escalation of care (if not using automated alerts) remained variable.

The limited available qualitative data showed that after a period of adjustment and engagement system usability scores were high, although challenges and frustrations identified in paper-based systems, such as lack of senior medical staff engagement and feared loss of intuitive experiential knowledge remained. The improved accessibility and visibility of vital signs supported a proactive and remote response to patient deterioration.

Improvements in the detection arm of EWSs were important, but not sufficient to affect patient outcomes. The potential to improve patient outcomes sits with the response arm of EWSs: the improved escalation, response and management of deteriorating patients that may translate to improved patient outcomes. Numerous methods of escalating care such as the use of automated alerts, onscreen prompts and visible electronic dashboards reduced the total reliance on the bedside nurse to escalate care. Any escalation, however, irrespective of the source requires an adequately resourced individual or team who can provide a timely and appropriate response to deteriorating patients according to a pre-determined, realistic escalation pathway. With

the continued development and implementation of electronic EWSs worldwide, it will be interesting to see if they will be able to conclusively demonstrate improved patient outcomes associated with their use.

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## Appendix A Literature search of the CINAHL database

EBSCOhost

Monday, March 15, 2018 7:10:39 AM

#	Query	Limiters/Expanders	Last Run Via	Results
S13	s6 AND s11	Limiters - Published Date: 20080101-20180531; English Language; Peer Reviewed Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	84
S12	s6 AND s11	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	130
S11	s7 OR s8 OR s9 OR s10	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	79,369
S10	TX electronic	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	68,475
S9	TX real time alert*	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	17
S8	TX automat*	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	12,674

S7	TX electronic observation*	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database – CINAHL	3
S6	S1 OR S2 OR S3 OR S4 OR S5	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database – CINAHL	1,392
S5	TX e-trigger	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database – CINAHL	1
S4	TX EWS	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database – CINAHL	145
S3	TX rapid response*	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database – CINAHL	1,049
S2	TX "track and trigger"	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database – CINAHL	30
S1	TX early warning score*	Limiters - Published Date: 20080101-20180531; English Language Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database – CINAHL	234

## JBI Critical Appraisal Checklist for Quasi-Experimental Studies (non-randomized experimental studies)

Reviewer \_\_\_\_\_ Date \_\_\_\_\_

Author \_\_\_\_\_ Year \_\_\_\_\_ Record Number \_\_\_\_\_

	Yes	No	Unclear	Not applicable
1. 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)?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Were the participants included in any comparisons similar?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Was there a control group?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Were there multiple measurements of the outcome both pre and post the intervention/exposure?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Were the outcomes of participants included in any comparisons measured in the same way?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. Were outcomes measured in a reliable way?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Was appropriate statistical analysis used?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Overall appraisal:    Include <input type="checkbox"/> Exclude <input type="checkbox"/> Seek further info <input type="checkbox"/>				
Comments (Including reason for exclusion)				
<hr/>				
<hr/>				

## JBI Critical Appraisal Checklist for Text and Opinion Papers

Reviewer \_\_\_\_\_ Date \_\_\_\_\_

Author \_\_\_\_\_ Year \_\_\_\_\_ Record Number \_\_\_\_\_

	Yes	No	Unclear	Not applicable
1. Is the source of the opinion clearly identified?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Does the source of opinion have standing in the field of expertise?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Are the interests of the relevant population the central focus of the opinion?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Is the stated position the result of an analytical process, and is there logic in the opinion expressed?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Is there reference to the extant literature?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Is any incongruence with the literature/sources logically defended?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Overall appraisal:    Include     Exclude     Seek further info

Comments (Including reason for exclusion)

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## JBI Critical Appraisal Checklist for Qualitative Research

Reviewer \_\_\_\_\_ Date \_\_\_\_\_

Author \_\_\_\_\_ Year \_\_\_\_\_ Record Number \_\_\_\_\_

	Yes	No	Unclear	Not applicable
1. Is there congruity between the stated philosophical perspective and the research methodology?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Is there congruity between the research methodology and the research question or objectives?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Is there congruity between the research methodology and the methods used to collect data?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Is there congruity between the research methodology and the representation and analysis of data?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Is there congruity between the research methodology and the interpretation of results?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Is there a statement locating the researcher culturally or theoretically?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Is the influence of the researcher on the research, and vice-versa, addressed?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. Are participants, and their voices, adequately represented?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Is the research ethical according to current criteria or, for recent studies, and is there evidence of ethical approval by an appropriate body?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Do the conclusions drawn in the research report flow from the analysis, or interpretation, of the data?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Overall appraisal:    Include     Exclude     Seek further info   
 Comments (Including reason for exclusion)

Appendix C Data extraction table

Author/date	Study title	Type of study	Key findings	Strengths	Weaknesses	JB1 tool and score
Smith, L.B., Banner, L. Lozano, D., Olney, C.M. & Friedman, B. (2009)  Florida	Connected Care – Reducing Errors Through Automated Vital Signs Upload	Post-implementation study	<p><b>Positive patient identification</b> In this study a bar-code on a patient’s wristband was scanned to determine a patient’s identification.</p> <p><b>Automated transfer of observations via infrared technology to a PDA and after confirmation to electronic medical record</b> Vital signs were then captured with an observation machine and then transmitted automatically via infrared technology to a personal digital assistant (PDA). The registered nurse or nurse technician then confirmed the display of vital signs on the PDA by pushing a button which automatically transferred the vital signs to the patient’s EMR and to a vital sign sheet. Finally, in this study the nurse was required to review and validate the vital signs within the EMR before they became a permanent part of the EMR. This had to be done within 6 hours.</p> <p><b>Manual recording of respiratory rates</b> Respiratory rates were entered manually as the observation machine does not measure respiratory rates.</p> <p><b>Omission errors (Non-entry of a vital sign or non-validation of the EMR).</b> There were 53 errors of omission which accounted for 0.58% of the total recorded vital signs. Twenty respiratory rates were missing due to the requirement to enter the respiratory rate manually into the PDA or EMR. Three complete sets of vital signs were missing because</p>	<p>The units nursing staff were blinded to the study, although there was a requirement to printout a strip displaying the vital signs from the observation machine with the patient’s room number documented on it. This requirement may have alerted the nursing staff that some form of measurement was occurring.</p> <p>There was a baseline study conducted seven months prior to this study which showed a 10% error rate for vital signs captured on paper and then written onto a paper chart and 4.4% error rate for vital signs captured on paper and then typed manually into the patient’s EMR (ref). This demonstrated the significance of the reduction in error rates from 10% and 4.4% respectively to 0.66% for a system which automatically uploads the vital signs.</p>	<p>This study was conducted in only one inpatient nursing unit over a short time period of 3 weeks. The study did not identify whether the errors were made by registered nurses of nurse technicians or if accuracy was influenced by other factors such as experience level of staff, patient load or patient acuity. Not clear if nurse technicians are more likely to make transcription errors and nurse technicians are not used in New Zealand. This EMR system required the user to review and validate the vital signs within the EMR before they became a permanent part of the EMR. The study did not identify if this requirement added any value or if it was an additional step which could have affected outcomes.</p>	<p>JB1 MASTARI Score 78% No control group It was unclear if participants included in any comparisons were exposed to other treatment or care other than the intervention of interest Concern regarding the use of nurse technicians in this study, Are they more likely to make transcription errors. Unsure because we have no comparisons between NTs and RNs. This type of health professional is not used in New Zealand.</p>

			<p>the nurse did review and validate the vital signs within the EMR, which was a requirement to make the vital signs a permanent part of the EMR. Sixteen oxygen saturation values and five pulse rate values were missing. In 13 cases the nurse removed the saturation probe from the patient's finger before the data was transmitted from the observation machine to the PDA.</p> <p><b>Transcription errors (applies to manually entered values)</b></p> <p>There were seven transcription errors, which accounted for 0.08% of the total recorded vital signs. In one case, the respiratory was erroneously entered into the saturation parameter. In a second case, the nurse manually entered an entire set of six the vital signs directly into the EMR for the wrong patient, rather than reviewing and validating the vital signs from the PDA.</p> <p><b>Transmission errors (vital sign printout does not match a value in the PDA or EMR)</b></p> <p>There were no transmission errors</p> <p><b>Total errors/ Automated transfer of observations via infrared technology to a PDA and after confirmation to electronic medical record</b></p> <p>There were 60 errors in total which represented an error rate of 0.66% for this electronic, automated vital sign documentation.</p>			
Wager, K.A., Schaffner, M.J., Foulis, B., Kazley, A.B., Parker, C. & Walo, H.	Comparison of the Quality and Timeliness of Vital Signs Data Using Three Different Data-	An observational study	The purpose of this study was to measure the accuracy and timeliness of vital signs data before and after the implementation of a clinical documentation system using four different data-entry devices: a paper medical record system, a computer-on-wheels workstation kept outside		Observation studies can have a Hawthorne effect. Using observers who were familiar to staff recording the vital signs was an	<p>JBIMASTARI</p> <p>Score 78%</p> <p>No control group</p>

<p>(2010)</p> <p>South Carolina, USA</p>	<p>Entry Devices</p>		<p>the patient's room requiring the transcription of vital signs from a piece of paper to the computer and a system whereby vital signs were entered directly from the observation machine to an electronic tablet affixed to the observation machine.</p> <p>The fourth system with a direct feed of vital signs from the observation machine to the electronic tablet was not tested.</p> <p><b>Vital signs captured directly onto paper</b></p> <p>In phase one the technicians generally handwrote the vital signs directly into the patient's paper medical record at the point of care.</p> <p><b>Capturing vital signs on paper before writing into EMR via computer on wheels (bedside computer) or workstation away from patient's room</b></p> <p>In phase two the technicians typically handwrote the vital signs on pieces of paper and then transcribed them into the electronic medical record via a computer on wheels or workstation outside the patient's room.</p> <p><b>Capturing vital signs directly from observation machine to EMR via laptop attached to observation machine</b></p> <p>The documentation quality of vital signs improved when vital signs were entered at the point of care, directly from the observation machine, into an electronic tablet attached to the observation machine.</p> <p><b>Transcription errors</b></p> <p>Documentation errors (predominantly transcription errors which accounted for 90.3% of the documentation errors) in patients' clinical records decreased from 16.8% for the paper-based system, and 15.2% for vital signs transcribed</p>		<p>attempt to minimise this effect.</p> <p>The nurse observers could also have made documentation errors when transcribing the vital signs from the observation machine to the documentation form. Although they were advised to carefully check their work observer documentation errors could have occurred and remains a limitation of this study.</p> <p>There were fewer observations made in stage two: paper to computer, as medical staff expressed grave concern about the delay in inputting vital signs into the patients' clinical record. The smaller sample size in stage two is a further limitation of this study. There were 113 observation sets recorded in stage one , 33 observation sets recorded</p>	<p>Follow up not complete</p>
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			<p>from paper to computer, to 5.6% when vital signs were entered directly from the observation machine into a tablet.</p> <p><b>Faster documentation of vital signs</b></p> <p>It took an average of 9 minutes 15 seconds to input vital signs from paper into computers outside the patient's room as the computers were often occupied by other clinicians. It took an average of 1 minute 14 seconds to input the vital signs onto the paper observation chart after taking them and 35 seconds when entering vital signs directly into an electronic tablet. An electronic tablet affixed to the observation machine reduced the time required to record and document vital signs and improved the quality of the vital signs.</p> <p><b>Equipment/hardware issues</b></p> <p>The size of the computer on wheels meant that technicians could not enter the vital signs at the point of care as it was too difficult to manoeuvre the computer and observation machine into the patient's room. This delay could have implications for patient safety, especially in an acute ward.</p>		<p>in stage two and 124 in stage three, resulting in a total of 270 observation sets.</p> <p>Vital signs were recorded by nurse technicians (nursing assistants) rather than registered nurses, so results between studies may not be directly comparable.</p> <p>The observers in this study checked the accuracy of 4 vital sign recordings: BP, pulse, temperature and oxygen saturation. These are the four vital signs displayed on the observation machine. They did not check the documentation accuracy of the respiratory rate, or comment on whether this frequently omitted vital sign was recorded.</p> <p>This study appeared to focus only on capturing vital signs and not on</p>	
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					determining an early warning score and observers in this study noted that the nurse technicians were not notifying the nurse if the vital signs were outside the reference range.	
Meccariello, M. Perkins, D., Quigley, L.G., Rock, A. & Qiu, J. (2010)  USA	Vital Time Savings Evaluating the Use of an Automated Vital Signs Documentation System on a Medical/Surgical Unit	A quasi- experimental design	<p>The study compared the accuracy and time efficiency of documenting vital signs manually into the patient's EMR to using a data management system that automatically documents vital signs into the EMR. In both periods an observation machine was used to obtain BP, temperature, pulse and oxygen saturations. Respiratory rate and pain score were obtained manually in both periods, but in the study phase they were entered into the observation machine. In the pre-implementation period the vital signs were written on paper and then transferred manually via computers in the hallway to the EMR or entered directly from the observation machine to the EMR via a bedside computer.</p> <p><b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b> Handheld devices were also available but were not preferred by technicians so only one set of vital signs was completed with this device.</p> <p><b>Vital signs captured automatically from observation machine directly to EMR after vital signs on observation machine confirmed.</b> With the study's automated vital sign documentation system the clinician verified the accuracy of the vital signs</p>		<p>The clinicians only had a one hour training session and one day to familiarise themselves with the new method of acquiring and documenting vital signs after implementing the automated documentation system. Despite this a significant time saving still occurred with the study vital sign machine and automated documentation system.</p> <p>The time lag between acquiring and documenting the vital signs into a computer outside the patient's room was not recorded when this method was used. This delay in entering vital signs can</p>	<p>JBIMAStARI</p> <p>Score 78%</p> <p>No control group</p> <p>Not sure if participants included in any comparisons were receiving similar treatment/care other than exposure to intervention</p>

		<p>on the observation machine before pressing a confirmation button to automatically transfer the vital signs to the patient's EMR thus eliminating manual documentation.</p> <p><b>Positive patient/clinician identification</b></p> <p>The study observation machine had a bar-code scanner used to identify the patient and clinician.</p> <p><b>Documentation errors/accuracy</b></p> <p>The use of an automated documentation system as opposed to manual documentation system reduced documentation errors by 75%. Out of 52 sets of vital sign there was an error rate of 13.5% (7 errors) in the manual documentation period.</p> <p><b>Capturing vital signs directly from observation machine to EMR via a bedside computer</b></p> <p><b>Documentation errors/Typographic errors/Transcription errors/forgetting vital sign</b></p> <p>Four of these errors occurred when documenting from the observation machine to the bedside computer as follows: two typographical errors (typing into the computer incorrectly), one transcription error (transposed digits) and once having to repeat observations due to forgetting a vital sign.</p> <p><b>Capturing vital signs onto a piece of paper to document into a computer outside patient's room</b></p> <p><b>Documentation errors/typographical error/transcription error/forgetting vital sign</b></p> <p>Three errors occurred when the technician wrote the vital signs on paper and then manually documented the vital signs into a computer in the hallway. Of these three errors one was a typographical error, one was a transcription error and one was forgetting a vital sign.</p>		<p>negatively affect patient care as others will not be able to access and evaluate the vital signs until they are entered.</p>	
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		<p><b>Vital signs captured automatically from observation machine directly to EMR after vital signs on observation machine confirmed.</b></p> <p><b>Documentation errors/difficulty scanning identification barcode/typographical error/omission error</b></p> <p>Of the 92 sets of vital signs done utilising the automated documentation system an error rate of 3.3% occurred. The three errors that occurred were difficult scanning the patient's identification bar-code, one typographic error (for the manually entered result) and one omission error (failure to enter a result that required manual entry i.e. pain or respiratory rate).</p> <p><b>Faster documentation of vital signs</b></p> <p>An average time saving of 96.19 seconds was achieved using the vital sign acquisition/automated documentation method compared to the vital sign acquisition/manual documentation method. This equated to almost 120 hours a month for a 36 bed unit where vital signs were recorded on average four times a day.</p> <p><b>Faster documentation of vital signs</b></p> <p><b>Vital signs captured automatically from observation machine directly to EMR after vital signs on observation machine confirmed</b></p> <p>It took an average of 107.5 seconds to acquire and document the vital signs using the automated documentation system.</p> <p><b>Capturing vital signs onto a piece of paper to document into a computer outside patient's room</b></p> <p>The acquisition and manual documentation method where vital signs were recorded on paper and then entered into a computer in the hallway took the most time, namely</p>			
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			203.69 seconds. <b>Capturing vital signs directly from observation machine to EMR via a bedside computer</b> The acquisition and manual documentation to a bedside computer took an average of 131.63 seconds.			
Jones, S., Mullally, M., Ingleby, S., Buist, M., Bailey, M. & Eddleston, J.M. (2011)  United Kingdom	Bedside electronic capture of clinical observations and automated clinical alerts to improve compliance with an Early Warning Score protocol	Historically controlled study	<b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b> <b>Real time clinical alerts to doctor's pager</b> <b>Reduction in length of stay</b> In this study when automated alerts were sent to doctors there was a significant reduction in the patient's length of stay from 9.7 days to 6.9 days. <b>Vital signs captured directly onto paper</b> <b>Documentation errors/accuracy</b> During the baseline data capture phase (on paper) the early warning score was calculated accurately on 81% of occasions. Calculation errors produced both overestimates and underestimates of the early warning score. <b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b> <b>Documentation errors/accuracy</b> This increased to 100% with the electronic system. <b>Timeliness of rechecking observations</b> The electronic system did not improve the timeliness of rechecking observations. Compliance with rechecking observations according to the recommended timeframe for deteriorating patients did not change significantly between the baseline and alert phase. <b>Real time clinical alerts to doctor's pager</b> <b>Response to patient deterioration</b> During the automated alert phase the clinical response to	This was a large study of many observation sets – 13668	In this study there are external factors which may have had an influence on the length of stay. The study was conducted in three consecutive phases which spanned seasons (the baseline phase was conducted in northern hemisphere winter and the alert phase was in the summer) and therefore the influence of seasonal illness may have been a factor influencing los. There was a five year median age range between the baseline and the alert phase. The median age in the baseline phase was 70 compared to 65 in the alert phase. Difference in patient acuity was not determined. One cannot guarantee a homogenous patient group. This is a significant	JBIMASARI  Score: 78%  No control group  Not sure if participants included in any comparisons were similar  It is unclear if there was a difference in the acuity of the patients in the two phases. This is a significant omission especially when LOS is a focus. In addition there is a strong commercial link to this paper – they are trying to sell their system.

		<p>patient deterioration increased from 29% at baseline to 78%.</p> <p><b>Vital signs captured directly onto paper</b></p> <p><b>Response time to patient deterioration</b></p> <p>It was not possible to determine compliance with the EWS protocol in terms of response times in the baseline group due to poor documentation of attendance times in the paper record.</p> <p><b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b></p> <p><b>Real time clinical alerts directly to doctors</b></p> <p><b>Response time to patient deterioration</b></p> <p>In contrast, the electronic system documented the time of data entry, automatically calculated the early warning score and recorded the clinical response times to the patient. Overall, at baseline patients with an early warning score of 3, 4, or 5 were responded to on 29% of instances. This increased to 78% during the automated alert phase. Patients with a high early warning score (&gt; 5) were responded to on 67% of deterioration instances in the baseline phase, compared to 96% during the alert phase.</p> <p><b>Vital signs captured directly onto paper</b></p> <p><b>Critical care admissions</b></p> <p>At baseline 14 patients were admitted to critical care and their length of stay was 51 bed-days.</p> <p><b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b></p> <p><b>Real time clinical alerts to doctor's pager</b></p> <p><b>Critical care admissions</b></p> <p>In comparison, when automated alerts were sent five patients were admitted to critical care and their length of</p>		<p>omission especially when los is the focus. In addition there may be a strong commercial link to this paper as one of the researchers is a founding director and shareholder of the Patientrack system used in this study.</p> <p>When the hospital introduced the electronic system they conducted additional deteriorating patient education to the nurses in the implementation wards. This training was not conducted at the baseline phase and may have had a resulted in improved clinical outcomes during the alert phase.</p>	
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			<p>stay was 26 bed-days.</p> <p><b>Cardiac arrest rates</b></p> <p>Reductions in cardiac arrest incidence and mortality did not reach statistical significance.</p> <p><b>Real time clinical alerts to doctor's pager</b></p> <p><b>Response to patient deterioration</b></p> <p>This study demonstrated significant improvement in clinician response to deteriorating patients. The Patientrack system used in this study not only issues alerts, but reissues reminders if clinicians do not attend the patient of respond within the EWS protocol time. If the reminders fail, an alert is sent to more senior doctors, for example a registrar or consultant until the alert is attended to and acknowledged. In this study on 96% of occasions senior medical doctors attended the most unwell patients (early warning score &gt; 6) compared to 67% in the baseline period.</p>			
<p>Bellomo, R., Ackerman, M., Bailey, M., Beale, R., Clancy, G., Danesh, V., Hvarfner, A., Jimenez, E., Konrad, D., Lecardo, M., Pattee, K.S., Ritchie, J., Sherman, K., &amp; Tangkau, P.</p>	<p>A controlled trial of electronic automated advisory vital signs monitoring in general hospital wards</p>	<p>Before-and-after controlled trial</p> <p>To determine if electronic automated advisory vital signs monitors may help identify such patients and improve the outcomes of deteriorating ward</p>	<p><b>Automated documentation system (Vital signs transferred automatically to advisory bedside patient monitors).</b></p> <p>In this study the following vital signs obtained from patient monitoring equipment were automatically transferred and displayed to bedside patient monitors: BP, heart rate, pulse oximetry and temperature. The nurse was then prompted to enter the patient's respiratory rate, level of consciousness and ward specific parameters such a nurse's concern and urine output. The early warning score was then calculated automatically and displayed on the monitor together with any actions required to be taken by</p>	<p>This was a large international study with a patient cohort of 18305. The RRT was blinded to the fact that a new monitoring protocol had been introduced so their response was not altered by the implementation of the monitors.</p> <p>No other modifications were made to nursing care or medical care in the study</p>	<p>The same group of nurses were exposed to both interventions, so there was no independent separate group used as a control group.</p> <p>The before-and-after study design meant that the 3 month intervention period occurred during a different season to the 3 month</p>	<p>JBIMASARI</p> <p>Score: 89%</p> <p>No control group</p>

<p>(2012)</p> <p>Multicentre, multinational trial – 12 general wards in ten hospitals in the United States, Europe and Australia</p>		<p>patients.</p>	<p>the nurse according to the hospital's escalation protocol. The monitor also advised the nurse when the next vital signs were due as per the patients Early Warning Score and hospital's EWS protocol. The monitor kept a record of all vital signs for review and could display vital sign trends on request.</p> <p><b>Automated documentation system (Vital signs transferred automatically to advisory bedside patient monitors).</b></p> <p><b>Faster acquisition of vital signs.</b></p> <p>A system that assists one to obtain, complete and display vital signs and automatically calculates the early warning score may decrease the time required to complete a set of observations and may result in improved identification of patient deterioration.</p> <p>Benefits associated with the implementation of automated advisory vital sign monitors:</p> <p>In this study the time required to complete and record a set of vital signs and automatically calculate an Early Warning Score resulted in a time saving of about 1750 nursing hours per ward per year. The time decreased from an average of 4.1 min to 2.5min.</p> <p><b>Automated documentation system (Vital signs transferred automatically to advisory bedside patient monitors).</b></p> <p><b>Increased RRT calls</b></p> <p>There were a similar number of RRT calls made during the control (205 calls) and intervention period (209 calls). However, RRT calls made for abnormal respiratory rates increased by 52% as the monitors forced nurses to enter</p>	<p>wards during the study period and no additional interventions were applied. The short period between interventions also minimised the effect of extraneous factors on outcomes and thousands of patients were studied. Hospital administrators coding outcome measures were blinded to the interventions of the study.</p> <p>The demographic data, admission status and diagnostic categories of patients (ICD-10 codes) were compared for patients in the control and intervention period so that one could determine if participants included in comparisons were similar. Robust and adjusted outcome measures were used to account for differences between patients, hospitals and seasons.</p>	<p>control period and this could potentially have affected patient outcomes.</p> <p>During the intervention period more RRT calls were made for less acutely unwell patients (possibly over triaging), which may have been responsible for improved patient outcomes during the intervention period.</p> <p>The price of one monitor was \$5275 and unless one could demonstrate a significant cost saving in terms of decreased length of stay this cost may be prohibitive.</p>	
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		<p>the respiratory rates in order to calculate the Early Warning Score (RR known to be a sensitive and early predictor of patient deterioration). RRT calls made for respiratory criteria increased from 21% to 31%.</p> <p><b>Automated documentation system (Vital signs transferred automatically to advisory bedside patient monitors).</b></p> <p><b>Response time to patient deterioration</b> Patients had fewer physiological abnormalities at the time of the RRT call indicating that the advisory monitors encouraged and prompted earlier calls for help.</p> <p><b>General medical interventions</b> Benefits associated with the earlier and improved response to patient deterioration included less need for mechanical ventilation, reduced arterial line insertion and vasopressor use. Rather, general medical interventions to address the deterioration more than tripled. This finding and the subsequent transfer of more deteriorating patients to higher acuity areas (only found in US hospitals) with additional monitoring, suggest that improved monitoring improves patient outcomes, not increased medical interventions.</p> <p><b>Survival rates/decreased mortality</b> Deteriorating patients for whom a RRT activation was made also had improved in-hospital and 90 day survival rates (86% - 92%). It was calculated that approximately 12 lives were saved by implementing the monitors.</p> <p><b>Cardiac arrests</b> 34 patients had cardiac arrests during the control period compared to 24 cardiac arrests during the intervention periods.</p>			
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			<p><b>Reduction in length of stay</b></p> <p>The use of the monitors was also associated with an overall decreased length of hospital stay (3.4 – 3.0 days) and a subsequent cost saving. This finding only reached significance in United States hospitals.</p>			
<p>Mwulu, U., Westwood, D., Edwards, D., Kelliher, F. &amp; Coleman, J.J. (2012)</p> <p>United Kingdom</p>	<p>Adoption of an Electronic Observation Chart with an Integrated Early Warning Scoring System on Pilot Wards</p>	<p>Early phase review</p>	<p><b>Capturing vital signs directly from observation machine to EMR via a bedside computer</b></p> <p>In this study vital signs were captured electronically via a bedside computer to the patient's EMR.</p> <p><b>On screen (advisory) warnings</b></p> <p>If the system calculated an abnormal SEWS based on the entered vital signs onscreen warnings and instructions as per the Standardised early warning score (SEWS) protocol appeared on the screen.</p> <p><b>Real time clinical alerts to email of critical care outreach team</b></p> <p>For patients with the highest SEWS email alerts were also sent via a mobile device to the critical care outreach team.</p> <p><b>Fully completed observation sets producing a EWS score</b></p> <p>In this study in 80.5% of the observation sets a full set of vital signs was completed and produced a SEWS. During the 4-month audit period an average of 419 observation sets produced a SEWs score every day. 82.5% of these SEWs did not produce an alert or alarm.</p> <p><b>On screen (advisory) warnings</b></p> <p>A daily average of 74 SEWS (from 419 fully completed observation sets) produced onscreen alerts to clinical staff.</p> <p><b>Real time clinical alerts to email of critical care outreach team</b></p>		<p>This study did not evaluate the impact of electronic vital sign recording on patient outcomes.</p> <p>A multi method evaluation to fully explore the implementation of an electronic EWS is required.</p> <p>This is an implementation study and the authors should have used implementation theory, for example, Consolidated Framework for Improving Implementation Science Research (CFIR) or other to provide useful information to the reader.</p> <p>Does not add much to papers already reviewed.</p>	<p>JBIMASARI</p> <p>Score 75%</p> <p>No control group</p>

			<p>On average only two SEWS produced a level 3 (red alert) per day indicating severe deterioration which resulted in an email been sent to the Critical Care Outreach team.</p> <p><b>Highest incidence of alarms</b></p> <p>Of the six inpatient pilot wards where the study was conducted, the two medical wards produced 42.2% of the SEWS alarms and the majority of the level 3 (red) alarms each day.</p> <p><b>Omission errors (Non-entry of a vital sign or non-validation of the EMR).</b></p> <p>Completed observation sets ranged from 69%-92%. This study also found traditional gaps in vital sign recordings, like the recording of respiratory rate. The researchers acknowledge that expecting a complete set of observations to be recorded on every occasion of vital sign monitoring is unrealistic. Occasionally if there is clinical concern around only one or two vital signs it is appropriate to only monitor the pertinent vital signs more frequently. Although an incomplete observation set will not produce a valid SEWS score, completing a full set of observations 100% of the time is unlikely.</p> <p><b>Initials fears related to technology</b></p> <p>Nurses were initially anxious to use an electronic chart. They feared the use of new technology and increased monitoring and expected it would increase their workload. After a period of adjustment, engagement with the electronic chart was generally good.</p>			
Hands, C., Reid, E., Meredith, P., Smith, G.B., Prytherch, D.	Patterns in the recording of vital signs and early warning	Evaluation Study	<p><b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b></p> <p>In this study bedside vital signs were documented on an</p>	A major strength is that data was entered directly into PDA's at the bedside. The	This study does nicely demonstrate the lack of protocol adherence, but	<p>JBIMASARI</p> <p>Score 100%</p>

<p>R., Schmidt, P.E. &amp; Featherstone, P.I. (2013) United Kingdom</p>	<p>scores: compliance with a clinical escalation protocol</p>		<p>electronic system called VitalPAC, using handheld devices (PDA's).</p> <p><b>On screen (advisory) warnings</b></p> <p>VitalPAC assigned a date and time stamp to documented observations and issued a warning if vital signs were entered in error, or if they were out of range. VitalPAC then automatically calculated the patient's ViEWS score and for patients with an elevated ViEWS score instantly displayed on the PDA the action to be taken by the nurse as per the hospital's clinical escalation protocol. This onscreen prompt included instructions on when the vital signs should be rechecked as determined by the ViEWS value. This time frame varied from 12 hours for patients with a low ViEWS score to 30 minutes for the severely ill patients.</p> <p><b>Timeliness of rechecking observations – factors influencing compliance – night vs day, times allocated to the recording of vital signs and ViEWS score.</b></p> <p>During the study period 950 043 observation sets were recorded. It was found that vital signs were measured infrequently between the hours of 23:00 and 05:59. Despite this time period comprising 29.2% of a 24 hour day, only 12.81% of the daily vital signs were recorded during this period. The percentage of vital signs recorded hourly between 10:00 and 17:59 ranged from 3.35–6.08% with two definite peaks in hourly vital sign recordings between 06:00–06:59 and 21:00–21:59. During these times 13.58% and 8.58% of the total vital signs were recorded, respectively. The study found that the percentage of hourly vital signs recorded between 23:00 and 05:59 increased to 23.84% for patients with a ViEWS</p>	<p>database consisted of 950 043 sets of vital signs each with an accurate date and time stamp. No retrospective review of pen and paper charts would be able to replicate the collection, extraction, analysis or audit of data on this scale.</p>	<p>does not investigate the reason as to why this is</p>	<p>This was a retrospective audit of electronic EWS utilising large datasets. In this study only the last three questions of the quasi-experimental tool relating to the way outcomes are measured and the statistical analysis used, were applicable</p>
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		<p>score of 9 or greater, indicating that deteriorating patients were monitored more frequently during these hours.</p> <p>However, irrespective of the ViEWS value, adherence to protocol in terms of frequency of required vital signs was always greater during the day than at night.</p> <p>This study demonstrates that there were large variations in the frequency of vital sign recording across a 24 hour period with two large peaks between 06:00–06:59 and 21:00–21:59 and lower frequency of vital sign recording at night-time. This was a common finding for every day of the week. There was less variability in the frequency of vital sign recording among patients with a high ViEWS value, indicating that sicker patients were more frequently monitored and more likely to have vital signs recorded overnight. However, even though sicker patients were more likely to have their vital signs rechecked before 06:00, the study found that 47.42% of patients with a recorded ViEWS of 7-8 between 20:00 and 23:59 and 31.22% of patients with a recorded ViEWS value <math>\geq 9</math> between 20:00–23:59 did not have their vital signs rechecked in the next 6 hour period. In contrast, only 18.81% of patients with a recorded ViEWS value of 7-8 between 08:00 and 11:59 and 13.35% of patients with a recorded ViEWS value <math>\geq 9</math> between 08:00–11:59 did not have their vital signs rechecked in the next 6 hour period.</p> <p><b>Continuous electronic monitoring and mandatory documentation times</b></p> <p>For patients on continuous electronic monitoring it was mandatory for staff to document the vital signs on VitalPac as frequently as required according to the hospital's clinical escalation protocol for the ViEWS score.</p>			
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		<p>For example if a patient's vital signs generated a ViEWS score = 7, data from a continuous electronic monitoring device must be entered each hour. However, during the day-time, for patients with a ViEWS of 3-6, it took 5.64 hours to record their next set of observations, 4.91 hours for patients with a ViEWS of 7-8 and 4.22 hours for patients with a ViEWS<math>\geq</math>9. At night-time it took 7.88 hours (ViEWS=3-6), 6.59 h (ViEWS=7-8) and 5.17 h (ViEWS<math>\geq</math>9), respectively.</p> <p>Patients with lower ViEWS values (0-6) were more likely to have their vital signs rechecked within the protocol's required time than patients with a ViEWS greater than 7. This demonstrates that there is only partial compliance with the hospital's clinical escalation protocol in terms of frequency of vital signs monitoring.</p> <p><b>Reasons for not rechecking observations as per the clinical escalation protocol.</b></p> <p>Perhaps ward staff prefer to use their clinical judgement and professional experience to determine when patients need their vital signs checked rather than using ViEWS and the escalation protocol. Perhaps the ViEWS escalation protocol, although closely based on the NICE recommendations, is inappropriate or unachievable based on staffing levels, equipment availability and competing clinical priorities.</p> <p>Consequently, out of necessity staff appeared to have established predetermined times during the day to record vital signs possibly as a means of ensuring an uninterrupted period where vital signs can be recorded without compromising competing patient and clinical activities. This may explain the large peaks in vital sign</p>			
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			<p>recording in this study at 06:00 and 21:00.</p> <p><b>Consequences of not rechecking observations as per the clinical escalation protocol.</b> This study found that the RRT was more frequently activated during the peak times of vital sign recording than at night, so failure to check observations may miss early patient deterioration and undermine the effectiveness of any EWS.</p>			
<p>Evans, R.S., Kuttler, K.G., Simpson, K.J., Howe, S., Crossno, P.F., Johnson, K.V., Schreiner, M.N., Lloyd, J.F., Tettelbach, W.H., Keddington, R.K., Tanner, A., Wilde, C. &amp; Clemmer, T.P. (2014)</p> <p>Salt Lake City, Utah</p>	<p>Automated detection of physiologic deterioration in hospitalized patients</p>	<p>Prospective Observational Study</p>	<p><b>Continuous patient monitoring Automated documentation system (Vital signs transferred automatically to a bedside computer and the EMR every 5 minutes).</b></p> <p>All patients admitted to a 33-bed medical and oncology ward (A) and a 33-bed surgical trauma ward (B) were continuously monitored. Vital signs were then transferred automatically to a bedside computer and the EMR every 5 minutes to detect early sign of physiological deterioration</p> <p><b>Real time clinical alerts to CNM's pager Automated documentation system (Vital signs transferred automatically to a bedside computer and the EMR every 5 minutes).</b></p> <p>During the trial period charge nurses received a pager alert generated by the system if the early warning score triggered signs of physiologic patient deterioration. The charge nurse manager then reviewed the patient and their vital signs, discussed that patient with their nurse and then made a decision to notify a physician or make RRT call.</p> <p>To allow time to resolve the deterioration the system only sent one alert per patient during a four hour period. Nurses caring for patients who had triggered an alert were asked</p>	<p>The patients in both units had similar characteristics in the intervention and pre-intervention periods.</p>	<p>The same group of nurses were exposed to both interventions so there was no independent separate group used as a control group.</p> <p>When bedside nurses failed to complete the evaluations after an alert was generated the evaluation was completed by RRT leads and ICU nurses who retrospectively examined the patient. Due to the nurses' acceptance and approval of the system their evaluations may have been biased and swayed towards a higher positive predictive value (over 95% on both wards).</p>	<p>JBIMASARI</p> <p>Score: 89%</p> <p>No control group</p>

		<p>to fill out an evaluation form to evaluate the alerts.</p> <p><b>Automated documentation system (Vital signs transferred automatically to a bedside computer and the EMR every 5 minutes).</b></p> <p>In this study the use of continuous patient monitoring which graphically displayed the vital signs helped overcome the barrier of insufficient patient visualisation and failure to recognise physiologic deterioration. This study found that by continuously monitoring vital signs, automatically calculating the modified early warning score (MEWS) and generating an alert according to a predefined pathway, patients were consistently monitored and identifying early signs of deterioration impacted favourably on patient care.</p> <p><b>Nurses' perceptions of continuous monitoring, automated documentation and automated clinical alerts.</b></p> <p><b>Positive predictive value</b></p> <p><b>Trending of vital signs</b></p> <p>The positive predictive value of the alerts as perceived by the nurses was 91-100%, depending on the presence of incorrectly captured vital signs.</p> <p>Nurses reported that the systems graphical display of vital signs enabled them to identify trends to quickly evaluate the patient's condition. The system also gave them more confidence in their assessment of the patient and in requesting additional help. The nurses and the RRT reported that information provided by the system meant care was expedited to deteriorating patients and in some cases a RRT call was averted.</p> <p><b>Real time clinical alerts to CNM's pager</b></p>		<p>In this study the high PPV and timing of the alerts has resulted in physicians and advance practice clinician demonstrating an increased interest in being included in follow up of the alerts.</p> <p>The researcher cannot rule out that there may have been other interventions or changes in the ward in either the intervention or pre-intervention period which may have affected the outcomes.</p> <p>Another limitation of the study is that physiologic deterioration alerts were generated by the system during the entire intervention period, the requirement for bedside nurses, the RRT and intensive care nurses to evaluate the alerts was terminated early due to the added workload required to do so. The shortened period of collecting the</p>	
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		<p><b>Response to patient deterioration</b></p> <p>On both study units the nurses called the physician on 51% (unit A) and 44% (unit B) of occasions when the system generated an alert and interventions were initiated for 59% (unit A) and 52% (unit B) of these alerts.</p> <p><b>RRT Calls/Mortality rates</b></p> <p>more RRT calls were made (60 vs 29 pre-intervention) and significantly fewer patients died (2.6% vs 3.7%) compared to the pre-intervention year. On unit B there was an insignificant increase in RRT calls made during the intervention year (21 vs 11), but unlike unit A there was no significant decrease in mortality. The patients on unit A were much older and had many more co-morbidities than the patients on unit B. Therefore, they were more prone to physiologic deterioration as evidenced by higher number of alerts generated (17% vs 9%) and triple the number of RRT activations during the intervention period compared to the pre-intervention period. Based on these results it appears that the benefits associated with an EWS may be higher for older patients with multiple co-morbidities.</p> <p><b>Length of stay</b></p> <p>The patients in unit A had a significantly longer hospital stay compared to the patients on unit B during the intervention year compared to the pre-intervention year. This may be because the alerted patients generated more RRT calls, had more interventions or were transferred to ICU early enough to increase their chances of survival to discharge. This resulted in a longer length of stay and increased hospital cost.</p> <p><b>ICU Admissions</b></p> <p>During the intervention year on unit A, more patients were</p>		<p>evaluation results was however not perceived to have altered the study outcome.</p> <p>No impact of the simulation training on unit A was detected or of other secular trends at the unit level. Other unit changes cannot be totally ruled out.</p> <p>Although this before-after study found a significant increase in RRT calls and reduction in mortality during the intervention years, this was found only in the one unit with older patients with multiple co-morbidities. Therefore further study is required to eliminate potential confounding.</p>	
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			transferred to an ICU 163 (5.1%) of 3189 compared to 146 (4.1%) in the pre-intervention year			
Schmidt, P.E., Meredith, P., Prytherch, D.R., Watson, D., Watson, V., Killen, R.M., Greengross, P., Mohammed, M.A., & Smith, G.B. (2015)	Impact of introducing an electronic physiological surveillance system on hospital mortality	Retrospective, observational study	<p><b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b></p> <p>The EPSS—VitalPAC—allows nurses to use a handheld electronic device at the patient’s bedside to record a complete set of vital signs within an appropriate timeframe.</p> <p><b>On screen (advisory) warnings</b></p> <p>The system automatically calculates the patient’s early warning score and displays a required escalation response based on the score, including when to repeat the vital sign recordings, who to escalate care to and the required timeframe of the response. These messages are displayed on the screen of the handheld device, but do not automatically generate the alert.</p> <p><b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b></p> <p>These devices automatically and wirelessly transfer the recorded data to the patient’s electronic medical record which can be viewed from any device linked to the hospital’s intranet with the required access rights.</p> <p><b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b></p> <p><b>Documentation errors/accuracy</b></p> <p>The EPSS required users to enter a full set of vital signs on each occasion of taking routine observations. Both of the study sites showed that a complete set of vital signs was completed 98% of the time.</p> <p><b>Mortality rate</b></p>	It is improbable that the Hawthorne effect could have caused or contributed the reduction in mortality as the project teams’ involvement following implementation did not extend beyond two weeks and the reduction in mortality was sustained over two years. The reductions in mortality in each speciality, in two different hospitals, consistently coincided with the implementation of the Electronic EWS suggesting that the electronic EWS was responsible for this. Although it is impossible to prove a direct cause-and-effect relationship between the electronic EWS implementation and mortality reduction, the almost identical results at two hospitals, 240 kilometres apart was viewed as a significant finding. The consistent results following the implementation of the	It is possible that other changes in practice may have been introduced other than the electronic EWS (eg, introducing care bundles or altering nurse-patient ratios) which could have caused or contributed to the sustained reduction in mortality, but the mortality reductions did not necessarily coincide with their implementation. There was no independent separate control group in the wards at the same time.	<p>JBIMASARI</p> <p>78%</p> <p>No control group</p> <p>Unclear if participants included in any comparisons receiving similar treatment/care other than exposure to the intervention</p>

			<p>During EPSS implementation, crude mortality fell from 7.75% to 6.42% which equated to 397 fewer deaths in one hospital. At the second hospital crude mortality fell from 7.57% to 6.15% and equated to 372 fewer deaths. Year on year statistics at both hospitals showed abrupt and sustained reductions in mortality, in all specialities, coincided with the implementation of the system.</p> <p>In both hospitals, mortality was highest amongst elderly, medically admitted, unscheduled admissions and ensuring monitoring in this patient group, for their entire admission, was found to be important in reducing mortality.</p>	<p>electronic EWS at different hospitals, across different specialities, at different times suggests the implementation of the electronic EWS is generalisable and reproducible based on a plausible cause and effect relationship.</p> <p>There were no major changes in patient types admitted during the study accounting for the reductions in mortality. In fact, the age and number of emergency admissions in one hospital increased during the study period and at the other hospital there was no notable change in either.</p> <p>This was a very large study conducted across and throughout two-centres to measure mortality in all adult specialities, as opposed to prior smaller implementation studies limited to specific patient groups or focussing on process measures.</p>		
Kollef, M.H.,	Mortality and Length	Retrospective	<b>Real time clinical alerts to dedicated RRT nurse's</b>		Given the retrospective	JBIMASARI

<p>Heard, K., Chen, Y., Lu, C., Martin, N. &amp; Bailey, T. (2017) Missouri, USA</p>	<p>of Stay Trends Following Implementation of a Rapid Response System and Real-Time Automated Clinical Deterioration Alerts</p>	<p>analysis</p>	<p><b>mobile device</b> Patients identified with signs of clinical deterioration from predominantly manually obtained vital signs had a real time automated alert sent to a nursing member of the RRT. These alerts were generated 24 hours per day 7 days per week. Starting in 2009 the RRT could be activated by either nursing staff or the RTCDA. After 2012 the RTCDA were sent to a hospital issued mobile phone held by a dedicated RRT nurse with no other clinical responsibilities.</p> <p><b>Response to patient deterioration</b> The RRT nurse had to attend to all alerts within 20 minutes. Internal audits showed that in 95% of cases the RRT nurse responded to alerts within 10 minutes. Initially the RRT nurse would assess the alerted patient using the Modified Early Warning Score and then determine the most appropriate response based on the MEWS score escalation criteria and discussions with the patient's treating physician or the RRT physician. The study used RTCDA and nursing assessments to trigger the RRT.</p> <p><b>Mortality rates</b> This study demonstrated that a EWS using RTCDAs on general medicine units reduced mortality, <b>Cardiac Arrests</b> decreased the occurrence of cardio-pulmonary arrests and <b>Length of stay</b> reduced hospital stay. The hospital introduced their EWS in 2006 and added RTCDAs in 2009 in a staged process. Statistically significant year-to-year decreases in mortality, cardio-pulmonary arrests and median lengths of stay were observed through 2014.</p>		<p>nature of this study over a number of years the reductions in mortality, CPAs, and hospital stay could not be definitively attributed to the introduction of the EWS/RTCDAs. Other variables during that time may also have affected the findings making it difficult to determine the relative contribution of the EWS/RTCDA on observed outcome improvements. However, the correlation between increased number of RRT activations and decreased CPAs gives merit to the clinical findings of this study. A major limitation of this study is that no physiologic severity of illness record was kept for the duration of the study to determine if less ill patients were perhaps admitted when patient outcomes showed improvement. Although this may have introduced a</p>	<p>78%</p> <p>No control group</p> <p>Cannot guarantee that participants included in any comparisons were receiving similar treatment care other than exposure to the intervention of interest</p>
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			<p><b>RRT Activations correlated to cardiac arrests</b></p> <p>There was a statistically significant year-to-year increase in the number of RRT activations that was inversely correlated with the occurrence of cardio-pulmonary arrests. The study also found reductions in CPAs were significantly correlated with increasing RRT activations.</p> <p><b>Real time clinical alerts to dedicated RRT nurse's mobile device</b></p> <p><b>Response to patient deterioration</b></p> <p>The study found that the use of an EWS and RTCDA, in addition to nursing assessments, ensured rapid activations of the RRT and minimised delays often associated with a non-automated system.</p> <p><b>Response to patient deterioration</b></p> <p>The study found that there was a daily average of one RRT activation, which was lower than expected. An explanation offered was that the EWS/RTCDA system was designed to avoid false negative alerts.</p>		<p>potential bias, the Charlson comorbidity scores in the study units increased over the study's duration, so the study team felt a bias was unlikely.</p> <p>As this was a single centre study using a locally developed EWS and RTCDA system in medical wards only, it is unknown if the study's results would be generalisable and reproducible in another hospital environment. The study results may have been influenced by the implementation of a dedicated, permanent RRT nurse position during the study. This would have allowed dedicated time to assess and pre-emptively identify deteriorating patients.</p>	
Wong, D., Bonnici, T., Knight, J., Gerry, S., Turton, J. & Watkinson, P.	A ward-based time study of paper and electronic documentation for	Before- and- after observational study.	<p><b>Capturing vital signs to EMR via tablet mounted alongside observation machine</b></p> <p><b>On screen advisory warnings</b></p> <p>In 3 medical inpatient wards in two hospitals existing</p>		<p>The participants knew they were being observed so the Hawthorne effect could have stimulated an</p>	<p>JBIMAStARI 87.5%</p>

<p>(2017)</p> <p>United Kingdom</p>	<p>recording vital sign observations</p>	<p>The primary objective of this study was to determine whether introduction of an e-Obs system alters the time required to record a complete set of vital sign observations.</p>	<p>paper observation charts were replaced with an electronic observation system, called SEND.</p> <p><b>Positive patient identification</b></p> <p>In this study positive patient identification occurred by scanning the barcode on the patient's wristband.</p> <p><b>Vital signs captured directly onto paper.</b></p> <p><b>Capturing vital signs to EMR via tablet mounted alongside observation machine</b></p> <p><b>Faster documentation of vital signs</b></p> <p>The pre- and post-implementation period on each ward was 5-weeks respectively. The primary outcome measure was the difference in time taken to record a complete set of vital signs and calculate an early warning score between the paper and electronic EWS.</p> <p>153–280 complete sets of vital signs were recorded per ward for each period. The majority nurses observed were at the same level.</p> <p>Introduction of an electronic observation system resulted in a statistically significant reduction in the time taken to record and document vital signs compared to paper. The reduction was significant, even after allowing for differences between wards, nursing levels, individual nursing behaviour and encountered interruptions. The time reductions varied between wards and was only clinically significant in 1 of the 3 wards studied. The geometric mean time was 215 seconds to complete a set of vital signs on paper compared to 150 seconds on the electronic system.</p> <p><b>Capturing vital signs to EMR via tablet mounted alongside observation machine. Improved standardisation with the electronic system</b></p>		<p>improvement in performance, but this would have been applicable in the pre- and post-implementation period.</p> <p>No control group</p>
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			<p>It appears that an electronic system improved standardisation with regards the recording and documentation of vital signs. Standardisation of processes contributes to improved quality of care. <b>Manual recording of respiratory rates</b></p> <p>The majority time saved occurred in the taking of vital signs subtask, despite the electronic system including a 60 second timer for the recording of respiratory rate. Sixty seconds is the gold standard for counting respiratory rate which is known to be an important indicator of clinical deterioration.</p>			
<p>Pullinger, R., Wilson, S., Way, R., Santos, M., Wong, D., Clifton, D., Birks, J. &amp; Tarassenko, L. (2017)</p> <p>United Kingdom</p>	<p>Implementing an electronic observation and early warning score chart in the emergency department: a feasibility study.</p>	<p>Before and after study</p>	<p>In this study approximately 3,000 subjects were enrolled pre-implementation of the electronic EWS and 3000 were enrolled post-implementation.</p> <p><b>Vital signs captured directly onto paper</b></p> <p>In stage one vital signs were captured on paper, the early warning score was manually calculated and actions taken based on the early warning score were documented on the chart.</p> <p><b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b></p> <p>In Stage 2, vital signs were captured on handheld electronic devices (iPods) which automatically populated the electronic observation chart (Vitalpac) and automatically calculated the early warning score. The electronic system also prompted the frequency of subsequent vital signs based on the early warning score and EWS protocol.</p> <p>The primary outcome measure was to determine how</p>		<p>The influence of extraneous variables cannot be ruled out.</p>	<p>JBIMASTARI</p> <p>78%</p> <p>No Control group</p> <p>It was unclear if participants included in any comparisons were exposed to other treatment or care other than the intervention of interest</p> <p>Improvements in staff training, workflow, and quality assurance may also have contributed to such an improvement .</p>

			<p>many patients had an accurately recorded early warning score in each stage. Secondary outcome measures were mortality rates, the frequency and duration of elevated early warning scores, length of stay, transfers to the resuscitation room, unplanned admissions to ICU and in-hospital cardiac arrests.</p> <p><b>Fully completed observation sets producing a EWS score</b></p> <p>Pre-implementation of the electronic EWS 52.7% of subjects had an accurately calculated early warning score compared to 92.9% after implementation.</p> <p>In stage one only 66% of the subjects had full EWS documentation that was available for review as 5.7% of the subjects had no ED notes or EWS charts that could be reviewed,</p> <p>1.6% of the subjects had ED notes but no vital signs recorded in them and 2.6% of subjects had vital signs recorded, but no associated time record. An additional 24% of subjects had vital signs written in their ED notes, but there was no EWS chart.</p> <p>In stage two 93% of subjects had full documentation available for review. Of the 7% of subjects that did not have EWS documentation available for review, 2.2% was due to downtime of the electronic system, 4.3% were not registered on the electronic observation system and 0.6% did not have vital signs recorded on the electronic EWS.</p> <p><b>Mortality rates/Cardiac arrests rates/Length of stay/Critical care admissions</b></p> <p>There were no statistically significant differences between mortality, cardiac arrests, transfers to the resuscitation room or ICU, and length of</p>			
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			<p>stay. Stage two subjects were slightly more likely to be admitted as in-patients (66.4%) than stage one subjects (61.6%). A clinical process change was implemented between the two stages and therefore it was not possible to equate this difference in admission rates to improved completeness and accuracy of early warning scores with the electronic system.</p> <p><b>Timeliness of rechecking observations</b></p> <p>A retrospective analysis of the vital signs revealed that with the electronic system vital signs were recorded more frequently for patients with a high early warning score than with the paper-based system. This may have been due to increased awareness of patient deterioration over time or to the automated prompts given by the electronic system to increase the frequency of vital signs in deteriorating patients.</p>			
<p>Pedersen, N.E., Rasmussen,L.S., Petersen, J.S., Gerds,T.A., Østergaard, D. &amp; Lippert, A. (2017)</p> <p>Denmark</p>	<p>A critical assessment of early warning score records in 168,000 patients</p>	<p>Observational Study of NZEWS data</p>	<p><b>Capturing vital signs and manually entering them into the EMR</b></p> <p>Vital signs were recorded by ward staff and entered manually into the EMR. The system allows for the partial entry of vital signs. If all seven vital signs making up the NEWS were entered the system automatically calculated the early warning score. The required frequency of vital sign measurement is dependent on the preceding NEWS score and the escalation protocol.</p> <p><b>Omission errors (Non-entry of a vital sign)</b></p> <p>Of 2,835,331 NEWS records, 271,103 (10%) were incomplete and 0.2% of the records had values that were implausible. An incomplete set of vital signs may be entered due to protocol non-adherence, but in certain</p>	<p>A strength of this study is access to NEWS data from a public hospital system covering 1.7 million people and the ability to reliably merge data from multiple hospitals.</p>	<p>Weaknesses of the study include having limited knowledge on the quality of data collection practices in the different hospitals. The time stamps of vital signs entered on the EMR may not represent the true time that vital signs were measured. This is a recognised problem with data that is manually entered into the EMR.</p>	<p>JBIMAStARI</p> <p>100%</p> <p>This was a retrospective audit of electronic EWS utilising large datasets. In this study only the last three questions of the quasi-experimental tool relating to the way outcomes are measured and the statistical analysis used, were</p>

			<p>clinical situations it may be appropriate to focus on specific vital signs.</p> <p>A large percentage of these partially entered records were followed by complete records shortly after.</p> <p><b>Transcription errors (applies to manually entered values)</b></p> <p>0.2% of the records had erroneous or extreme values entered indicating that wrong values were entered, or values were entered in the wrong fields. Some of these errors may have been eliminated If the system was programmed to identify erroneous records at the point of entry.</p> <p>Digit preferences for even numbers were found for respiratory rate, oxygen flow rates, heart rate, and systolic blood pressure. An unusually high recording of heart rate records just below 91 beats per minute could indicate bias towards a value that does not generate a NEWS point, as this is the cut-off point between a NEWS value of 0 and 1.</p> <p><b>Capturing vital signs and manually entering them into the EMR</b></p> <p><b>Fully automated systems.</b></p> <p>The findings in this study demonstrate that data quality in systems where NEWS values are entered manually may be problematic.</p> <p><b>Fully automated systems.</b></p> <p>This issue could be addressed by replacing systems requiring the manual entry of vital signs with fully automated systems where recorded vital signs are captured automatically. However, most EWS have been developed and validated in systems where vital signs are entered manually, so EWS performance in fully automated</p>			applicable
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			<p>systems would need to be assessed. This study acknowledges that human factors and clinical staff perceptions of the patient's condition may have an influence on the data recorded. Thus, the replacement of a manually entered parameter, such as respiratory rate, with a parameter which is entered automatically may result in a loss of information. The inclusion of staff concern, as a parameter in an automated system, may help overcome this shortfall.</p>			
<p>Heal, M., Silvest-Guerrero, S., &amp; Kohtz, C. (2018)</p> <p>United States</p>	<p>Design and Development of a Proactive Rapid Response System</p>	<p>Quasi-experimental</p>	<p><b>Capturing vital signs and manually entering into EMR (method not described). (Only dedicated crisis nurse aware of aggregate early warning score and response protocol)</b></p> <p>The wards involved in the study were similar and the nursing staff worked across both units. At baseline, the two wards had an equivalent patient population, staff to patient ratio, patient numbers and RRT call rates.</p> <p><b>Capturing vital signs and manually entering into EMR (method not described). (Only dedicated crisis nurse aware of aggregate early warning score and response protocol)</b></p> <p>In the intervention and control wards vital signs were entered into the EMR of patients. Nurses working on both wards were not aware of the vital sign parameters and aggregate scores that would trigger a response.</p> <p><b>Routine checking of early warning score on EMR to detect deteriorating patients</b></p> <p>On the intervention ward the EMR automatically calculated the early warning score and a dedicated crisis nurse was required to check and respond to any early</p>		<p>The study missed an opportunity to determine how proactive rounding vs reactive rounding affects length of stay after the RRT is activated. A new early warning system was developed and implemented on both the intervention and control ward. Nurses working on both wards were not aware of the vital sign parameters and aggregate scores that would trigger a response. Only the crisis nurse knew the vital sign parameters and aggregate score that would trigger a response. The bedside nurses escalated care based on</p>	<p>JBIMASTARI</p> <p>100%</p>

		<p>warning score of 3 or more every 4 hours. The EMR could be viewed at any time from any location.</p> <p><b>Response to patient deterioration</b></p> <p><b>RRT calls</b></p> <p>On the control ward the EMRs of those patients did not automatically calculate the early warning score to report triggers. Instead the bedside nurse was required to place a call to the crisis nurse or RRT when they perceived a need. Data was collected on both wards over 6 months.</p> <p><b>Routine checking of early warning score on EMR to detect deteriorating patients</b></p> <p><b>RRT calls</b></p> <p>On the intervention unit, the crisis nurse encountered 794 early warning scores that generated a trigger when reviewing the EMR every 4 hours. The crisis nurse assessed and/or sought further intervention in 412 of these triggers to prevent further potential deterioration. On 132 occasions the RRT was activated on the intervention ward. On the control unit staff activated the RRT 110 times.</p> <p><b>Capturing vital signs and manually entering into EMR (method not described). (Only dedicated crisis nurse aware of aggregate early warning score and response protocol)</b></p> <p><b>Cardiac arrests</b></p> <p>The difference in cardiopulmonary arrest rates between the intervention and control wards did not reach clinical significance, at one versus three respectively.</p> <p><b>Capturing vital signs and manually entering into EMR (method not described). (Only dedicated crisis nurse aware of aggregate early warning score and response protocol)</b></p>		<p>perceived need. Had the bedside nurses in both units been familiar with the new EWS and escalation protocol they may have activated the RRT more frequently.</p>	
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			<p>The study identifies the potential role of nurses in EWSs. The electronic alert on the EMR responded to by the crisis nurse did not rely on the bedside nurse to recognise subtle signs of patient deterioration and activate the RRT. However, the response to patient deterioration in the intervention ward was still dependent of the crisis nurse reviewing the EMR every four hours. <b>Real time clinical alerts to dedicated RRT nurse's mobile device</b></p> <p>An automated alert sent to a crisis nurse's mobile phone could eliminate the potential of the crisis nurse missing triggers on the EMR.</p>			
<p>Fletcher, G.S., Aaronson, B.A., White, A.A. &amp; Julka, R. (2018) USA</p>	<p>Effect of a Real-Time Electronic Dashboard on a Rapid Response System</p>	<p>Repeated treatment design</p>	<p><b>Overview Screen (Real-time electronic dashboard)</b></p> <p>The dashboard was updated as soon as vital signs were entered which enabled the entire care team, including the RRT, to rapidly identify patients with abnormal vital signs who could trigger the RRT. The study evaluated the effect of the dashboard on RRT activations, cardiopulmonary arrests and unexpected ICU admissions and mortality. The study used a repeated treatment design where the dashboard was turned on for a week and then off for a week and so on. This alternating exposure continued for 20weeks. On weeks where the dashboard was on it could be used to activate the RRT, in addition to the traditional method of the RRT being activated by the bedside nurse. The intervention and control patients were similar in terms of patient demographics, acute diagnosis and co-morbidities.</p> <p><b>Overview Screen (Real-time electronic dashboard)</b> <b>RRT calls</b> <b>Cardiac arrests</b></p>	<p>A strength associated with the repeated treatment design is that it enabled the examination of the effect of the dashboard on RRT activations in a real life setting with a comparable control group [20]. This type of study has greater internal validity than a pre-post study designs as the influence of confounders is less likely. The limitations of this randomization approach are offset by basing the analysis on the first alert to compensate for spillover effects.</p>	<p>Although the study showed that there was an increase in initial RRT activations the clinical benefit associated with this was not proved. There was no significant reduction in cardiopulmonary arrests and unexpected ICU admissions and mortality. However due to the infrequent nature of these events the study was not powered sufficiently to determine these outcomes and length or cost of hospital stay may have been better outcome measures.</p>	<p>JBIMASARI Score 89%</p> <p>Multiple measurement of the outcome both pre and post exposure difficult with repeated treatment design.</p>

		<p><b>Mortality</b></p> <p>The dashboard did not significantly reduce overall RRT activations, cardiopulmonary arrests and unexpected ICU admissions and mortality. There was a 20% increase in first RRT activations, which was statistically significant, but overall RRT activations did not increase. First RRT activations were measured since it was hypothesised the dashboard would draw attention to a deteriorating patient, but after an initial RRT call the staff may likely be vigilant to subsequent deterioration without relying on the dashboard. The reason for this may have been that the dashboard alerted the RRT to patients who met activation criteria, but were not escalated. Alternatively, the dashboard displayed patients from high to low early warning scores and the RRT may have responded to deteriorating patients with raised early warning scores below the usual level for activation. The activation threshold may have been lowered for the initial RRT review, but subsequent RRT thresholds were maintained.</p> <p><b>Real-time electronic dashboard</b></p> <p><b>RRT Calls</b></p> <p>The dashboard utilises real-time, population based data displayed in the EMR to support clinical decision making without the reliance on the bedside nurse to activate the RRT.</p> <p><b>Real-time electronic dashboard</b></p> <p><b>Proactive vs reactive approach to deteriorating patients</b></p> <p><b>Situational awareness</b></p> <p><b>Reduction in alert fatigue</b></p> <p>The dashboard display which could be viewed</p>		<p>This was a single centre study so the findings may not be generalisable.</p> <p>The study did not directly measure if the RRT was activated or if bedside interventions were instituted as a result of a notification from the dashboard. The time from notification to activation of the RRT was also not measured.</p> <p>Staff were not blinded to the use of the dashboard and knowing that they were being observed may have prompted them to activate the RRT without viewing the dashboard scores.</p> <p>A disadvantage associated with the repeated treatment design where the time between crossover is short, is spillover effects.</p> <p>Measuring the first RRT activation for a patient may have compensated for this, but it is possible that staff awareness of a high</p>	
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			<p>simultaneously by all members of the health care team, including the RRT, encouraged a proactive, rather than reactive approach to monitoring and reviewing patients at risk. This mitigates the risk of bedside nurses not calling the RRT for deteriorating patients. Additional benefits associated with the dashboard was an increase in situational awareness amongst all team members and a reduction in alert fatigue, as the dashboard was designed to be non-interruptive. When an elevated early warning score generated an alert it was displayed on the dashboard, but did not sound an alarm. The allows users to review the information associated with the alert and respond without interrupting their workflow. However non-interruptive alerts can be ignored more easily, but since there was an increase in first RRT activations in this study, it appears this was not the case.</p> <p><b>Overview Screen (real time electronic dashboard)</b></p> <p><b>Trending of vital signs</b></p> <p><b>Dedicated RRT nurse</b></p> <p>The dashboard, ranking all acute patients in order of severity, facilitated rapid assessment of the status of all acute patients and identification of deteriorating trends over time.</p> <p>In this study, a full-time, dedicated RRT nurse was tasked with monitoring the dashboard and managing deteriorating patients. This may have reduced the chance of users developing alert fatigue.</p>		<p>dashboard score during the on period may have led to them activating the RRT during the following off periods.</p>	
Mackintosh, N., Rainey, H. & Sandall, J. (2011)	Understanding how rapid response systems may improve safety for the acutely ill	Ethnographic study	<p><b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b></p> <p>Vital signs were captured from observation machines to the electronic medical record via a handheld personal</p>			<p>JB I QARI</p> <p>Score 90%</p>

United Kingdom	patient: learning from the frontline		<p>digital assistant.</p> <p><b>On screen (advisory) warnings</b></p> <p>The system calculated the early warning score automatically displaying it on the PDA screen, together with prompts advising when the next set of observations are due and actions to take for high EWS scores according to the hospital's escalation protocol. All hospital staff could view the electronic observation chart from any location on the hospital's intranet.</p> <p><b>Documentation errors/accuracy</b></p> <p>The electronic system had inbuilt safety prompts advising when an incomplete set or "unlikely vital signs" were entered. These prompts together with a record of who entered the vital signs and flags assigned to overdue vital signs improved the completeness of vital signs and compliance with the EWS protocol. The electronic system provided access to real-time vital signs and information about the quality of recorded data and adherence to protocol.</p> <p><b>Timeliness of rechecking observations</b></p> <p>The study found that although there was an overall improvement in compliance to protocol, it remained variable after implementation of the electronic system. The percentage of vital signs recorded late still ranged from 30% to 70%. Managers, nursing staff and doctors perceived that the electronic EWS made clinical practice more reliable by automatically calculating the early warning score and reducing the variations in the time taken to repeat vital sign recordings.</p> <p><b>Overview Screen (real time electronic dashboard)</b></p> <p>The nurses and HCA's reported that the electronic</p>			Influence of the researcher on the research and via versa not addressed
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		<p>dashboard display of patients and their early warning scores assisted them with sharing information, planning and allocating workloads by glancing at the dashboard.</p> <p><b>Remote access to EWS</b> The ability to access the observation data from the EMR remotely, along with other clinical data such as blood results, enabled doctors to better understand the deteriorating patient picture and “keep an eye” on patients at risk without being physically present on the ward. However, the study found that medical staff working in wards not utilising the electronic system did not routinely utilise the early warning scores as part of their assessment or when handing over patient information. Interviews conducted with the doctors substantiated this finding. However, the fact that the hospital utilised more than one EWS and did not have a clear escalation protocol may have contributed to this.</p> <p><b>Improved standardisation with the electronic system</b> Intuitive-experiential knowledge was acknowledged by a number of senior nursing and medical staff to be a valid element in detecting early deterioration. However, the study found that the PDA used to record vital signs on directed the users to follow a routine with every instance of vital sign recording. On some occasions junior staff and HCA’s in particular were so focussed on adhering to the routine that they lost sight of other subtle or significant signs of deterioration, such as increased restlessness or chest tightness. <b>On screen (advisory) warnings</b></p> <p><b>Compliance to protocol</b> The study found that although compliance to protocol</p>			
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			<p>greatly increased with prompts for escalating care provided by the electronic system, fears of over reliance on the EWS were expressed. The prompts provided by the electronic system reduced the potentially beneficial dialogue between staff regarding patient deterioration.</p> <p><b>Equipment/hardware issues</b></p> <p>With the electronic record, vital signs, early warning scores and flags were “disconnected” from patients and only accessible when staff logged in to retrieve the charts and during busy times computers were not readily available to do so.</p> <p><b>Facilitation of data collection</b></p> <p>The electronic system also facilitated the collection of data for analysis and benchmarking performance, such as completeness and timeliness of observations and adherence to escalation protocol.</p>			
<p>Yeung, M.S., Lapinsky, S.E., Granton, J.T., Doran, D.M., Cafazzo, J.T. (2012) Toronto, Ontario</p>	<p>Examining nursing vital signs documentation workflow: barriers and opportunities in general internal medicine units</p>	<p>Qualitative ethnographic analyses and quantitative time– motion study were conducted</p>	<p><b>Capturing vital signs on paper before writing into EMR via bedside computer or workstation away from patient’s room</b></p> <p><b>Faster acquisition/documentation of vital signs</b></p> <p>This study found that on average a nurse spent 12 minutes recording vital signs. However, at the hospital using an electronic system in which to document vital signs, it took an average of 53.2 minutes before vital signs were documented</p> <p><b>Vital signs captured directly onto paper</b></p> <p>compared to 17.2 minutes at the paper-based hospitals.</p> <p><b>Capturing vital signs on paper before writing into the EMR via bedside computers or remote computers</b></p> <p><b>Faster acquisition/documentation of vital signs</b></p> <p>In this study 66% of the recorded vital signs were</p>			<p>JBI QARI</p> <p>Score: 80%</p> <p>Influence of the researcher on the research and via versa not addressed</p> <p>There is no statement locating the researcher culturally and ethically</p>

		<p>transcribed from one documentation medium to another. The majority transcription instances occurred at the hospital using the electronic documentation system where vital signs were always transcribed onto interim paper notes before being documented electronically. Only 47% of the recorded vital signs were documented within one minute of acquiring them. The remaining 53% of the vital sign measurements were memorised for more than one minute before they were documented. Vital signs were memorised for the longest period before documentation in the hospital where vital signs were documented electronically leading to a delay in the communication of critical patient information. This study found that the clinical environment needs to support the documentation system utilised. Vital sign documentation into the medical record occurred more promptly when the patient's chart or documentation tool was located in a convenient location for the nurse.</p> <p><b>Vital signs captured directly onto paper</b> In this study fewer transcription instances occurred at the paper-based hospitals where vital sign charts were conveniently located at the patient's bedside.</p> <p><b>Capturing vital signs on paper before writing into the EMR via bedside computers or remote computers</b> In the electronic-based hospital the documentation was not conducive to vital sign documentation at the point of care because the system required an extensive amount of additional mandatory data to be entered. The time required to do so deterred nurses from documenting directly into the bedside or hallway computers were the ergonomics were unfavourable. For security purposes the computers</p>			
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			<p>were also locked in cabinets which needed to be unlocked before nurses could access them and launch the vital sign application. Nurses also chose not to use the bedside computers due to perceived privacy concerns and distractions like interruptions from patients and/or visitors, noise or environmental odours. Computers at the central nursing stations were also frequently occupied. These challenges associated with vital sign documentation in this study meant that nurses frequently wrote vital signs on interim pieces of paper at the point-of-care and deferred the documentation of vital signs in favour of more imminent clinical tasks or until the end of their shifts.</p> <p><b>Capturing vital signs on paper before writing into the EMR via bedside computers or remote computers</b></p> <p><b>Transcription errors</b></p> <p>Transcription was common at the hospital using the electronic documentation system. This increased the risk of transcription errors, delayed the documentation of critical patient information, duplicated the task of documentation and may have contributed to gaps in the recorded data.</p>			
Lang, A., Pinchin, J., Brown, M & Sharples, S. (2016)  United Kingdom	Report: Handheld Technologies in the Ward.	Evaluation using observation and interviews/focus groups	<p><b>Capturing vital signs directly from observation machine to EMR via a handheld Devices (PDA)</b></p> <p><b>On screen (advisory) warnings</b></p> <p><b>More time spent interacting with patients and colleagues</b></p> <p><b>Less time interacting with paper charts etc.</b></p> <p>After the electronic system was introduced medical and nursing staff were observed spending more time visible to patients, colleagues and visitors and less time in office</p>			<p>JBIR QARI</p> <p>Score 80%</p> <p>Influence of the researcher on the research and vice versa not addressed</p>

		<p>spaces. For nurses the time spent in the office decreased from 40.8% to 16.2% and for doctors the time decreased from 68.7% to 25.6%. Both doctors and nurses spent more time with patients after the electronic system was introduced. The time doctors spent with patients more than doubled (2.9% to 7.3%). Collectively doctors and nurses spent more time interacting with the handheld devices (3.7% to 8.3% and 2.2% to 6.4% respectively). This time increase was small compared to the time saved searching for, looking in or writing in paper charts, using desktop PC's and talking on the phone. After the electronic system was introduced the time nurses spent looking at and writing in patient notes decreased from 36.2% to 22.3% and 26.3% to 16.0% respectively.</p> <p>The time spent searching for paperwork dropped from 4.9% to 3.1%.</p> <p>These findings were reinforced by interview data where the medical staff expressed that it appeared the electronic system and handheld devices assisted with task and time management and reduced the time spent searching for people or information.</p> <p><b>Accessibility of data.</b></p> <p>Interview data revealed the following benefits associated with the electronic system: Staff reported that the electronic system and the ability to view patient observations on handheld mobile devices improved accessibility to patient observations and improved team communication by fast tracking discussions about the care of deteriorating patients.</p> <p>The nurses also reported the accessibility of information provided them with reassurance concerning the patient's</p>			<p>There is no statement locating the researcher culturally and ethically</p>
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		<p>state of health.</p> <p>Nursing staff also reported that the handheld devices facilitated communication with patients and their relatives as requests for information could be responded to without having to locate colleagues or paper charts.</p> <p>Medical staff also reported regularly accessing the system to monitor the progress of patients they had treated. While this was done for personal and clinical reassurance it may be problematic if this practice interferes with work life balance.</p> <p><b>Allocation of workloads</b></p> <p>Once use of the electronic system was established nurses reported that the mobile devices were like personal tools which allowed them to manage workloads and improved situation awareness of patients' status and team capacity.</p> <p><b>Initials fears related to technology</b></p> <p>When the electronic system was first introduced staff reported that the technology increased their workload and stress. This stress persisted when staff felt unsupported by the Information technology (IT) help service and by the lack of a sustainable procedure to provide feedback to IT. In the initial stages of implementation nursing staff reported that they felt the technology disempowered nursing staff and allowed a "Big Brother" culture.</p> <p><b>Remote access to EWS</b></p> <p>The ability to access real time vital signs on handheld mobile devices facilitated the ability for doctors to make decisions and implement actions remotely.</p> <p><b>On screen (advisory) warnings</b></p> <p><b>Alarm fatigue</b></p> <p>Nurses reported that onscreen alerts created alarm fatigue</p>			
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			<p>and cognitive overload resulting in work arounds to turn alarms off.</p> <p><b>Disempowerment of nurses</b></p> <p>Senior nurses expressed concern that nurses may become over reliant on the electronic EWS and lose the ability to detected patient deterioration through clinical assessment. They also felt that the ability of staff to interpret electronic early warning score parameters may be hampered by the systems automated scoring. Nurses would also need to be empowered to escalate care when there is a discrepancy between the early warning score and staff concern based on clinical expertise and judgement.</p> <p><b>Technology/Hardware issues</b></p> <p>A reliance on the electronic EWS may be problematic if the technology infrastructure fails or if there are insufficient personal devices to accommodate casual nurses or student nurses. <b>Access and permissions</b></p> <p>Doctors expressed frustrations about policies which restricted their access and permissions in the electronic EWS causing disruptions to working practices. For example, some electronic EWSs only allow consultants to modify parameters although registrars work independently within the system and only access advice from consultants when required.</p> <p><b>Lack of senior medical staff engagement</b></p> <p>Both nursing and medical staff expressed frustration about the lack of senior medical staff engagement with the new electronic system and this was perceived as hindering team communication around the use of the system. This lack of buy in was also perceived as limiting the system in terms of realising its potential benefits in practice.</p>			
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<p>Wong, D., Bonnici, T., Knight, J., Morgan, L., Coombes, P. &amp; Watkinson, P. (2015)</p> <p>United Kingdom</p>	<p>SEND: a system for electronic notification and documentation of vital sign observations</p>	<p>Post-implementation assessment</p>	<p><b>Capturing vital signs directly from observation machine to EMR via a tablet computer and monitor mounted to an observation machine</b></p> <p>The SEND system was implemented on three pilot wards, containing 59 beds in total, within a UK hospital. At the time of the study the system had been in use for nine months.</p> <p>This study assessed the ability of the electronic system to allow the documentation of vital signs as expected. The acceptability of the system to users was also assessed using a ten question Likert scale, 2 weeks after the implementation of the system in the clinical area.</p> <p><b>Positive patient identification (and staff)</b></p> <p>In order to positively identify the user and the patient the user had to scan their identification badge barcode to access the vital signs screen. The user is then asked to scan the patient's identification wristband in order to eliminate the possibility of vital signs being recorded against the wrong patient.</p> <p><b>Capturing vital signs directly from observation machine to EMR via a tablet computer and monitor mounted to an observation machine</b></p> <p>After entering the vital signs into a PDA the early warning score is calculated automatically and the observation data is simultaneously exported the patient's EMR.</p> <p><b>On screen (advisory) warnings</b></p> <p>Once the vital signs have been saved, onscreen advice relevant to the current early warning score is provided.</p> <p><b>Overview Screen</b></p> <p>The system also provides for a patient overview screen which allows nurses to easily see a list of all the patients</p>		<p>Only 65 of the 111 identified users completed the feedback forms. Feedback forms which were sent out electronically and via paper. An email reminder was sent to complete the forms but the paper version was not resent. Staff averse to technology may have been more inclined to complete the paper feedback form and they were not sent a reminder. The addition of further feedback may have altered the results.</p> <p>This study showed qualitative acceptance of the system, but it's quantitative effect on clinical care was not evaluated.</p>	<p>JB1 Notari</p> <p>100%</p>
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			<p>on the ward and their current early warning score in a descending order from highest to lowest early warning score. This will facilitate switching between multiple patients' observation charts which will be useful during doctors' ward rounds and nurses' handovers and will also assist with the immediate recognition of patients with abnormal vital signs. Secondary sorting is also supported if a user wants to use different parameters to sort patients, for example time since last observations.</p> <p><b>Usability/ acceptability of electronic EWS</b></p> <p>Over 9 months 21,316 sets of vital signs were recorded and the system had 111 users indicating that the system was being used to record routine vital signs.</p> <p>User acceptability of the system was high as indicated by the System Usability Scale score of 77.8 (all scores above 68 are considered above average). Of the 111 users, 65 returned completed feedback forms which were sent out electronically and via paper. Clinical users' perception of the training received prior to the send application being implemented was also assessed. 95.3% (62 of 65 users) indicated that they had been taught how to use the system. 4.8% of those said the training was "not enough", 95.2% said it was "just right" and no-one said it was too much. The SEND system appears to be well accepted by staff with system usability scores ranging from 3.9/5 to 4.3/5.</p>			
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*Appendix D Table of excluded literature*

Author	Year	Country	Title	Reasons for exclusion
Guay, C., Murphree, P. & Steele-Moses, S.	2011	Los Angeles	Developing an automated RRT trigger	The study did not meet the quality appraisal cut off of 70%. JBI MASTARI Score 66.6%. No control group. Not sure if participants included in any comparisons were similar Not sure if participants included in any comparisons received similar treatment/care other than exposure or intervention of interest
Kollef, H.K., Chen, Y., Heard, K., LaRossa, G.N., Lu, C.L., Martin, N.R., Martin, N., Micek, S.T. & Bailey, T.	2014	Missouri	Randomized Trial of Real-Time Automated Clinical Deterioration Alerts Sent to a Rapid Response Team	This study did not meet the inclusion criteria because in addition to manually obtained vital signs a number of other variables, such as laboratory and pharmacy data, were required to determine the early warning score.