HEALTH TECHNOLOGY ASSESSMENT REPORT | HTA

KEMENTERIAN KESIHATAH MALAYSIA

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NEWS

NATIONAL EARLY WARNING SCORE

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MaHTAS

Malaysian Health Technology Assessment Section

MEDICAL DEVELOPMENT DIVISION
MINISTRY OF HEALTH

HEALTH TECHNOLOGY ASSESSMENT REPORT

NATIONAL EARLY WARNING SCORE (NEWS)

HEALTH TECHNOLOGY ASSESSMENT SECTION (MaHTAS)
MEDICAL DEVELOPMENT DIVISION
MINISTRY OF HEALTH

DISCLAIMER

This Health Technology Assessment has been developed from analysis, interpretation and synthesis of scientific research and/or technology assessment conducted by other organisations. It also incorporates, where available, Malaysian data, and information provided by experts to the Ministry of Health Malaysia. While effort has been made to do so, this document may not fully reflect all scientific research available. Additionally, other relevant scientific findings may have been reported since completion of the review.

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EXECUTIVE SUMMARY

Background

Reduction in the incidence of hospital adverse events and the number of preventable deaths in hospital has been the major focus of many quality improvement initiatives worldwide. It is a reflection on the capacity of the healthcare service in delivering high quality care to the patients. 'Catastrophic' medical or sentinel events which include in-hospital cardiopulmonary arrests and deterioration in the patient's clinical condition are often preceded by a steady accumulation of small clinical clues or a period of abnormal physiological status of the patient. In numerous studies, this abnormality was reflected on recorded patient's vital signs (blood pressure, heart rate, respiratory rate and temperature) suggesting that potential serious complications or adverse events in patient outcomes can be avoided if they were anticipated early. Recording patient's physiological observations is considered part of daily routine management in hospital either in acute hospital setting like in emergency department or in general ward setting. It is currently based mostly on intermittent measurements of basic parameters; blood pressure, heart rate, temperature and oxygen saturation by nursing staffs. Several hours can pass between such measurements and patient deterioration can go unnoticed especially on busy wards or during the night. Early Warning Scores (EWSs) are clinical bedside decision support tools used by care teams to potentially predict a patient's risk of deterioration and facilitate changes in management. Currently, it has been implemented across a variety of specialties and international settings.

At present, there has not been a formal adoption of single standardised EWS at national level that can be used across Malaysian healthcare system. While the few have adopted EWS either in its original version or adapted versions, tailored to their personalised hospital needs, majority of local hospitals are still using a conventional observation chart with routine four basic vital signs monitoring. Consistent use of a single nationally agreed EWS system as a tool for detection and response to clinical deterioration in adult patients will ensure that all patients are objectively assessed in the same way, regardless of the clinical expertise of the clinician or where the patient is assessed. This will ensure that the severity of illness and the rate of deterioration can be explicitly stated and understood throughout the entire Malaysian healthcare system. Hence, this Health Technology Assessment (HTA) was requested by Head of Department and Senior Consultant of General Surgery from Kuala Krai Hospital, Kelantan, to assess the effectiveness, safety, economic and organisational impacts of National Early Warning Score (NEWS) as standardised approach for the detection of and response to clinical deterioration in patients with acute illness.

Technical features

The NEWS is based on an aggregate scoring system in which a score is allocated to physiological measurements. Six simple physiological parameters form the basis of the scoring system: i) Respiratory rate ii) Oxygen saturations iii) Temperature iv) Systolic blood pressure v) Pulse rate vi) Level of consciousness. A score is allocated to each as they are measured, the magnitude of the score reflecting how extreme the parameter varies from the norm. The individual scores are then combined. Depending on the total score, the escalation of care is linked to recommendations on the frequency of observations and the urgency of clinical review.

Policy Question

Should National Early Warning Score (NEWS) be implemented in Ministry of Health (MOH) hospitals to improve safety, efficiency and standardisation of patient care?

Objectives

i. To assess the effectiveness and safety of NEWS in timely detection of patient's clinical deterioration by evaluating its predictive ability and impact on patient's clinical outcomes
ii. To determine the economic implications of a nationally implemented Early Warning Score system
iii. To evaluate the organisational, ethical, legal and social implications of NEWS implementation

Research Questions

i. How effective and safe is NEWS as a clinical decision support tools, in predicting patient's clinical deterioration?
ii. What is the estimated economic impact of NEWS implementation in minimizing occurrence of adverse events and preventable hospital mortality?
iii. What are the organisational, ethical, legal and social issues related to NEWS implementation?

Methods

Electronic databases were searched for published literatures pertaining to NEWS. The following electronic databases were searched through the Ovid interface: Ovid MEDLINE® In-process and other Non-indexed citations and Ovid MEDLINE® 1946 to September 9, 2019, EBM Reviews - Cochrane Central Register of Controlled Trials – August 2019, EBM Reviews - Cochrane Database of Systematic Reviews - 2005 to September 5, 2019, EBM Reviews - Health Technology Assessment – 4th Quarter 2016, EBM Reviews – NHS Economic Evaluation Database 1st Quarter 2016. Searches were also run in PubMed and CINAHL. Google was used to search for additional web-based materials and information. No limits were applied. Additional articles were identified from reviewing the references of retrieved articles. The search strategies used in the major databases are provided in Appendix 1. The searches were undertaken on 3 April 2019 and 13 August 2019 using the same strategies. Supplementary searches were undertaken between 21 May 2019 and 13 August 2019. Last search was conducted on 9 September 2019.

Results and Conclusion

A total of 3084 records were identified through the Ovid interface, PubMed and CINAHL databases. Additional 25 articles were identified from references of retrieved articles. After removal of 1407 irrelevant and duplicate articles, 1677 tittles were screened. Of these, 114 relevant abstracts were retrieved in full text. After reading, appraising and applying the inclusion and exclusion criteria, 79 full text articles were included for qualitative synthesis. A total of 35 full text articles were excluded due to irrelevant study design (n=5), irrelevant population (n=11), irrelevant outcome measure(s) (n=7), validation study of other models (8), master degree dissertation of quality improvement (n=3) and no full text article in English (n=1). The 79 full text articles comprised of one HTA, two systematic review, seven randomised control trials (RCTs), 51 cohort studies, one case-control, four pre-post intervention studies, three audit survey/cross-sectional studies, seven qualitative study and three economic evaluation studies.

Effectiveness

1. Discriminative Ability and Predictive Validity

NEWS

There was a substantial fair level of evidence to suggest;

Emergency department

- The NEWS was an effective assessment tool to identify and triage the patient for the most appropriate acute care assessments and interventions.
- The NEWS was a good predictor for serious adverse events (mortality and unanticipated ICU admission) in adult patients of varying severity of illness presenting to emergency department. It was able to rapidly predict prognosis and evaluate disease progression of critical patients in resuscitation room.
- The performance of NEWS was superior than quick Sequential Organ Failure Assessment (qSOFA), Systemic Inflammatory Response Sydrome criteria (SIRS) and Modified Early Warning score (MEWS), in risk-stratifying patients with suspected infection or sepsis and predicting death and unanticipated ICU admission in this subpopulation. Table-based aggregate weighted systems, such as NEWS, were more predictive and robust compared with tally-based single parameter scores such as qSOFA and SIRS.
- However, NEWS may not be the optimum scoring system for all patient subgroups. The NEWS showed moderate predictive ability for patient with community acquired pneumonia and low accuracy for in-hospital mortality in critically ill geriatric patients.

General wards

- The NEWS assessed on ward admission was able to risk stratify clinical deterioration and a good predictor of in-hospital serious adverse outcomes.
- NEWS discriminates high risk patients in a heterogenic general ward population independently of multiple confounding factors (age, gender, cumulative comorbidity, admission characteristic).
- The NEWS outperformed 33 other widely used Early Warning Scores (EWSs) for combined outcome of death, cardiac arrest and unanticipated ICU admission within 24 hours in the general population of patients.
- Between non-elective surgical patients and non-elective medical patients, NEWS had almost equal discriminative ability for prediction of serious adverse events.
- The NEWS accurately discriminates patients at risk of death, admission to the intensive care unit, or cardiac arrest within a 24-hour period for a range of liver-related diagnoses.
- A local study showed that NEWS was able to independently predict death or unanticipated ICU admission with an excellent prognostic performance (AUROC 0.905, $p<0.001$) in general surgical and orthopaedic wards. A score of 5 or more had the optimal sensitivity (87%) and specificity (91.3%) with PPV of 26.9% to predict serious adverse events in general ward (OR 2.828; 95%CI 1.632, 4.902). The number needed to screen at this threshold was 3.6.
- National Early Warning Score was identified as independent predictor of early clinical deterioration 24 hours after ICU discharge and readmission to ICU or High Dependency Unit (HDU). A NEWSdc > 7 showed the best sensitivity (93.6%) and specificity (82.2%) to detect early clinical deterioration 24 hours after ICU discharge.
- The NEWS also had reasonable discrimination for any ICU patient's discharge location within 24 hours of admission to any ICU specialty. Hence, it could potentially be applied within a universal discharge planning tool for ICU, improving patient safety at the point of discharge (reduce the likelihood of both

premature discharge and discharge delay by allowing care providers adequate time to plan accordingly).

- However, the NEWS system, whilst beneficial, lacks sensitivity and specificity in subpopulations of older adult patients (with/without comorbidity, high frailty index), patients with chronic obstructive pulmonary diseases (COPD) and oncology patients at risk of deterioration.

Pre-hospital setting

- In pre-hospital setting whereby NEWS was calculated using parameters recorded on the scene or prior ambulance transfer, NEWS showed good discriminative performance for both short term and long term mortality, and ICU admission from ED.
- A threshold level of 7 was associated with increased risk for the combined outcome of death or critical care unit escalation within 48 hours of hospital admission.
- Pre-hospital NEWS had better diagnostic accuracy in cases where the initial dispatch code was specified as trauma.
- Pre-hospital NEWS had poor prognostic performance for in-hospital mortality in elderly patients.
- Among pre-hospital patients with suspected infection, an elevated NEWS, was associated with increased levels of adverse outcomes (ICU admission within 48 hours of presentation and/ or 30-day mortality). The aggregated total NEWS score was, significantly superior to qSOFA at identifying patients at combined risk. A NEWS of medium or high clinical risk could be used according to sepsis guideline to prompt clinicians to further investigate for organ dysfunction, to initiate or escalate therapy as appropriate, and to consider referral to critical care or increase the frequency of monitoring.

NEWS2

- In predicting 24 hours mortality among patients with documented or at risk of type 2 respiratory failure, NEWS2 did not show superior performance to original NEWS. The NEWS2 did not improve discrimination for unanticipated ICU admission, cardiac arrest or combined outcomes compared to NEWS either.
- In acute exacerbation of chronic obstructive pulmonary disease (AECOPD) cohort, NEWS2 at admission did not outperform the original NEWS.
- In pre-hospital setting, NEWS2 had the best prognostic performance [AUROC of 0.896 (95%CI 0.82, 0.95)], in comparison with other EWS namely EWS [Early Warning Score (EWS), Modified Early Warning Score (MEWS), Vital-PAC Early Warning Score (ViEWS), Hamilton Early Warning Score (HEWS) and Scottish Early Warning Score (SEWS).
- The NEWS2 accurately predicted in-hospital mortality particularly among patients with suspected infection. At the critical threshold (≥ 5), the NEWS2 had sensitivity of 84.5% (95%CI 82.8, 86.2) and specificity of 49.0% (95%CI 47.4, 50.7). The number needed to examine (NNE) was 2.20 (95%CI 2.16, 2.25). NEWS2 was superior to qSOFA for screening for sepsis with organ dysfunction, infection-related mortality or intensive care due to an infection both among infected patients and among undifferentiated patients at emergency departments.

2. Impact on clinical outcome (NEWS and NEWS2)

Despite having good prognostic performance of death and ICU admission, the implementation of NEWS has not yet been reported to have any change in overall patient outcomes (survival rate, serious adverse events rate, ICU mortality rate).

Safety

There was fair level of evidence to suggest;

- Accuracy of NEWS scoring decreased significantly with increasing score or worsening physiological derangement and it had become a safety concern.
- The NEWS that were calculated incorrectly had implications for trigger actions and associated clinical care. Increased mortality trend was observed among patients who received an incorrect response.
- Patients admitted at the weekend had a worse clinical response [adjusted OR 4.15 (95%CI 2.24, 7.69), p<0.001].
- Non-adherence to NEWS escalation protocol at one or several levels was associated with the occurrence of serious adverse events.

Economic evaluation

There was no retrievable evidence on cost-effectiveness. However, there were one cost analysis and two budget impact analysis conducted on implementation of NEWS. They suggested that the NEWS leads to cost and/or efficiency savings. If this trend is continuous and savings can be realised, it could be hypothesized that NEWS may indeed be cost effective.

Organisational implication

There was fair level of evidence to suggest:

- Length of stay (LOS) was found to be significantly correlated with NEWS, where median LOS was more than doubled for a NEWS score >7 compared with a score of 0–4.
- Level of workload was inversely associated with NEWS scoring or threshold level. A NEWS score of 3 as a trigger would have increased doctors workload by 40% with only a small increase in the number of detected adverse outcomes per day (a 3% improvement in detection) whereas NEWS threshold of 5 would generate lower workload and higher detection rates (medical: workload 12.3%, detection 70.2%; surgical: workload 6.1%, detection 60.6%).
- Reduced sensitivity of the triggering system and the overall effectiveness of the NEWS were likely to be caused by poor recording of vital signs, incorrect calculations and non-adherence to the escalation protocol.
- Chart design affected the speed and accuracy of documentation. The use of graphical display and avoiding visual clutter, and the use of overlapping graphical displays of data helped to improve adherence.
- Interdisciplinary, multimodal and follow-up educational programmes were most effective in improving adherence rate.
- Improved efficiency and accuracy of recording vital sign parameters and compliance with escalation protocols were seen with automation of EWS.

Ethical and legal issues

There was evidence to suggest that in overcoming ethical and legal challenges of performing predictive analytics on healthcare, developing a governance structure at the earliest phase of model development is recommended in order to guide patients and participating stakeholders across the process. Liability issues such as failure to obtain crucial knowledge of patient's medical history due to dependency on predictive model to make clinical decision which lead to harm, overriding an alert or recommendation or following the recommendations of faulty predictive analytic model should be anticipated and preventive measures should be put in place. Ethical issue surrounding doctor-patient relationship whereby the treatment approach could be shifted from catering to individual patient's best interest to the

interest of healthcare organization in maximizing population based health should be foreseen.

Social implication

There was evidence to suggest that understanding the organisational culture, systems, practices, barriers and facilitators and the stakeholders' perceptions and interactions with the NEWS pre-implementation is important. The success of NEWS intervention depends on human interaction with the system and understanding the variable organisational practices; this involved understanding how the nursing staff incorporate the EWS system into their daily work routines and how they feel the system works for them. Organisations also need to address power hierarchy between medial teams to reduce delays in response to deteriorating patients. A 'whole system' approach incorporating a EWS, well designed chart, communication tool, decision aides, evidence based care bundles, Rapid Response Team (RRT), bedside evaluation, education, reinforcement and audit is most effective at identifying and responding to deteriorating patients. A poor-quality implementation likely to worsen patient care.

Recommendations

Based on the findings of this review, NEWS may have a role in the early identification of deteriorating patient and can be used for adult non-obstetric patients within the hospital system to improve safety and efficiency of patient care through standardisation of early warning score application. The following considerations should be taken into account in the development of national approach of early warning score in order to ensure its effective implementation;

- A requirement for systems approach supported by appropriate governance as NEWS is a system-level complex intervention. The emphasis should be given on regular reinforcement and auditing to promote high levels adherence to NEWS to ensure effectiveness.
- For effective escalation of care, the appropriate trigger levels should be set and a mechanism should be in place to ensure that the appropriate individuals with higher NEW scores are reviewed promptly by health care professionals with critical care competencies and diagnostic skills.
- Ensuring regular training and continuous education of all health care providers using NEWS; such training and education should include: interdisciplinary in person simulations/case-reviews; be multimodal, and inclusion of regular reinforcement.
- In healthcare settings where automated healthcare service is available, the potential use of electronic data capture, EWS triggering, notification and tracking of outcomes should be carefully considered. The implementation of electronic NEWS should be initiated as a pilot programme before expansion to other hospitals.
- In settings that still utilize manual system in delivering services to patients, a structured manual approach (paper-based NEWS) would be a more suited choice.

Abbreviations

AMU	Acute medical unit
APACHE II	Acute Physiology and Chronic Health Evaluation Score II
ARLD	Alcohol-related liver disease
ASA	American Society of Anesthesiologists classification of physical status
AUROC	Area Under the Receiver Operating Characteristic Curve
BIA	Budget Impact Analysis
CAP	Community acquired pneumonia
CCI	Charlson Comorbidity Index
CI	Confidence Interval
ED	Emergency Department
EMS	Emergency Medical Services
ESI	Emergency Severity Index
EWS	Early Warning Score
GDP	Gross domestic product
HDU	High dependency unit
HEWS	Hamilton Early Warning Score
ICU	Intensive care unit
LOS	Length of stay
MEDS	Mortality in Emergency Department Sepsis
MEES	Mainz Emergency Evaluation Score
MEWS	Modified Early Warning Score
MTS	Manchester Triage Scale
MV	Mechanical ventilation
NEWS	National Early Warning Score
NPSA	National Patient Safety Agency
NPV	Negative Predictive Value
OR	Odd ratio
PARS	Patient at Risk Score
PEDS	Prince of Wales Emergency Department Score
PIRF-14	Post-ICU respiratory failure before day 14
PIRO	Predisposition/ Infection/Response/Organ Dysfunction Score
PPV	Positive predictive value
PSI	Pneumonia Severity Index
RCPL	Royal College of Physicians of London
REMS	Rapid Emergency Medicine Score
RRT	Rapid Response Team
SAPS	Simplified Acute Physiology Score
SCS	Simple Clinical Score
SEWS	Scottish Early Warning Score
SIRS	Systemic Inflammatory Response Syndrome criteria
SOFA	Sequential Organ Failure Assessment
qSOFA	quick Sequential Organ Failure Assessment
T2RF	Type 2 respiratory failure
THERM	The Resuscitation Management score
TTS	Track and Trigger System
ViEWS	Vitalpac Early Warning Score

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NATIONAL EARLY WARNING SCORE

1.0 BACKGROUND

Reduction in the incidence of hospital adverse events and the number of preventable deaths in hospital has been the major focus of many quality improvement initiatives worldwide. It is a reflection on the capacity of the healthcare service in delivering high quality care to the patients. In 2016, approximately 24% of all deaths in the UK were considered preventable (141,101 deaths out of 597,206).[1] About one-third of potentially preventable deaths in the UK relate to poor clinical monitoring.[2] The total number of deaths in EU that could have potentially been prevented through effective medical interventions was just over 1.2 million in 2015.[3] According to a newly published analysis led by Harvard Medical School, eight million largely preventable deaths from lack of high quality medical care cost $6 trillion in lost economic welfare in low- and middle-income countries. If current conditions persist, low- and middle-income countries could lose collectively $11 trillion in gross domestic product (GDP) by 2030.[4]

'Catastrophic' medical or sentinel events which include in-hospital cardiopulmonary arrests and deterioration in the patient's clinical condition are often preceded by a steady accumulation of small clinical clues or a period of abnormal physiological status of the patient. In numerous studies, this abnormality was reflected on recorded patient's vital signs (blood pressure, heart rate, respiratory rate and temperature) suggesting that potential serious complications or adverse events in patient outcomes can be avoided if they were anticipated early.[5-10] Research suggests that patients suffering from a cardiac and/or respiratory arrest usually display physiological deviations (changes in vital signs and/or mental status) at least eight hours prior to their need for more intensive care.[10] A study reported that 86% of code blue events or rapid response team (RRT) activation could have been predicted beforehand, with a median advanced warning time of 11.5 hours.[9]

Recording patient's physiological observations is considered part of daily routine management in hospital either in acute hospital setting like in emergency department or in general ward setting. It is currently based mostly on intermittent measurements of basic parameters; blood pressure, heart rate, temperature and oxygen saturation by nursing staffs. Several hours can pass between such measurements and patient deterioration can go unnoticed especially on busy wards or during the night.[11] Analysis of 576 deaths reported to the UK National Patient Safety Agency's (NPSA) National Reporting and Learning System (NRLS) over a one year period identified that 11% were as a result of deterioration not recognised or acted upon.[12] According to the report produced by the UK NPSA, contributing factors for failure to recognise and respond to patient's clinical deterioration were observations not being taken or poorly documented, observations causing concern not being reported, early signs of deterioration not being recognised or misinterpreted and not responding appropriately.[12] These were often due to demanding workloads, poor staffing level, time limitation and communication failure between teams.[13, 14] Studies revealed that this failure had led to delays in diagnosis, treatment or referral, resulting in increased patient morbidity, mortality and admission to intensive care units or cardiac arrests, which were preventable.[15-19]

In order to address these challenges, hospitals require robust escalation of care processes to ensure that worsening conditions in patients are recognised and treated. A high quality response is essential to stop the potential transition from an initial serious complication to a progressive cascade of adverse occurrences

that can lead to preventable patient harm and death, or 'failure to rescue'. Current nursing practise (routine vital signs observation) in hospitals is not sensitive enough to detect a deteriorating or critically ill patient at an early stage. Providing clinical staffs with the tools they need, to be aware of those patients who are deteriorating fast will be a significant step forward. Early warning scores (EWS) are clinical bedside decision support tools used by care teams to potentially predict a patient's risk of deterioration and facilitate changes in management. Currently, it has been implemented across a variety of specialties and international settings.

1.1 Local Background and Context

In Malaysia, Ministry of Health is the major provider of healthcare services in public sector and consists of 144 hospitals (including special medical institutions namely Rehabilitation Hospital, Women & Children Hospital, National Leprosy Control Centre, Institute of Respiratory Medicine, National Cancer Institute and Psychiatric Institutions) with a total inpatient bed capacity of 42 302.[20] A total of 57 831 doctors and 106 289 nurses are currently working in public and private healthcare facilities, delivering services for patients, with a doctor and nurse to population ratio of 1:554 and 1:302, respectively.[20] There are challenges in sustaining the quality and patient safety in Malaysia. As the population increases, demand for healthcare increases as well.[21] The highly subsidised government healthcare services with inequitable distribution of resources, changing in pattern of diseases and rising costs have resulted in heavy workload and long waiting time for patients to receive treatment.[21] Nowadays, patients are better informed and have an expectation that the care they receive is evidence based, effective, safe and of high quality. Advances in medical technology are constantly pushing the healthcare providers for better services but at great cost. According to Malaysia Health Systems Research Key Findings 2016, 219 deaths for every 100 000 population in Malaysia can be prevented with better healthcare.[22]

In order to elevate patient care and outcomes, a number of Ministry of Health hospitals as well as private hospitals have introduced EWS into their routine nursing practice for monitoring patient's clinical parameters as one of the strategic steps to strengthen its ability to better serve patients while easing the tasks of the hospital's personnel and management team. Early warning score is mostly used in general adult medical and surgical wards. In recent years, some of these hospitals mainly private hospitals started transitioning their EWS from paper observation charts to electronic platforms. University Malaya Medical Centre (UMMC) has become the first public hospital in the country to implement a warning score system that is fully integrated into its electronic patient management system.[23] Penang Adventist Hospital and Bagan Specialist Centre in Penang are two examples of private hospitals that have adopted fully automated early warning scoring system.[24],[25]

At present, there has not been a formal adoption of single standardised EWS at national level that can be used across Malaysian healthcare system. While the few have adopted EWS either in its original version or adapted versions, tailored to their personalised hospital needs, majority of local hospitals are still using a conventional observation chart with routine four basic vital signs monitoring. The staff use their clinical judgement regarding the frequency of observations and adjust where necessary. Consistent use of a single nationally agreed EWS system as a tool for detection and response to clinical deterioration in adult patients will ensure that all patients are objectively assessed in the same way, regardless of the clinical expertise of the clinician or where the patient is assessed. This will ensure that the severity of illness and the rate of deterioration can be explicitly stated and understood throughout the entire Malaysian healthcare system. Hence, this Health Technology Assessment (HTA) was requested by Head of Department and Senior Consultant of General Surgery from Kuala Krai Hospital, Kelantan, to assess the effectiveness, safety, economic and organisational impacts of National Early

Warning Score (NEWS) as standardised approach for the detection of and response to clinical deterioration in patients with acute illness.

2.0 TECHNICAL FEATURES

2.1 Early Warning Scores/Systems (EWS) [26-28]

Early Warning Scores/Systems, also referred to as 'Track and Trigger Systems', are simple scoring systems for bedside monitoring, to serve as clinical support tools using routinely collected vital sign data. The scoring tools have been established in acute clinical care settings to facilitate early detection of deterioration by categorising a patient's severity of illness and prompting nursing staff to request a medical review at specific trigger points utilising a structured communication tool while following a definitive escalation plan. They were developed initially as paper based approach then later moved to electronic platform.

In its simplest form, Early Warning/Track and Trigger Systems require an efficient data collection mechanism to '**track'** physiological signs or changes followed by a data analysis algorithm to generate an early '**trigger'** to intervene and escalate care. Overall, these systems focus on combating the problem of "failure to rescue"; they are then broken down into issues of "failure to identify" (afferent limb) and "failure to escalate" (efferent limb). The afferent limb of the system is meant to identify patient deterioration and trigger a response indicating the need for a higher level of care. The efferent limb is the response to the trigger—delivered through higher levels of monitoring and care or a rapid response/medical emergency team. (Figure 1) Numerous EW/TTS are used internationally to detect patients at risk of deteriorating. They are broadly divided into single parameter, multiple parameter and aggregate weighted systems, which are shown in the Table 1.

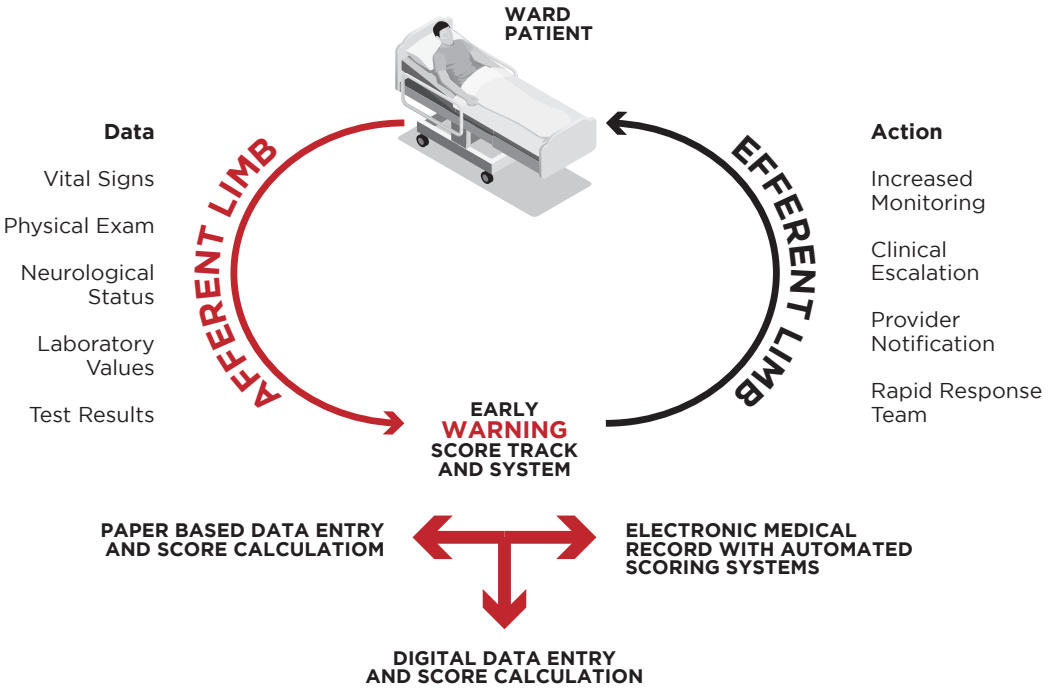


Figure 1: A schematic representation of early warning/track-and -trigger systems demonstrating the afferent and efferent limbs of the system.[28]

Table 1: Types of Early Warning System

System	Characteristics
Single parameter system	Periodic observation of selected vital signs or laboratory values that are compared with a simple set of criteria with predefined thresholds, with a response algorithm being activated when any single criterion is met. ❖ Thresholds for classifying the values as abnormal are not uniform among hospitals and scoring systems are chosen somewhat arbitrarily based on local preferences and expertise. ❖ Examples: qSOFA, SIRS
Multiple parameter system	Response algorithm requires more than one criterion to be met or differs according to the number of criteria met. ❖ Example: shock index (SI)—heart rate divided by systolic blood pressure
Aggregate scoring system	**Weighted scores are assigned to physiological values and compared with predefined trigger thresholds.** ❖ **Examples: NEWS, MEWS, ViEWS**

2.2 Electronic early warning systems[29]

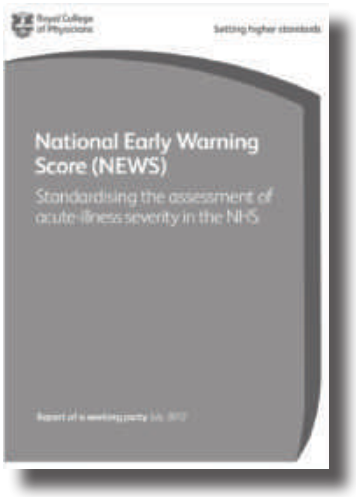
While commercial electronic early warning systems may comprise a wide range of features, there are four core elements that are common to all systems.

a. Electronic reporting (information capture) of vital sign parameters at the bedside using a mobile, user-friendly platform
b. Computer learning systems that calculate the early warning score
c. Escalation of care when appropriate
d. Communication of the actions to be taken/or have been taken to address deteriorating vital sign and patient parameters.

When an electronic early warning system is introduced into a setting, the threshold parameters are usually set in line with national or local guidelines for early warning scores and escalation protocols.

2.3 National Early Warning Score (NEWS)[26]

National Early Warning Score was developed in 2012, through collaborative work of Royal College of Physicians (RCP) and National Health Service (NHS) Trusts in UK on the basis of there should be a national system for recognising very sick patients whose condition is deteriorating and who need more intensive medical or nursing care. It is a pragmatic approach, with a key emphasis on system-wide standardisation and the use of physiological parameters that are already routinely measured in hospitals and in prehospital care, recorded on a standardised clinical chart. The NEWS is an **adjunct** to decision making, used in combination with clinical judgement and communicated across the care pathway. NEWS **does not replace** disease-specific validated scoring systems but highly recommended to be used alongside these validated scoring systems as dictated by patient need. It offers the following features;



- a standardised method to characterise acute illness severity
- a standardised method to detect patient deterioration
- a common language of illness severity
- system-wide unitary documentation - instantly recognisable
- a standardised system for education, training and accreditation for all staff in the local healthcare system

Based on EWS concept, it is used to quickly determine the degree of illness of a patient and simplify trend tracking, enabling a more timely response using a common language across hospitals nationally. The principles of the NEWS highlight a key triad consists of early detection, speed of response and competencies of the responder(s) that determine the clinical outcomes (hospital mortality, cardiac arrest, admission to critical care).

In 2017, NEWS was updated to NEWS2 to include additional features (Chart 1);

- Observation chart re-odered to reflect the resuscitation council ABCDE format
- Chart colours changed from red/amber/green as they were not ideal for staff with red/green colour blindness. (Chart 1)
- New section for scoring oxygen saturations for patients with **hypercapnic respiratory failure** (SpO_2 Scale 2). (Figure 2)
- "New confusion / delirium" added and scores 3. (Figure 3)
- Strong emphasis use of NEWS to raise suspicion of potential sepsis as a cause for a NEWS score of 5 or more. (Chart 3)

Physiological parameter	Score						
	3	2	1	0	1	2	3
Respiration rate (per minute)	≤ 8		9-11	12-20			
SpO_2 Scale 1 (%)	≤ 91	92-93	94-95	≥95	93-94 on oxygen	95-96 on oxygen	≥ 97 on oxygen
SpO_2 Scale 2 (%)	≤ 83	84-85	86-87	88-92 ≥ 93 on air			
Air or oxygen		Oxygen		Air			
Systelic blood pressure (mmHg)	≤ 90	91-100	101-110	111-219			≥ 220
Pulse (per minute)	≤ 40		41-50	51-90	91-110	111-130	≥ 131
Consciouness				Alert			CVPU
Temperature (°C)	≤ 35.0		35.1-36.0	36.1-38.0	38.1-39.0	≥ 39.1	

Physiological parameter	Score						
	3	2	1	0	1	2	3
Respiration rate	≤ 8		9-11	12-20		21 - 24	≥ 25
Oxygen Saturations	≤ 91	92-93	94-95	≥95			
Any Supplemental Oxygen		Yes		No			
Temperature	≤ 35		35.1 -36.0	36.1 - 38.0	38.1 - 39.0	≥ 39.1	
Systolic BP	≤ 90	91-100	101-110	111-219			≥ 220
Heat Rate	≤ 40		41-50	51-90	91-110	111-130	≥ 131
Level of Conscousness				A			V,P, or U

NEWS (2012) → **NEWS2 (2017)**

Chart 1: Physiological Parameter Score Chart

Six simple physiological parameters form the basis of the NEWS scoring system.

1. Respiratory rate
2. Oxygen saturation
3. Systolic blood pressure
4. Pulse rate
5. Level of consciousness or new confusion
6. Temperature

A score is allocated to physiological measurements already undertaken when patients present to, or are being monitored in hospital, with the magnitude of the score reflecting how extremely the parameter varies from the norm. The score is then aggregated. The score is uplifted by 2 points for people requiring supplemental oxygen to maintain their recommended oxygen saturation. The clinical parameters [6 vital signs as well as the AVPU scale ("alert, voice, pain, unresponsive")] produces an aggregate score between 0 and 20. (Chart 1)

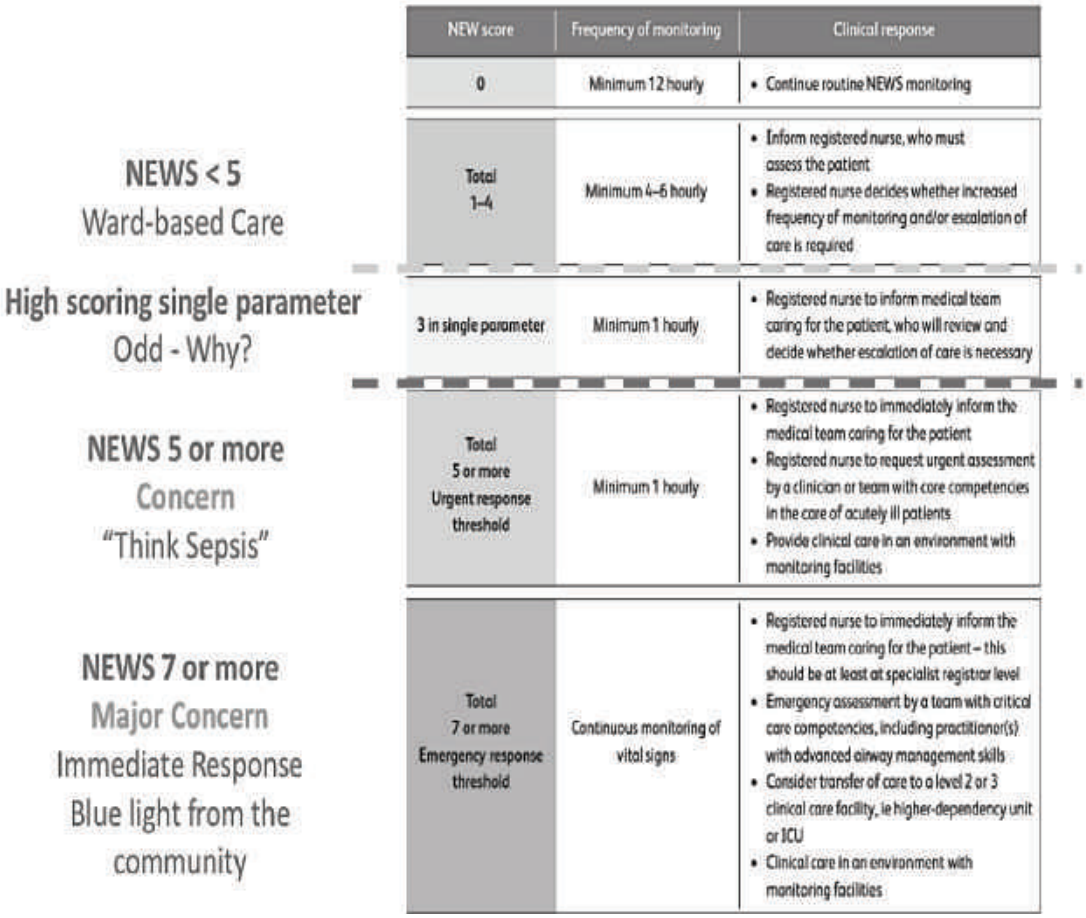
NEW Score	Clinical Risk	Response
Aggregate score 0-4	Low	Ward - based response
Red score Score of 3 in any individual parameter	Low - medium	Urgent ward - based response*
Aggregate score 5-6	Medium	Key threshold for urgent response*
Aggregate score 7 or more	High	Urgent or emergency response**

Chart 2: NEWS Thresholds and Triggers

NEWS recommends four trigger levels for a clinical alert requiring clinician assessment based on the NEWS (Chart 2) :

- **LOW score:** an aggregate NEW score of 1–4
- **A single red score:** an extreme variation in an individual physiological parameter (a score of 3 in any one parameter, which is colour-coded **red** on the NEWS chart)
- **MEDIUM score:** an aggregate NEW score of 5 or 6. **A NEW score of 5 or more is a key threshold** and is indicative of potential serious acute clinical deterioration and the need for an urgent clinical response
- **HIGH score:** an aggregate NEW score of 7 or more.

NEWS recommends that these triggers should determine the urgency of the clinical response and the clinical competency of the responder(s). (Chart 3)



NEW score	Frequency of monitoring	Clinical response
0	Minimum 12 hourly	• Continue routine NEWS monitoring
Total 1–4	Minimum 4–6 hourly	• Inform registered nurse, who must assess the patient • Registered nurse decides whether increased frequency of monitoring and/or escalation of care is required
3 in single parameter	Minimum 1 hourly	• Registered nurse to inform medical team caring for the patient, who will review and decide whether escalation of care is necessary
Total 5 or more Urgent response threshold	Minimum 1 hourly	• Registered nurse to immediately inform the medical team caring for the patient • Registered nurse to request urgent assessment by a clinician or team with core competencies in the care of acutely ill patients • Provide clinical care in an environment with monitoring facilities
Total 7 or more Emergency response threshold	Continuous monitoring of vital signs	• Registered nurse to immediately inform the medical team caring for the patient – this should be at least at specialist registrar level • Emergency assessment by a team with critical care competencies, including practitioner(s) with advanced airway management skills • Consider transfer of care to a level 2 or 3 clinical care facility, ie higher-dependency unit or ICU • Clinical care in an environment with monitoring facilities

Chart 3: Clinical response to the NEWS trigger threshold

NEWS recommends the use of the standardised NEWS observation chart for the routine recording of clinical observations, across the hospitals. The NEWS chart is colour-coded to provide both visual and numeric prompts to aid identification of abnormal clinical parameters. It is recognised that the rest of the chart area will be customised to reflect other key parameters not incorporated in the NEWS, eg urine output and pain scores, according to the clinical environment. (Chart 4)

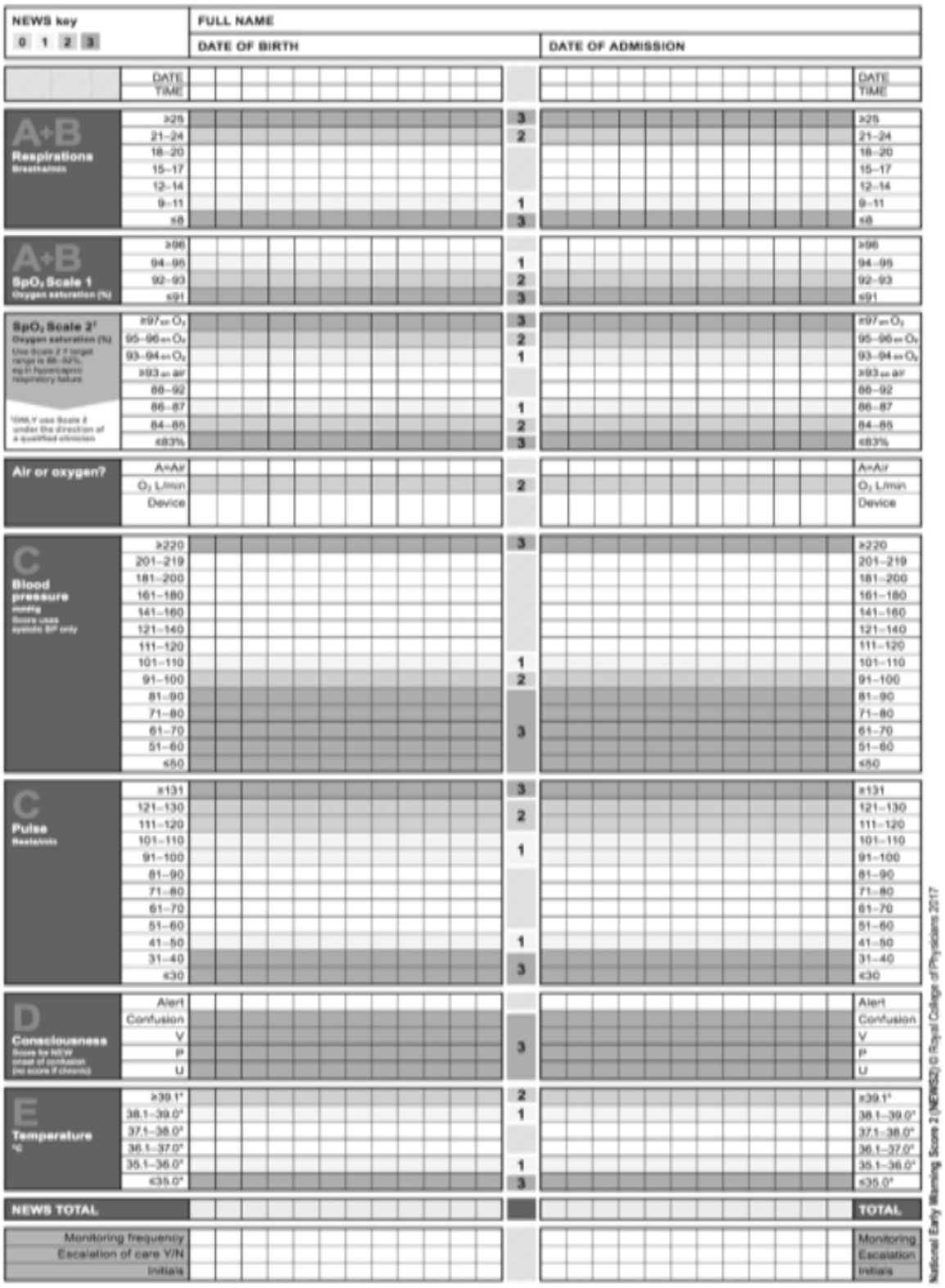


Chart 4: NEWS Observation Chart

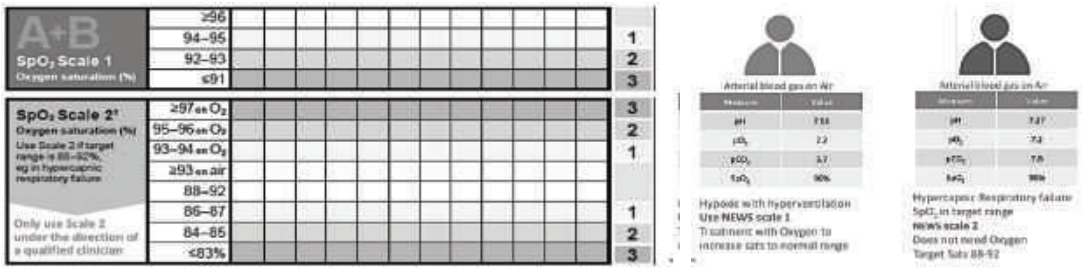


Figure 2: Using NEWS2 in COPD with Hypercapnic Respiratory failure - safer oxygen use

A C V P U

C = acute confusion or delirium
C = potent sign of acute clinical deterioration

Score = 3

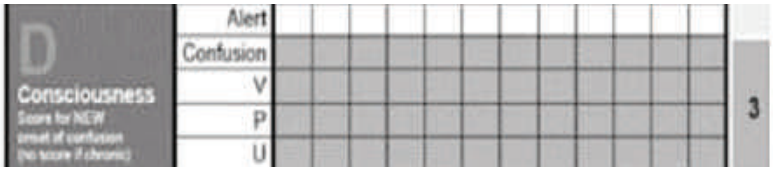


Figure 3: NEWS 2 Acute Confusion/Delirium

In order to support the safe adoption of NEWS2, NHS Improvement has produced a resource pack. (Figure 4)

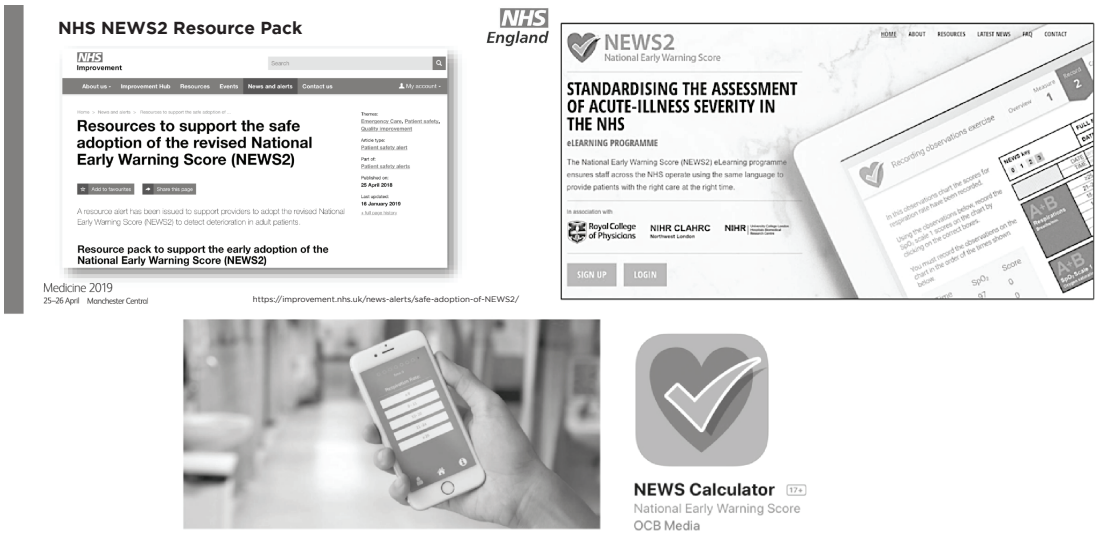


Figure 4: NHS Resource Pack, E-Learning Platform and NEWS Apps iOS and Android

3.0 POLICY QUESTION

Should National Early Warning Score (NEWS) be implemented in Ministry of Health (MOH) hospitals to improve safety, efficiency and standardisation of patient care?

4.0 OBJECTIVE

4.1 To assess the effectiveness and safety of NEWS in timely detection of patient's clinical deterioration by evaluating its predictive ability and impact on patient's clinical outcomes

4.2 To determine the economic implications of a nationally implemented Early Warning Score system

4.3 To evaluate the organisational, ethical, legal and social implications of NEWS implementation

Research Questions

iv. How effective and safe is NEWS as clinical decision support tools, in predicting patient's clinical deterioration?

v. What is the estimated economic impact of NEWS implementation in minimizing occurrence of adverse events and preventable hospital mortality?

vi. What are the organisational, ethical, legal and social issues related to NEWS implementation?

5.0 METHODS

5.1 Literature search strategy

Electronic database was searched for published literatures pertaining to NEWS. The following electronic databases were searched through the Ovid interface: Ovid MEDLINE® In-process and other Non-indexed citations and Ovid MEDLINE® 1946 to September 9, 2019, EBM Reviews - Cochrane Central Register of Controlled Trials – August 2019, EBM Reviews - Cochrane Database of Systematic Reviews - 2005 to September 5, 2019, EBM Reviews - Health Technology Assessment – 4th Quarter 2016, EBM Reviews – NHS Economic Evaluation Database 1st Quarter 2016. Searches were also run in PubMed and CINAHL. Google was used to search for additional web-based materials and information. No limits were applied. Additional articles were identified from reviewing the references of retrieved articles. The search strategies used in the major databases are provided in Appendix 1. The searches were undertaken on 3 April 2019 and 13 August 2019 using the same strategies. Supplementary searches were undertaken between 21 May 2019 and 13 August 2019. Last search was conducted on 9 September 2019.-

5.2 Study selection

Based on the policy question the following inclusion and exclusion criteria were used:

5.2.1 Inclusion criteria

a	Population	i. All adult patients (aged 16 years old and above) in pre-hospital and hospital settings ii. Healthcare staffs who are involved in delivering the intervention
b	Intervention	National Early Warning Score
c	Comparator	i. Other established scoring system designed to identify deteriorating patients [ie Patient at Risk (PAR) score, Physiological Scoring Systems (PSS), Vital Sign Score (VSS), BioSign] ii. Standard/Usual care (Standard Observation Charts) iii. Clinical judgement iv. No comparator
d	Outcomes	i. Effectiveness • Predictive ability to detect clinical deterioration - model discrimination for outcomes of mortality, cardiopulmonary arrest and unanticipated ICU admission • Patient's clinical outcomes - in-hospital mortality - cardiovascular (CV) events (cardiac arrest, acute coronary syndrome, cardiogenic shock) ii. Safety • Adverse events [Adoption issues ie. inconsistency in NEWS application among staffs and across medical specialties, the inaccuracies and miscalculations related to manual data collection leading to inappropriate clinical response or misalerts.] iii. Economic impacts • Cost effectiveness analysis • Cost utility analysis • Cost benefit analysis • Cost analysis • Any other measure of economic outcomes iv. Organisational issues • Resource utilisation - Length of hospital stay (LOS) - Admission to ICU - Use of Rapid Response or Code Team Training/Education • Change in work process - Workload - Compliance rate • NEWS application adaptability - in resource limited settings - cross specialty application • Opportunity for automation (electronic charting and scoring system for NEWS) v. Ethical and legal issues vi. Social implication [Nursing staff and doctors] • Acceptance • Attitude • Satisfaction • Experience
e	Study design	HTA reports, systematic review with meta- analysis, systematic review, randomised controlled trial (RCT), cohort, case-control, cross-sectional, qualitative studies and economic evaluation studies.
e	English full text articles	

5.2.2 Exclusion criteria

a. Studies that involved subgroup populations: obstetric and paediatric patients
b. Study design: Animal study, laboratory study, narrative review
c. Non-English full text articles

Based on the above inclusion and exclusion criteria, study selection was carried out independently by two reviewers. Disagreement will be resolved by discussion.

5.3 Critical Appraisal of Literature

Assessment of risk of bias in included studies

The methodological quality of all the relevant full text articles retrieved was assessed using the Critical Appraisal Skills Programme (CASP) tool by two reviewers depending on the type of the study design (systematic reviews, economic evaluation, cohort and case control studies).[30] For systematic review the criteria assessed include selection of studies, assessment of quality of included studies, heterogeneity of included studies. For randomised control trial, The Cochrane Collaboration's tool was utilised. The criteria assessed by this tool were randomisation, allocation concealment, blinding, explanation on loss to follow-up, and intention to treat analysis.[31] For non-randomised experimental studies, with and without control group, Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Quasi-Experimental and NIH Quality Assessment Tool for Before-After (Pre-Post studies) were utilised.[32, 33] For cohort study, the criteria assessed were selection of the cohort, accurate measurement of exposure and outcome, confounding factors, follow-up adequacy and length. For case control study, the criteria assessed were selection of the cases and control, accurate measurement of exposure, blinding and confounding factors. For economic evaluation, the criteria assessed include comprehensive description of competing alternatives, effectiveness established, effects of intervention identified, measured and valued appropriately, relevant resources and health outcome costs identified, measured in appropriate units and valued credibly, discounting, incremental analysis of the consequences and costs of alternative performed and sensitivity analysis performed. The Cochrane's Collaboration Tool is as in Appendix 5. All full text articles were graded based on guidelines from the U.S./Canadian Preventive Services Task Force (Appendix 1).[34]

5.4 Analysis and Synthesis of Evidence

5.4.1 Data extraction strategy

The following data were extracted:

i. Details of methods and study population characteristics
ii. Detail of intervention and comparators
iii. Details of individual outcomes specified

Data were extracted from selected studies by a reviewer using a pre- designed data extraction form and checked by another reviewer. Disagreements was resolved by discussion.

We reported the c-statistic (AUROC value), with 95% confidence interval when available, to describe model discrimination. The AUROC which is equivalent to the area under the receiver operating characteristic curve, is the proportion of times the model correctly discriminates a pair of high- and low-risk individuals.[35] The AUROC value of 0.5 indicates the model performs no better than chance;

AUROC value of 0.6 to 0.7 indicates poor discriminative ability, AUROC value of 0.7 to 0.8 indicates modest or acceptable discriminative ability, 0.8 to 0.9 as good discriminative ability and a threshold of greater than 0.9 indicates excellent discriminative ability. [36, 37] If the AUROC value was not reported, other operational statistics such as sensitivity, specificity and predictive values were extracted for representative risk score cut-offs when available.

5.4.2 Methods of data synthesis

Data were synthesized qualitatively focusing on NEWS model discrimination, the populations in which the NEWS model has been tested, impact of NEWS model implementation on health outcomes and resource utilisation, economic and social impacts of NEWS model implementation. Data on the outcome measures were presented in tabulated format with narrative summaries. A meta-analysis of prognostic accuracy studies that reported AUROC value for mortality outcomes was performed. For computing meta-analysis summary estimates, we combined eligible studies' data using Stata 15 statistic software. A random-effects model was applied. We assessed statistical heterogeneity using the Cochran Q test by calculating I^2 values (I^2 >75% considered to be high level of heterogeneity).[38] When heterogeneity was substantial (I^2>75%), we investigated the sources of heterogeneity by determining the effect of important modifiers: sample details (type and quantity), study design and risk for bias, and the effect of the imputed data. The pooled estimates with 95% Confidence Interval (CI) were reported as appropriate. Statistical significance was set at p value less than 0.05 for all outcomes.

6.0 RESULTS

6.1 Search results

A total of 3084 records were identified through the Ovid interface, PubMed and CINAHL databases. Additional 25 articles were identified from references of retrieved articles. After removal of 1407 irrelevant and duplicate articles, 1677 tittles were screened. Of these, 114 relevant abstracts were retrieved in full text. After reading, appraising and applying the inclusion and exclusion criteria, 79 full text articles were included for qualitative synthesis. A total of 35 full text articles were excluded due to irrelevant study design (n=5), irrelevant population (n=11), irrelevant outcome measure(s) (n=7), validation study of other models (8), master degree dissertation on quality improvement(n=3) and no full text article in English (n=1). The 79 full text articles comprised of one HTA, two systematic review, seven randomised control trials (RCTs), 51 cohort studies, one case-control, four pre-post intervention studies, three audit survey/cross-sectional studies, seven qualitative study and three economic evaluation studies. The selection of studies is showed in Figure 5.

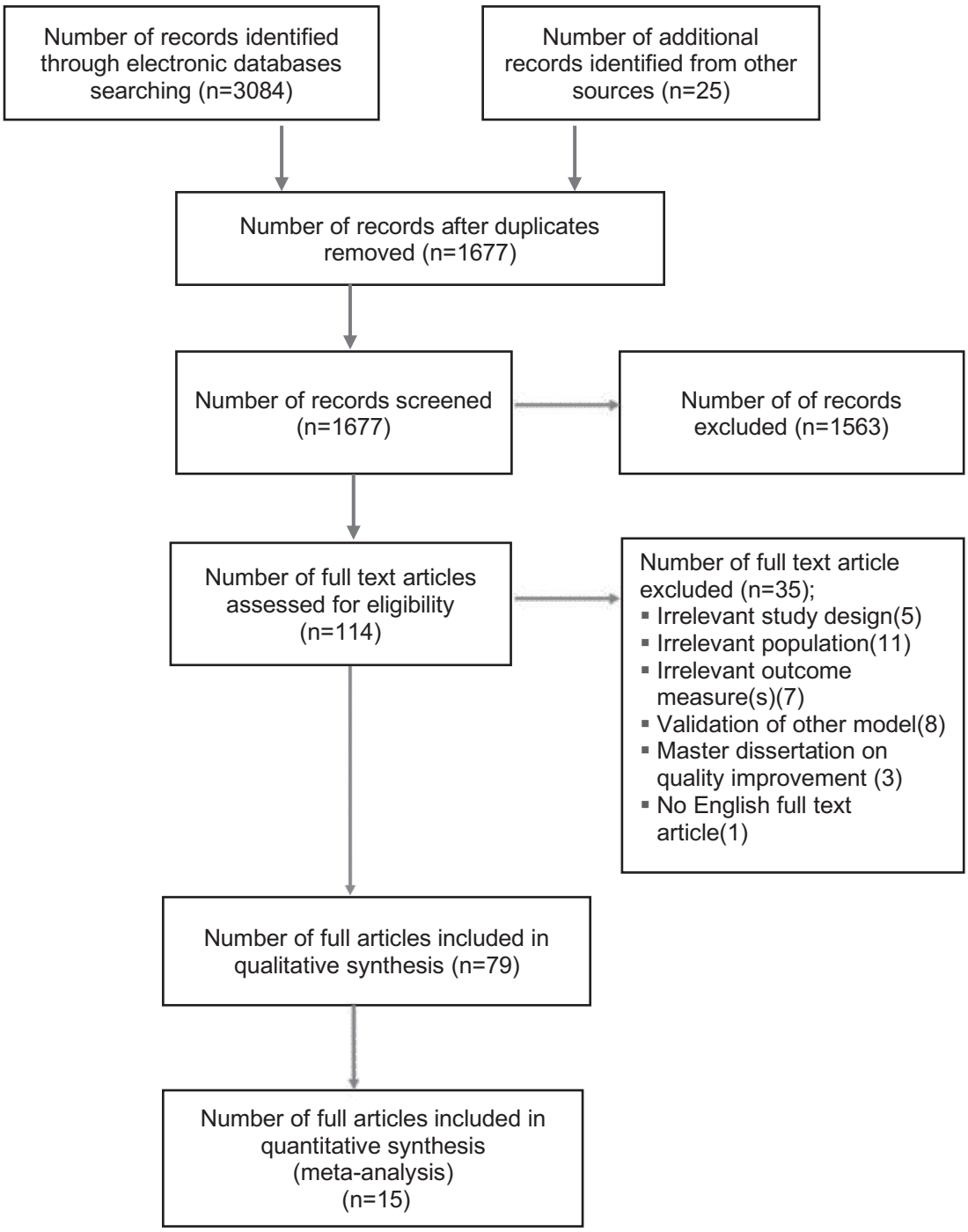


Figure 5: Flow chart of study selection

Characteristics of included studies

Setting 1 : Emergency Department								
Study (Year)	**Country**	**Study Design**	**Number of participants**	**Type of study population**	**Mean/Median* Age (years)**	**Comparator**	**Outcome Measures**	**Reported Outcome(s)**
Wuytack F et al. (2017)	Ireland	Systematic Review	48 studies; 162-1024	Heterogenous	Not reported	27 other EWSs	❖ In-hospital mortality ❖ Combined outcome of death and ICU admission	AUROC
Kivipuro et al. (2018)	Finland	Prospective cohort	1354	Heterogenous	65*	Control NEWS (low risk)/ Clinical judgement	❖ In-hospital mortality ❖ 30-day mortality	AUROC, OR
Alam et al. (2015)	Netherlands	Prospective cohort	274	Heterogenous	60	Emergency Severity Index (ESI)	❖ 30-day mortality ❖ Hospital admission ❖ ICU admission ❖ Length of stay	AUROC
Liu F et al. (2015)	China	Prospective Cohort	540	Heterogenous	65	Clinical judgement	❖ 24-hour mortality	AUROC, OR
Bilben B et al. (2016)	Norway	Prospective Cohort	246	Respiratory distressed patients	71*	Manchester Triage Scale (MTS)	❖ 90-day, 30-day ❖ and in-hospital survival ❖ 90-day mortality	AUROC, OR
Sbiti-Rohr D et al. (2016)	Switzerland	Prospective Cohort	925	Confirmed CAP	73*	PSI and CURB-65	❖ All-cause mortality within 6 years follow-up ❖ ICU admission, empyema and unplanned hospital readmission occurring within 30 days after admission	AUROC, OR
Dundar ZD et al. (2019)	Turkey	Retrospective Cohort	455	Geriatric patients	77	Lactate, NEWS-L	❖ In-hospital mortality	AUROC, sensitivity, specificity
Yuan WC et al. (2018)	China	Retrospective Cohort	621	Heterogenous	65	MEWS, APACHE II	❖ ICU admission ❖ 28-day mortality	AUROC, Sensitivity, Specificity
Lee SB et al. (2019)	Korea	Retrospective cohort	81 520	Heterogenous	64*	TREWS, MEWS, REMS	❖ 24-hour, 48-hour, 7- day and 30-day mortality	AUROC, OR
Keep JW et al. (2015)	UK	Retrospective cohort	500	Suspected severe sepsis and septic shock	47*	Manchester Triage System (MTS)	❖ Detection of at risk for severe sepsis and septic shock at ED triage	AUROC, Sensitivity, Specificity, PPV, NPV

Setting 1 : Emergency Department								
Study (Year)	**Country**	**Study Design**	**Number of participants**	**Type of study population**	**Mean/Median* Age (years)**	**Comparator**	**Outcome Measures**	**Reported Outcome(s)**
Corfield et al. (2014)	UK	Prospective cohort	2003	Sepsis patients based on SIRS criteria	72*	Control NEWS	❖ 48-hour ICU admission ❖ 30-day mortality (in-hospital) ❖ Combined endpoint of ICU admission and/or mortality	AUROC, OR
Usman OA et al. (2019)	USA	Retrospective cohort	930	Suspected sepsis	47	SIRS, qSOFA	❖ Triage detection of severe sepsis and septic shock ❖ Sepsis-related mortality ❖ All-cause mortality	AUROC, Sensitivity, Specificity
Brink A et al. (2019)	Netherlands	Retrospective cohort	8204	Suspected sepsis	57*	SIRS, qSOFA	❖ 10-day mortality ❖ 30-day mortality	AUROC, Sensitivity, Specificity
Churpek MM et al. (2017)	US	Retrospective cohort	30 677	Patients with suspicion of infection	58	MEWS, SIRS, qSOFA	❖ In-hospital mortality ❖ Composite outcome (death or ICU transfer)	AUROC, Sensitivity, Specificity
Setting 2 : General Ward								
Study (Year)	**Country**	**Study Design**	**Number of participants**	**Type of study population**	**Mean/Median* Age (years)**	**Comparator**	**Outcome Measures**	**Reported Outcome(s)**
Smith GB et al. (2013)	UK	Prospective cohort	35 585 patient episodes	Acute medical patients	68	33 other EWS	❖ Cardiac arrest, unanticipated ICU admission, death and any of the outcomes within 24 hours of admission	AUROC
Badriyah T et al. (2014)	UK	Retrospective cohort	35 585 patient episodes	Acute medical patients	68	DTEWS	❖ 24-hour mortality, cardiac arrest and unanticipated ICU admission	AUROC
Jarvis S et al. (2015)	UK	Retrospective cohort	45 678 episodes of care	General ward admission	Not reported	Control NEWS	❖ 24-hour mortality, cardiac arrest and unanticipated ICU admission	OR
Kovacs C et al. (2016)	UK	Prospective cohort	87 399 admissions (35 174 surgical admission and 52 225 medical admission)	Medical and surgical patients	Surgical - 57 Medical - 68	Clinical judgement	❖ 24-hour mortality, cardiac arrest and unanticipated ICU admission	AUROC
Abbott TEF et al. (2016)	UK	Prospective cohort	322	Heterogenous medical patients	63	Control NEWS, blood gas variables	❖ Composite mortality or critical care unit escalation within 48 hours of hospital admission ❖ Hospital length of stay	OR

Setting 2 : General Ward								
Study (Year)	**Country**	**Study Design**	**Number of participants**	**Type of study population**	**Mean/Median* Age (years)**	**Comparator**	**Outcome Measures**	**Reported Outcome(s)**
Spangfors M et al. (2019)	Denmark	Retrospective cohort	1107	Heterogenous population with deviating vital sign (NEWS ≥1)	66*	Control NEWS	❖ In-hospital mortality ❖ 30-day mortality	AUROC, OR
Spagnolli et al. (2017)	Italy	Prospective cohort	2677	Heterogenous medical patients	72*	Control NEWS	❖ In-hospital mortality ❖ Unanticipated ICU admission ❖ Combined outcome	OR
Lee YS et al. (2018)	Korea	Retrospective cohort	1300	Heterogenous	62	Clinical judgement	❖ In-hospital mortality	AUROC, Hazard ratio (HR)
Roberts D et al. (2017)	Sweden	Retrospective cohort	358	In-hospital cardiac arrest (IHCA) patients	67% aged less than 70 years old	Clinical judgement	❖ 30-day survival ❖ NEWS-aggregrate score prevalence within 12 hours before IHCA	OR
Tirkkonen J et al. (2014)	Finland	Point prevalence study	615	Heterogenous	65*	Conventional dichotomised criteria	❖ 30-day mortality ❖ 60-day mortality	OR
Eccles SR et al. (2014)	UK	Prospective cohort	196	Patient with chronic hypoxaemia	70	CREWS	❖ 30-day mortality	AUROC
Hodgson LE et al. (2017)	UK	Retrospective cohort	942	AECOPD	74*	CREWS, Salford-NEWS	❖ In-hospital mortality	AUROC, Sensitivity, Specificity PPV, NPV
Forster S et al. (2018)	UK	Retrospective cohort	6091	Patients with respiratory disease	63	Local EWS	❖ Projected workload ❖ Sensitivity and specificity in predicting mortality based on outcome within 24 hours of a score being recorded.	Sensitivity, Specificity
Grudzinska FS et al. (2019)	UK	Retrospective cohort	1545	Hospitalized community acquired pneumonia (CAP) patients	76*	CURB65, Lac-CURB-65, qSOFA score	❖ ICU admission ❖ In-hospital mortality ❖ 30-day mortality ❖ Length of inpatient stay	AUROC, sensitivity, specificity PPV, NPV,LR+, LR-
Hydes TJ et al. (2018)	UK	Retrospective cohort	4770	Liver disease patients	57	Clinical judgement	❖ 24-hour in-hospital mortality, unanticipated ICU admission, or cardiac arrest	AUROC

Setting 2 : General Ward								
Study (Year)	**Country**	**Study Design**	**Number of participants**	**Type of study population**	**Mean/Median* Age (years)**	**Comparator**	**Outcome Measures**	**Reported Outcome(s)**
Cooksley T et al. (2012)	UK	Retrospective cohort	840	Oncologic patients	63*	MEWS	❖ CCU admission ❖ 30-day mortality	AUROC
Uppanisakorn S et al. (2017)	Thailand	Prospective cohort	440	ICU discharged patients	61*	APACHE II	❖ Clinical deterioration (acute respiratory failure or circulatory shock) within 24 hour after discharge from the ICU	AUROC, sensitivity, specificity
Klepstad PK et al. (2019)	Norway	Retrospective cohort	124	Gastrointestinal surgical patients after transfer from an ICU/ HDU	66	SAPS II	❖ In-hospital mortality ❖ Readmission to ICU	OR
Chen YC et al. (2019)	Taiwan	Retrospective cohort	272	Elderly patients with MV use and successful liberation from MV and ICU (ICUmv-lib)	81	SOFA, SIRS, qSOFA	❖ Post-ICU respiratory failure before day 14 (PIRF-14) requiring reinstitution of MV	AUROC, sensitivity, specificity OR
Jarvis et al. (2015)	UK	Retrospective cohort	64,285 episodes of care	Heterogenous	62	34 other EWSs	❖ 24-hour mortality	AUROC
Zaidi H et al. (2019)	US	Retrospective cohort	28,523	ICU patients	Not reported	-	❖ Discharge location for a patient leaving the ICU.	AUROC
Abbott et al. (2015)	UK	Prospective cohort	453	Medical patients	61	PARS	❖ Composite of critical care admission or mortality within 48 hours of admission ❖ Hospital length of stay	OR
Khwannimit B et al. (2019)	Thailand	Retrospective cohort	1589	Sepsis patients	63*	MEWS, SOFA,SOS, qSOFA	❖ In-hospital mortality ❖ ICU mortality ❖ 30-day mortality ❖ Multi-organ failure	AUROC, sensitivity, specificity
Yu et al. (2014)	US	Nested case-control	328	Patient diagnosed with infection	67*	SOFA, PIRO,SCS, MEDS, MEWS, SAPS II, APACHE II, REMS	❖ 0-12 hour mortality ❖ 12-24 hour mortality ❖ 24-48 hour mortality ❖ 48-72 hour mortality	AUROC, sensitivity, specificity, OR

Setting 3 : Pre-hospital Setting

Study (Year)	Country	Study Design	Number of participants	Type of study population	Mean/Median* Age (years)	Comparator	Outcome Measures	Reported Outcome(s)
Silcock DJ et al. (2015)	UK	Retrospective cohort	1684	Heterogenous	Not reported (No access to supplementary files)	Clinical judgement	❖ 48-hour mortality ❖ 48-hour ICU admission ❖ Combined endpoint of 48-hour mortality or ICU admission ❖ 30-day mortality	AUROC, Sensitivity, Specificity, PPV, NPV, Risk ratio (RR)
Abbott TEF et al. (2018)	UK	Retrospective cohort	189	Heterogenous	61	Clinical judgement	❖ Composite of death or critical care unit escalation within 48 h of hospital admission ❖ Length of hospital stay	OR
Pirneskoski J et al. (2019)	Finland	Retrospective cohort	35 800	Medical and Trauma patients	66	Clinical judgement	❖ 24-hour , 7-day and 30-day mortality of EMS despatch	AUROC, OR
Hoikka M et al. (2018)	Finland	Prospective cohort	12 426	Heterogenous	63	Clinical judgement	❖ 24-hour and 30-day mortality	RR Sensitivity, specificiity, PPVs, NPVs, LR+, LR-
Shaw J et al. (2017)	UK	Retrospective cohort	287	Heterogenous	63	Standard clinical observation	❖ Interaction effects between initial and final NEWS scores and disposition (discharged, admitted to a ward, ITU or died)	OR
Mitsunaga T et al. (2019)	Japan	Retrospective cohort	2204	Elderly patients (>65 years old)	78	MEWS	❖ Admission and in-hospital mortality	AUROC, Sensitivity, Specificity, OR
Silcock DJ et al. (2018)	Scotland	Retrospective cohort	1713	Suspected infection	58	qSOFA	❖ 30-day mortality ❖ 48-hour ICU admission ❖ Combined endpoint of 48 h. ICU admission or 30-day mortality	AUROC, OR

NEWS 2									
Study (Year)	**Country**	**Study Design**	**Number of participants**	**Setting**	**Type of study population**	**Mean/Median* Age (years)**	**Comparator**	**Outcome Measures**	**Reported Outcome(s)**
Pimentel MAF et al. (2019)	UK	Retrospective cohort	251 266	General ward	Patient at risk or documented Type 2 Respiratory Failure (T2RF)	68*	NEWS	❖ In-hospital mortality, unanticipated ICU admission and cardiac arrest within 24 hours	AUROC
Hodgson LE et al. (2018)	UK	Retrospective cohort	2361	General ward	AECOPD	74	No comparator	❖ Number of patients reclassified to lower risk groups by NEWS2 both in those who survived and in those who died during their hospital admission.	Median and interquartile ranges
Echevarria C et al. (2019)	UK	Prospective cohort	2645	General ward	COPD	73	NEWS	❖ In-hospital mortality	AUROC, Sensitivity, Specificity, PPV, NPV
Fernando SM et al.(2019)	Canada	Retrospective cohort	5491	General ward	Patients with suspected infection	67	HEWS	❖ In-hospital mortality ❖ Number needed to examine (NNE)	AUROC, Sensitivity, Specificity
Mellhammar L et al. (2019)	Sweden	Retrospective cohort	843	Emergency Department	Patients with suspected infection	Cohort A – 70 Cohort B - 76	qSOFA	❖ Composite outcome of sepsis with organ dysfunction ❖ Infection-related mortality and intensive care due to an infection within 72 hours	AUROC, Sensitivity, Specificity
Martin-Rodriguez F et al. (2019)	Spain	Prospective cohort study	1054	Pre-hospital setting	Heterogenous	68*	Clinical judgement	❖ Mortality from any cause within 48 hours, stratified by the level of hospital triage assigned in the ED. ❖ 7-day and 30-day mortality	Sensitivity, Specificity, PPV, NPV, LR+, LR-
Martin-Rodriguez F et al. (2019)	Spain	Prospective cohort study	349	Pre-hospital setting	Heterogenous	66	EWS, MEWS, ViEWS,HEWS, SEWS	❖ 48-hour mortality	AUROC, Sensitivity, Specificity, LR+,LR-

Risk of bias assessment

+	Indicates YES (low risk of bias)
?	Indicates UNKNOWN risk of bias
-	Indicates NO (high risk of bias)

Assessment for Systematic Review Using Critical Appraisal Skills Programme (CASP) Checklist

Criteria assessed	Author look for appropriate paper?	Selection of studies (all relevant studies included?)	Assessment of quality of included studies?	If the results of the review have been combined, is it reasonable to do so (heterogeneity)?
EFFECTIVENESS: EMERGENCY DEPARTMENT				
Wuytack F et al.[45]	+	+	+	+
SAFETY				
HTA HIQA [28]	+	+	+	+
ORGANISATIONAL ISSUES				
Smith ME et al.[17]	+	+	+	+

Figure 6: Summary of risk of bias assessment for systematic review

Assessment for Randomised Controlled Trial Using Cochrane Collaboration Tools

Criteria assessed	Adequate sequence generation	Allocation concealment	Blinding of participants and personnel	Incomplete outcome data addressed	Free of selective reporting	Free of other bias
EFFECTIVENESS: HEALTH OUTCOME						
Haegdorens F et al.[90]	+	?	?	+	+	+
ORGANISATIONAL ISSUES						
Liaw SY et al. [98]	+	+	?	+	+	+
Cornish L et al.[101]	+	?	-	+	+	?
Fung et al.[102]	+	?	-	+	+	+
Christofidis MJ et al.[103]	+	?	-	+	+	+
Christofidis MJ et al.[104]	+	?	-	+	+	+
Christofidis MJ et al.[105]	+	?	-	+	+	+

Figure 7: Summary of risk of bias assessment for Randomised Controlled Trial Assessment for Before-After (Pre-Post) Studies With No Control Group Using NIH Quality Assessment Tool

Criteria assessed	Question or objective clearly stated?	Eligibility/selection criteria for study population clearly described?	Were participants representative for those who would be eligible for the test/ service/ intervention in the population of interest?	Were all eligible participants that met the prespecified entry criteria enrolled?	Sample size sufficiently large to provide confidence in findings?	Test/service/intervention clearly described and delivered consistently?	Outcome measures prespecified, valid, reliable, and assessed consistently?	People assessing the outcome measures blinded to participants exposure/ interventions?	Loss to follow-up after baseline 20% or less? Loss to follow-up accounted for in the analysis?	Statistical methods examine changes in outcome measures from before to after intervention? p value?	Outcome measures taken multiple times before and after intervention? Use interrupted time-series design	If intervention conducted at group level, did statistical analysis take into account of individual level data to determine effects at group level?
EFFECTIVENESS: CLINICAL OUTCOME												
Farenden S et al.[92]	+	+	+	+	?	+	+	-	?	+	+	+
Sutherasan Y et al.[93]	+	+	+	+	+	+	+	-	+	+	+	+
ORGANISATIONAL ISSUES												
Merriel A et al. [100]	+	+	+	+	+	+	+	?	+	+	+	+
Mestrom E et al. [106]	+	+	+	+	?	+	+	?	+	+	+	+

Figure 8: Summary of risk of bias assessment for Pre-Post Intervention Studies

Assessment for Cohort Studies Using Critical Appraisal Skills Programme (CASP) Checklist

Criteria assessed	Selection of cohort	Exposure accurately measured	Outcome accurately measured	Confounding factors	Follow-up of subjects
EFFECTIVENESS: EMERGENCY DEPARTMENT					
Kivipuro et al.[39]	+	+	+	+	+
Alam et al. [40]	+	+	+	?	+
Liu F et al.[41]	+	+	+	+	+
Bilben B et al.[42]	+	+	+	+	+
Sbiti-Rohr D et al.[43]	+	+	+	+	+
Dundar ZD et al.[44]	+	+	+	?	+
Yuan WC et al.[46]	+	+	+	?	+
Lee SB et al.[47]	+	+	+	+	+
Keep JW et al.[48]	+	+	+	?	+
Corfield et al.[49]	+	+	+	+	+
Usman OA et al.[50]	+	+	+	?	+
Brink A et al.[51]	+	+	+	+	+
Churpek MM et al.[52]	+	+	+	?	+
EFFECTIVENESS: GENERAL WARD					
Smith GB et al. [53]	+	+	+	?	+
Badriyah T et al.[54]	+	+	+	?	+

Criteria assessed	Selection of cohort	Exposure accurately measured	Outcome accurately measured	Confounding factors	Follow-up of subjects
EFFECTIVENESS: EMERGENCY DEPARTMENT					
Jarvis S et al. [55]	+	+	+	?	+
Kovacs C et al.[56]	+	+	+	?	+
Abbott TEF et al.[36]	+	+	+	+	+
Spangfors M et al.[57]	+	+	+	?	+
Spagnolli et al.[58]	+	+	+	?	+
Lee YS et al. [59]	+	+	+	+	+
Roberts D et al.[60]	+	+	+	+	+
Eccles SR et al.[62]	+	+	+	?	+
Hodgson LE et al.[63]	+	+	+	?	+
Forster S et al.[64]	+	+	+	+	+
Grudzinska FS et al.[65]	+	+	+	?	+
Hydes TJ et al[66]	+	+	+	?	+
Cooksley T et al.[67]	+	+	+	+	+
Uppanisakorn S et al.[68]	+	+	+	+	+
Klepstad PK[69]	+	+	+	+	+
Chen YC et al.[70]	+	+	+	+	+
Jarvis et al. [72]	+	+	+	?	+
Zaidi H et al.[71]	+	+	+	+	+
Abbott et al.[73]	+	+	+	+	+
Khwannimit B et al.[75]	+	+	+	?	+

Criteria assessed	Selection of cohort	Exposure accurately measured	Outcome accurately measured	Confounding factors	Follow-up of subjects
EFFECTIVENESS: PRE-HOSPITAL SETTING					
Silcock DJ et al.[76]	+	+	+	+	+
Abbott TEF et al.[77]	+	+	+	+	+
Pirneskoski J et al.[78]	+	+	+	+	+
Hoikka M et al.[79]	+	+	+	?	+
Shaw J et al.[80]	+	+	+	+	+
Mitsunaga T et al.[81]	+	+	+	+	+
Silcock DJ et al.[82]	+	+	+	?	+
EFFECTIVENESS: NEWS2					
Pimentel MAF et al.[83]	+	+	+	?	+
Hodgson LE et al.[84]	+	+	+	?	+
Echevarria C et al.[85]	+	+	+	+	+
Fernando SM et al.[86]	+	+	+	+	+

Mellhammar L et al.[87]	+	+	+	+	+
Martin-Rodriguez F et al.[88]	+	+	+	?	+
Martin-Rodriguez F et al.[89]	+	+	+	+	+
SAFETY					
Kolic I et al. [95]	+	+	+	+	+
Petersen JA et al.[96]	+	+	+	?	+

Figure 9: Summary of risk of bias assessment for Cohort Studies

Assessment for Case-Control Studies Using Critical Appraisal Skills Programme (CASP) Checklist

Criteria assessed	Selection cases and control	Exposure accurately measured	Confounding factors
EFFECTIVENESS: GENERAL WARD			
Yu et al.[74]	+	+	+

Figure 10: Summary of risk of bias assessment for Case Control Studies

6.2 Effectiveness

6.2.1 Discriminative Ability and Predictive Validity

Emergency Department

Kivipuro M et al (2018) investigated the performance of NEWS to predict in-hospital and 30-day mortality among a heterogeneous cohort of 1354 patients in a large tertiary referral center's multidisciplinary ED.[39] level II-2 In this prospective cohort study, the patients were followed up after admission to the general wards. The NEWS and outcome of the patients were compared among those patients admitted to ICU directly from ED (EDICU), triaged from ED to general ward with subsequent ICU admission within 72 hours (EDwardICU) and those who did not require intensive care during their first 72 hours of hospital stay following general ward admission (EDward). A higher ED-NEWS was associated with in-hospital mortality (OR 1.26, 95%CI 1.11,1.42; AUROC 0.75, 95%CI 0.64,0.86, p<0.001) and 30-day mortality (OR 1.27, 95%1.17,1.39; AUROC 0.78, 95%CI 0.71,0.84, p<0.001) irrespective of age and comorbidity. There were 64 patients in EDICU group, 12 patients in EDwardICU group and 1,278 patients in EDward group with median ED-NEWSs of 7, 3 and 2 (p< 0.001), respectively. After the first 24 hours in wards, median NEWSs of the EDwardICU patients had substantially increased as compared with EDward patients (6 vs. 2, p< 0.001). There were no statistical differences in last NEWS before ICU admission between the EDICU and EDwardICU patients (7 vs. 8, p = 0.534), or in ICU severity-of-illness scores or patient outcomes. The ability of NEWS to discriminate between survivors and non-survivors was acceptable.[39] level II-2

The performance of NEWS in emergency department (ED) was studied by Alam N et al. (2015) using a prospective cohort design and the authors found that among adult patients presenting at the ED, the NEWS score measured at different time points could further risk stratify ED patients within higher Emergency Severity Index (ESI) risk categories, for hospital admission, death and need for Intensive Care Unit (ICU)

admission.[40 level II-2] The three time points were arrival at ED (T0), one hour after arrival at the ED (T1) and at transfer to hospital ward or ICU when applicable (T2). The AUROCs (95%CI) for NEWS for hospital admission at T0, T1, T2 was respectively 0.664 (95%CI 0.599, 0.728), 0.687 (95%CI 0.620, 0.754), 0.697 (95%CI 0.609,0.786). The AUROCs (95%CI) for NEWS for 30 day mortality at T0, T1 and T2 was respectively 0.768 (95%CI 0.618, 0.919), 0.867 (95%CI 0.769, 0.964), 0.767 (95%CI 0.568, 0.966). Length of stay and ICU admission were significantly correlated with NEWS, at all of the measured time points. Median length of stay more than doubled for a score more than seven compared with a score of 0–4. Sixteen percent of patients with aggregate scores of seven or more was admitted to ICU as compared to 2.3% of patients who had an aggregate score of 0–4. The NEW score could be used to longitudinally monitor patients throughout their stay in the ED and in the hospital.[40 level II-2]

In the Chinese context, Liu et al. (2015) demonstrated NEW scores of seven or more were associated with increased risk of death (OR=16.8; 95%CI 6.6,42.9).[41 level II-2] Data on 540 consecutive Emergency ICU (EICU) patients were collected in a single centre prospective cohort study. The AUROC for death within 24 hours of admission was 0.848 (95%CI 0.792, 0.902, p<0.001). The discriminative ability of NEWS was good for patients with neurological, cardiovascular and respiratory diseases. [41 level II-2] (Table 1)

Table 1: AUROCs for NEWS ability to predict 24 hours mortality among people with different primary diseases.

Primary Disease	n	AUROC (95% CI)	P value
Neurological	188	0.873 (0.796-0.951)	0.000
Cardiovascular	176	0.874 (0.780-0.967)	0.000
Respiratory	70	0.870 (0.765-0.975)	0.001
Gastrointestinal	45	0.576 (0.135-1.000)	0.720

A cohort study by Bilben B et al. (2016) evaluated the effectiveness of NEWS in adult patients emergently presenting in a Norwegian ED with respiratory distress as main symptom.42 The authors wanted to investigate the correlation between NEWS and disease severity and hospital resource use in this population of patients. It was reported that NEWS correlated closely with triage category and maximum in-hospital level of care (ED, ward, high-dependency unit, ICU). (Figure 11) Controlled for age, ASA score (comorbidities status), and COPD, a higher NEWS (NEWS ≥ 5) on ED arrival predicted poorer 90-day survival (17% deaths) (OR 0.835, 95%CI 0.725–0.954). The AUROCs for NEWS for 90-day mortality on ED arrival was 0.809. Increased NEWS (NEWS ≥ 5) also correlated with decreased in-hospital and 30-day survival (6.5% and 11% deaths respectively) and a decreased probability for home-dwelling patients to be discharged directly home (Figure 12).[42 level II-2]

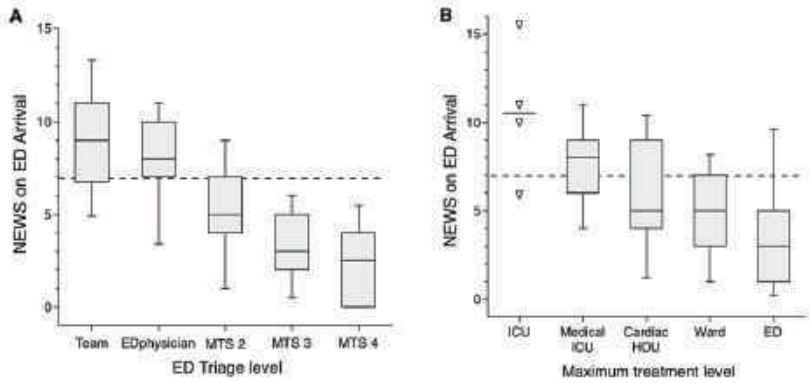


Figure 11: National Early Warning Score (NEWS) calculated on ED arrival versus A Manchester Triage Scale category (MTS) (MTS1 immediate-red; MTS2 very urgent_orange; MTS3 urgent_yellow; MTS4 standard_green; MTS5 non-urgent_blue) and B Maximum level of care during hospital stay, in 246 patients presenting with respiratory distress. Boxes comprise 25th–75th percentiles with median value shown, whiskers display 10th and 90th percentiles.

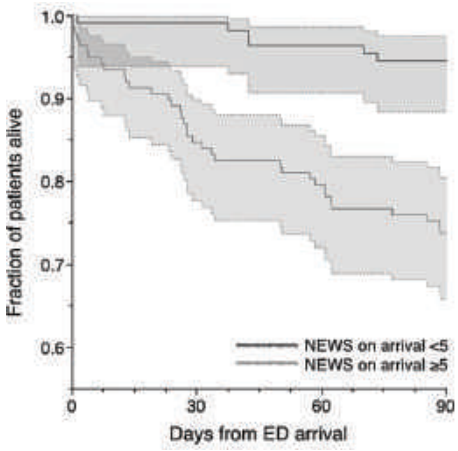


Figure 12: Survival plot of patients presenting in the ED with respiratory distress, 109 patients with NEWS <5 (blue line) on arrival and 137 patients with NEWS ≥5 (red line). Shaded areas display 95 % confidence areas. A higher NEWS value on ED arrival was associated with decreased long-term survival.

In the 6-year multicentre retrospective cohort study involving a large population of adult patients (n=925) with community-acquired pneumonia (CAP) from six tertiary care ED, Sbiti-Rohr D et al. (2016) investigated the accuracy of the NEWS to predict all-cause mortality and adverse clinical outcomes [intensive care unit (ICU) admission, empyema and unplanned hospital readmission all occurring within 30 days after admission].[43 level II-2] For the 30-day mortality, an increase in NEWS category was associated with a 16% increase in odds for reaching the event (OR 1.16, 95% 1.07,1.27, p=0.001). However, NEWS showed a low mortality discrimination with AUROC 0.65 (95%CI 0.58,0.72). Combining NEWS with standard CAP risk scores; pneumonia severity index (PSI) or CURB-65 in a statistical model did not improve the prognostic performance. For adverse clinical outcomes, NEWS was a moderate predictor, particularly ICU admission [OR 1.29 (95%CI 1.20,1.39)], and to a lesser degree for empyema [OR 1.16 (95%CI 1.04,1.29)] within 30 days after admission in patients presenting with CAP to the ED. It did not well predict rehospitalisation within 30 days of initial admission. The NEWS AUROC for ICU admission, empyema and rehospitalisation were 0.73 (95%CI 0.67, 0.78), 0.64 (95%CI 0.54,0.73) and 0.58 (95%CI 0.49, 0.66), respectively.[43 level II-2]

Dundar ZD et al (2019) conducted a retrospective cohort study and reported a poor predictive performance of NEWS for in-hospital mortality among critically ill geriatric ED patients (65 years of age or older); AUROC 0.686 (95%CI 0.628, 0.744).[44 level II-2] Combination of NEWS and the first lactate level measured in ED (NEWS-L) improved the prognostic power [AUROC 0.714 (95% CI 0.658, 0.770) however NEWS-L still not a powerful predictor to make definitive clinical decisions for critically ill geriatric ED patients.[44 level II-2]

Comparison with other established EWS or track and trigger system (TTS)

Wuytack F et al. (2017) in a systematic review of 47 studies revealed that there were 28 different EWS been used in ED worldwide.[45 level I] National Early Warning Score ranked sixth, behind The Resuscitation Management score (THERM), the Worthington EWS, MEES (Mainz Emergency Evaluation Score), PEDS (Prince of Wales Emergency Department Score) and Modified Early Warning Score (MEWS) in predicting the composite output of ICU admission or death of critically ill ED patients. Overall, PEDS, VIEWS-L and NEWS scores appeared relatively better at predicting mortality, providing excellent discrimination ability (AUROC ≥ 0.8). Finding suggested MEWS had a relatively lower ability to predict mortality compared to the four scores mentioned above, with only some studies indicating acceptable discriminatory ability (AUROC >0.7) and other studies indicating a lack of discriminatory ability (AUROC <0.7). The exception was one study that found excellent discriminatory ability of MEWS for the outcome in-hospital mortality (AUROC 0.89).[45 level I] (Table 2)

Table 2: Type of EWS and their predictive values in heterogenous ED population

EWS assessed	AUROC by outcome
	Combined outcome of death and ICU admission
THERM	0.84 (95% CI 0.79,0.88)
Worthing	0.78 (95% CI 0.72,0.83)
MEWS	0.76-0.73 (95% CI 0.71-0.67,0.81-0.79)
MEES	0.75 (95% CI 0.69,0.80)
PEDS	0.75 (95% CI 0.69,0.80)
NEWS	0.71 (95% CI 0.64,0.76)
REMS	0.70 (95% CI 0.64,0.76)
SCS	0.70 (95% CI 0.64,0.76)
MEDS	0.59 (95% CI 0.52.0.6)
	Mortality
PEDS	0.90 (95% CI 0.86,0.93)
NEWS	0.87-0.77 (95% CI 0.77-0.57,0.96-0.97)
VIEWS-L	0.83 (95% CI 0.77,0.91)
MEWS	0.89-0.63 (95% CI 0.84-0.61,0.94-0.65)
RTS	0.77 (95% CI 0.72,0.81)
REMS	0.77-0.70 (95% CI 0.72-0.64,0.82-0.75)

Abbreviations: THERM = The Resuscitation Management score, MEWS = Modified Early Warning Score, MEES = Mainz Emergency Evaluation Score, PEDS = Prince of Wales Emergency Department Score, REMS = Rapid Emergency Medicine Score, SCS = Simple Clinical Score, MEDS = Mortality in the Emergency Department Sepsis score, ViEWS-L = Vitalpac Early Warning Score combined with lactate, RTS = Revised Trauma Score.

A retrospective cohort study conducted by Yuan WC et al. (2018) sought to compare the predictive performance of NEWS with MEWS and the Acute Physiology and Chronic Health Evaluation (APACHE) II for predicting disease progression and prognosis.46 level II-2 A total of 621 cases from ED resuscitation room was included in the final analysis, which comprised of 258 cases with neurological disease (18.8%), 117 cases with cardiovascular disease (18.8%), 95 cases with respiratory disease (15.4%), 67 cases with digestive diseases (10.8%), 46 cases with urinary system disease (7.4%) and 38 cases of others and unknown diseases (6.1%). There were 563 cases of survivors (91%) and 58 cases of non-survivors (9%). The probability of ICU admission and mortality of patients significantly increase with the increased NEWS, MEWS and APACHE II scores ($p<0.01$). The predictive ability of NEWS for ICU admission was lower (AUROC 0.760; sensitivity 58.7%, specificity 79.3%) than the APACHE II score (AUROC 0.817; sensitivity 76.1%, specificity 74.1%), but higher than MEWS (AUROC 0.729; sensitivity 64.5%, specificity 68.7%). The study also reported similar performance result for the 28-day mortality prediction among heterogenous ED patients; APACHE II (AUROC 0.883; sensitivity 81.0%, specificity 78.0%), NEWS (AUROC 0.827; sensitivity 84.5%, specificity 66.7%) and MEWS (AUROC 0.723, sensitivity 56.9%, specificity 79.4%).[46] level II-2

Lee SB et al. (2019) using a retrospective cohort study, compared the prognostic performance of NEWS with Triage in Emergency Department Early Warning Score (TREWS), Modified Early Warning Score (MEWS) and Rapid Emergency Medicine Score (REMS).[47 level II-2] This seven years cohort study, involving 81 520 adult ED patients (≥ 16 years old), aimed to assess the prognostic power for in-hospital mortality within 24 hours, 48 hours, seven days and 30 days of arrival at the ED. National Early Warning Score showed superior performance in predicting in-hospital mortality compared to MEWS and REMS, but inferior to TREWS for patients arriving at the ED as shown in Table 3.[47 level II-2]

Table 3: Comparison of the NEWS, TREWS, MEWS and REMS

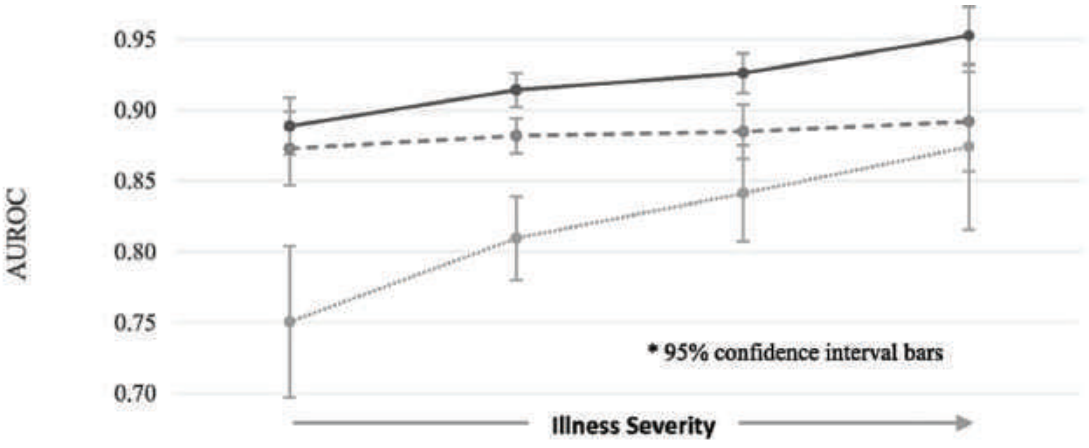
Mortality Outcomes	AUROC	95%CI
Mortality within 24hours		
TREWS	0.910	(0.907 - 0.914)
NEWS	0.884	(0.880 - 0.888)
MEWS	0.865	(0.861 - 0.869)
REMS	0.825	(0.820 - 0.829)
Mortality within 48hours		
TREWS	0.899	(0.895 - 0.903)
NEWS	0.874	(0.870 - 0.878)
MEWS	0.851	(0.846 - 0.855)
REMS	0.815	(0.810 - 0.819)
Mortality within 7 days		
TREWS	0.876	(0.872 - 0.880)
NEWS	0.848	(0.844 - 0.853)
MEWS	0.820	(0.815 - 0.825)
REMS	0.787	(0.782 - 0.792)
Mortality within 30 days		
TREWS	0.832	(0.828 - 0.837)
NEWS	0.813	(0.808 - 0.818)
MEWS	0.779	(0.774 - 0.784)
REMS	0.748	(0.742 - 0.753)

NEWS and sepsis in Emergency Department (ED)

In the retrospective, single-centre cohort study conducted by Keep JW et al. (2015) in a high volume ED in London, an aggregate NEWS score of ≥3 performed best for the identification of patients with severe sepsis and septic shock.[48 level II-2] For the identification of a patient at risk of severe sepsis and septic shock; NEWS AUROC =0.89 (95%CI 0.84, 0.94)[NEWS ≥3: Sensitivity=92.6%, Specificity=77%, PPV=18.7%, NPV=99.5% for sepsis; NEWS ≥4, Sensitivity=74.1%, Specificity=86.5%, PPV=23.8%, NPV=98.3%]. Authors noted that a NEWS ≥3 at ED triage may be the trigger to systematically screen for septic shock, obtain an early serum lactate and where appropriate start fluid resuscitation and antibiotic therapy.[48 level II-2]The use of NEWS in patients (n=2003) with sepsis in the ED (n=20 Scottish EDs) was evaluated by Corfield et al. (2014) in prospective cohort study, revealing an association between increased NEW scores on arrival and adverse outcomes (intensive care unit referral and mortality).[49 level II-2] The authors noted that for each rise in NEWS category there was an associated increased risk of mortality when compared to the lowest category: for 30-day mortality, the age-adjusted ORs for NEWS categories compared to the baseline category (≤4) 5–6: OR 1.95, 95%CI 1.21, 3.14 (p=0.01); 7–8: OR 2.26, 95%CI 1.42, 3.61 (p<0.00); 9–20: OR 5.64, 95%CI 3.70, 8.60 (p<0.00). The predictive ability of NEWS for 30-day in-hospital mortality were AUROC NEWS: 0.70 (95%CI 0.67, 0.74) and AUROC age-adjusted NEWS: 0.73 (95%CI 0.70, 0.76). For ICU admission within 48 hours the age-adjusted ORs for NEWS categories compared to the baseline category (≤4) 5–6: OR 1.22, 95%CI 0.59, 2.54 (p=0.59); 7–8: OR 2.01, 95%CI 1.02, 3.97 (p=0.04); 9–20: OR 5.76, 95%CI 3.22, 10.31 (p<0.01). The predictive values for ICU admission within 48 hours of attendance were AUROC NEWS: 0.67 (95%CI 0.61, 0.72) and AUROC age-adjusted NEWS: 0.61 (95%CI 0.56, 0.67). The NEWS AUROC characteristics for the combined endpoint of ICU and/or mortality were NEWS: 0.70 (95%CI 0.67, 0.73); AUROC age-adjusted NEWS: 0.71(95%CI 0.68,0.74). The positive predictive value illustrates that 27% of patients with a NEWS of 7 were admitted to the ICU within 2 days and/or died within 30 days. For a NEWS of 9 this rose to 35%. The use of NEWS could facilitate patient pathways to ensure triage to a high acuity area of the ED and senior clinician involvement at an early stage.[49 level II-2]

The predictive ability of NEWS for severe sepsis and septic shock in ED triage setting was compared to Systemic Inflammatory Response Syndrome (SIRS) and quick Sepsis-related Organ Failure Assessment (qSOFA) in two retrospective cohort studies. Based on data analysis of 930 ED septic patients in an urban, US tertiary-care academic center, Usman OA et al. (2019) found that NEWS was most accurate for triage detection of severe sepsis and septic shock (AUROC=0.9, 0.88, 0.81), septic shock (AUROC=0.93, 0.88, 0.84), and sepsis-related in-hospital mortality (AUROC=0.95, 0.89, 0.87) for NEWS, SIRS, and qSOFA, respectively (p<0.01 for NEWS versus SIRS and qSOFA) (Figure 13).50 level II-2 The sensitivity of NEWS≥4, SIRS≥2 and qSOFA≥2 to detect severe sepsis and septic shock were 84.2% (95%CI 81.5, 86.5%), 86.1% (95%CI 83.6, 88.2%), and 28.5% (95%CI 25.6, 31.7%) and specificities were 85.0% (95%CI 84.8, 85.3%), 79.1% (95%CI 78.9, 79.3%), and 98.9% (95%CI 98.8, 99.0%), respectively.50 Based on the studied institution's volume and sepsis prevalence, for the detection of severe sepsis and septic shock relative to NEWS (cutoff ≥4), qSOFA (cutoff ≥2) would have missed approximately five positive cases per week and SIRS (cutoff ≥2) would have inappropriately flagged approximately nine cases per day. The authors also found that table-based aggregate weighted systems, such as NEWS, were more predictive and robust compared with tally-based single parameter scores such as qSOFA and SIRS. National Early Warning Score may offer scoring flexibility relative to SIRS and qSOFA by allowing for the creation of multiple severity categories. Patients flagged as "moderate risk" (NEWS between 4-8) may suggest obtaining a lactic acid, whereas patients flagged as "high risk" (NEWS≥9) may benefit from the rapid mobilization of bundled resources and early ICU consultation.50 A Dutch study by Brink A et al. (2019) using a larger population of participants (n=8204) evaluated the predictive performance of NEWS for 10-day and 30-day mortality after ED presentation.51 level

II-2 The similarity of findings with US study was seen whereby NEWS outperformed qSOFA and SIRS in predicting in-hospital mortality; 10-day mortality [AUC (95% CI): 0.837 (0.812, 0.861), 0.744 (0.708, 0.78) and 0.646 (0.613, 0.679) respectively] and 30-day mortality [0.779 (0.755, 0.804), 0.697 (0.667, 0.726) and 0.631 (0.605, 0.656) respectively].[51 level II-2] The study, similarly also reported qSOFA showed the highest specificity, followed by NEWS and SIRS. Sensitivity was highest in SIRS, followed by NEWS and qSOFA. However, in contrast with US study, the cut-off value of ≥7 for NEWS was used in this study.



	Severe Sepsis excluding Septic Shock	Severe Sepsis including Septic Shock	Septic Shock	Sepsis-related Mortality
SIRS	0.87	0.88	0.88	0.89
qSOFA	0.75	0.81	0.84	0.87
NEWS	0.89	0.91	0.93	0.95

Figure 13: Prediction Across Disease Severity

A retrospective cohort study conducted by Churpek MM et al. (2017) did similar comparison with NEWS and in addition, MEWS was also included as one of the comparators.[52 level II-2] The study included 30 677 patients whereby 60% first met the suspicion of infection criteria in the ED. Suspected infection was defined as either (1) any culture order followed by an intravenous (IV) antibiotic within 72 hours or (2) an IV antimicrobial followed by a culture order within 24 hours. The time of the culture order or IV antimicrobial administration was denoted as the time of suspicion of infection, whichever came first. Discrimination for in-hospital mortality and composite outcome (death or ICU stay) were evaluated. The relationship among the scores was also compared between ward and ED subgroups. The accuracy in predicting in-hospital mortality was highest for NEWS (AUROC 0.77; 95%CI 0.76, 0.79), followed by MEWS (AUROC 0.73; 95%CI 0.71, 0.74), qSOFA (AUROC 0.69; 95%CI 0.67,0.70), and lowest for SIRS (AUROC 0.65; 95%CI 0.63, 0.66) ($p < 0.01$ for all pairwise comparisons).52 For those who experienced the composite outcome (death or ICU stay; n = 7 385), the median time to the outcome after time of first suspicion of infection was 14 hours [interquartile range, (IQR)6–66 hours], and 71% of patients who experienced the composite outcome did so within 48 hours. Using the highest non-ICU score of patients, NEWS ≥8 had a sensitivity of 67% and specificity of 66% for the composite outcome compared with 59% and 70% for MEWS ≥5, 91% and 13% for SIRS≥2, 54% and 67% for qSOFA ≥2, respectively. The relationship among the scores was consistent when comparing the ward and ED subgroups, with the AUCs being slightly lower on the wards.[52 level II-2] (Figure 14)

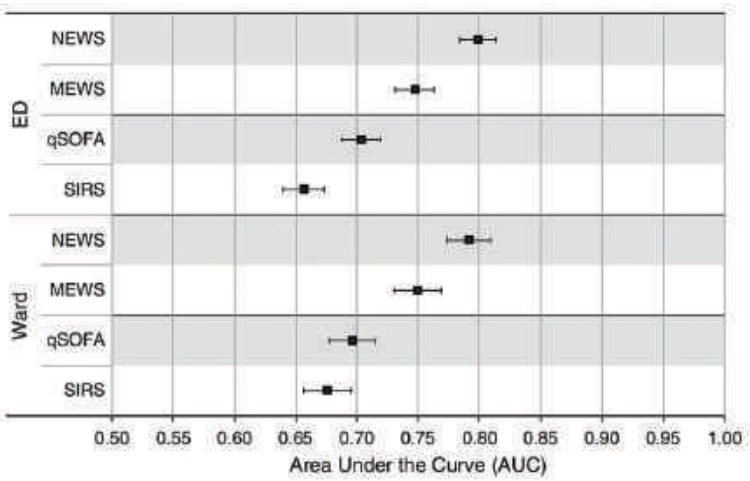
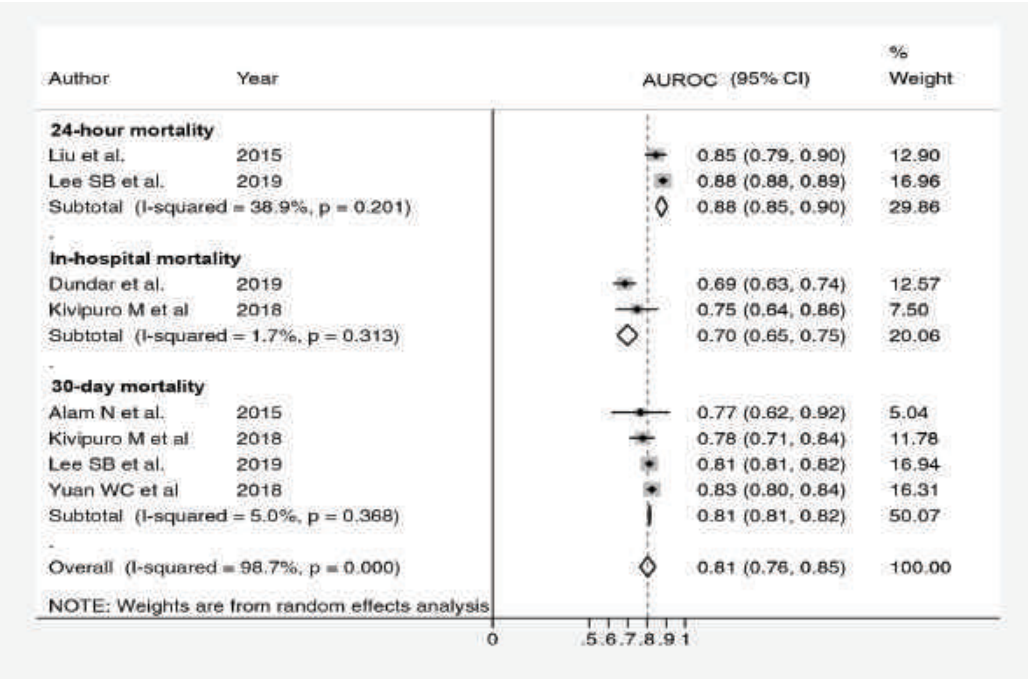


Figure 14: Discrimination of the different algorithms for predicting in-hospital mortality using each patient's highest score by location (solid squares represent point estimates, and error bars represent 95% confidence intervals). ED = emergency department; MEWS = Modified Early Warning Score; NEWS = National Early Warning Score; qSOFA = quick Sepsis -related Organ Failure Assessment; SIRS = Systemic Inflammatory Response Syndrome.

Weighted pooled result for mortality outcomes

The pooled AUROC values for NEWS showed good discriminative power for 24 hours mortality [AUROC 0.88 (95%CI 0.85,0.90), I^2 38.9%], in-hospital mortality [AUROC 0.70 (95%CI 0.65,0.75), I^2 1.7%) and 30-day mortality for heterogenous [AUROC 0.81 (95%CI 0.81,0.82), I^2 5%) population of ED patients. (Figure 15) High heterogeneity was observed when we pooled studies involving suspected infection or sepsis population with studies from heterogenous population. Hence we decided not to include these studies in our final analysis.



Test for overall effect Z=39.15, p<0.001

Figure 15: The pooled estimate of AUROC values for 24-hour mortality, in-hospital mortality and 30-day mortality for heterogenous ED population

General ward

In a prospective cohort study, Smith GB et al. (2013) used a large vital signs database (n=198,755 observation sets) collected from 35,585 consecutive, completed acute medical admissions to evaluate the NEWS: heart rate; diastolic and systolic blood pressure; respiratory rate; oxygen saturation; temperature; and mental status using the Alert-Verbal-Painful-Unresponsive (AVPU) scale or the Glasgow Coma Score (GCS).[53] level II-2 The NEWS score had an AUROC of 0.894 (95%CI 0.887, 0.902), 0.857 (95%CI 0.847, 0.868) and 0.722 (95%CI 0.685, 0.759) as a predictor of death, cardiac arrest and unanticipated ICU admission, respectively, within 24 hours of the observed score. This study did not report sensitivity at different specificities or show the AUROC curve for death, cardiac arrest and unanticipated ICU admission to estimate these data. However, as an example of the risk for a false positive, approximately 97% of patients with a NEWS value of 8 (of 20 possible points) did not die with 24 hours.[53] level II-2

For validation of NEWS among medical patients, Badriyah T et al. (2014) used Decision-Tree analysis to construct a decision-tree EWS (DTEWS) from a database of 198,755 vital signs observation sets collected from 35,585 consecutive, completed acute adult (>16 years) medical admissions within 24 hours of a given vital sign observation.[54] level II-2 The outcomes of DTEWS and NEWS were similar for mortality, cardiac arrest and unanticipated ICU admission: NEWS AUROC=0.894 (95%CI 0.88, 0.902), 0.722 (95%CI 0.685,0.759), 0.857 (0.847, 0.868); DTEWS AUROC=0.899 (95% CI 0.982, 0.907). 0.708 (0.669, 0.747), 0.862 (0.852, 0.872), respectively. The decision-tree technique independently validates the composition and weightings of NEWS (Figure 16).[54] level II-2

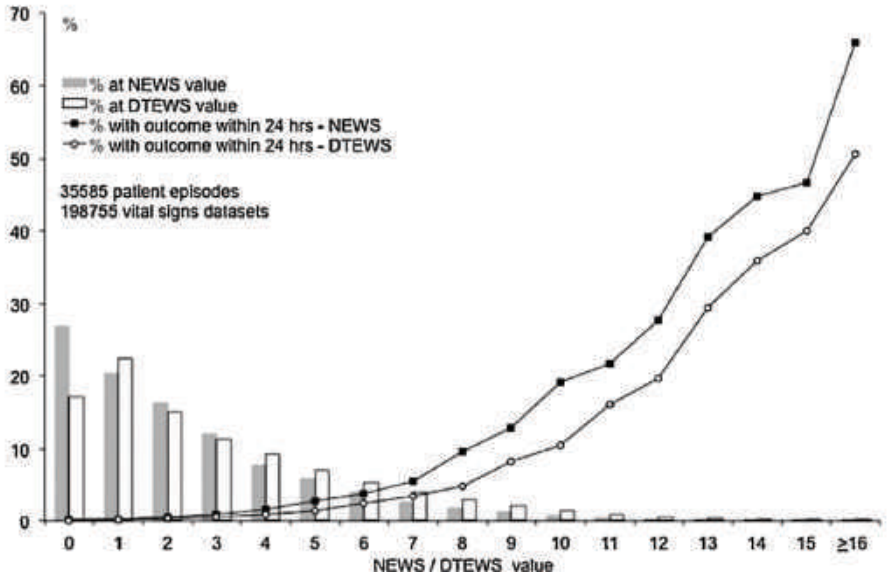


Figure 16: The "EWS efficiency curve", distribution of DTEWS and NEWS values, and their relationships to the primary outcome of cardiac arrest, unanticipated intensive care unit admission or death, each within 24 hours of a given vital signs. This compares the number of "triggers" that are generated at different values of DTEWS and NEWS. It demonstrates that the curves for DTEWS and NEWS are almost identical in shape and position; however the individual EWS values are positioned differently along their efficiency curves. For instance, the detection of 83% of those who will die within 24 hours of a given EWS value requires a response to only 25% of either DTEWS or EWS values. However to achieve this, the trigger point for DTEWS must be 5, whilst that for NEWS must be 4.

Jarvis S et al. (2015a) in a retrospective cohort study, using 10 000 observation sets randomly selected for analysis of the 24 hours risk of serious clinical outcomes (death, cardiac arrest and unanticipated ICU admission).[55] level II-2 The study found for all outcomes, an aggregate NEWS score of 5 was associated with a significantly higher risk than that of an aggregate score of 3 (with single vital sign scoring of 3); risk of death and any adverse outcome was significantly higher for a NEWS score of 5 than an aggregate score of 4 or 3 (with single vital sign scoring 3). Odds of adverse outcomes increased (almost doubled) with each increase of 1 point in the aggregate NEWS scores. Where a single vital sign had a score of 3, the odds increased, but not significantly. (Table 4) (Figure 17) Authors noted that escalation of care to a doctor when any component of NEWS scores 3 compared to when aggregate NEWS values ≥5, would have increased doctors workload by 40% with only a small increase in the number of detected adverse outcomes from 2.99 to 3.08 per day (a 3% improvement in detection).[55] level II-2

Table 4: Risk (expressed as the odd ratio, compared to an aggregate NEWS value of 5

	Odds ratio, compared to NEWS = 5 (95% CI)			
	Death	Cardiac arrest	Unanticipated ICU admission	Any of these outcomes
Triggering combinations of NEWS				
5	1.00 (0.72–1.29)*,**	1.00 (0.59–1.44)**	1.00 (0.55–1.49)**	1.00 (0.79–1.22)*,**
4 (includes a component = 3)	0.53 (0.25–0.85)	0.66 (0.17–1.26)	0.46 (0.00–0.99)	0.54 (0.32–0.79)*
3 (includes a component = 3)	0.26 (0.12–0.42)	0.24 (0.00–0.55)	0.23 (0.00–0.52)	0.25 (0.14–0.37)
Non-triggering combinations of NEWS				
4 (no component = 3)	0.38 (0.22–0.56)*	0.43 (0.14–0.74)	0.45 (0.13–0.80)	0.41 (0.27–0.55)*
3 (no component = 3)	0.20 (0.12–0.28)	0.21 (0.07–0.36)	0.22 (0.09–0.38)	0.20 (0.14–0.27)

* A significantly ($p < 0.05$) higher risk than the value immediately below.
** A significantly higher risk than the value two places below.

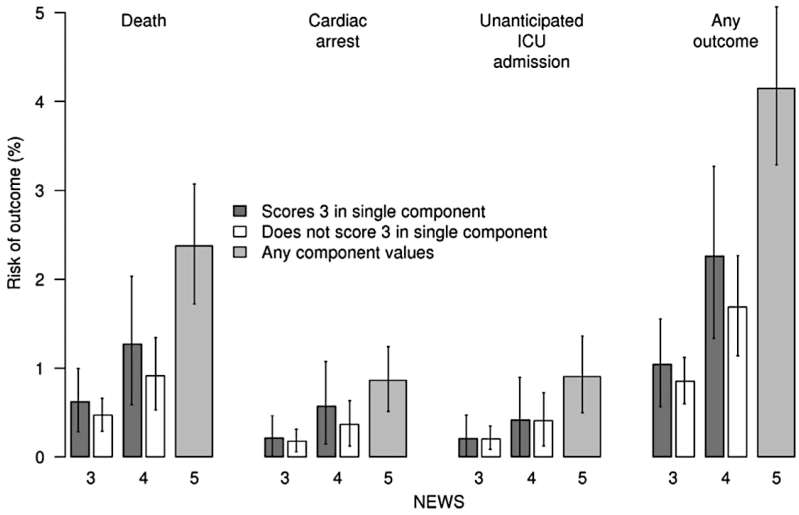


Figure 17: Risk of an adverse outcome within 24hours of an observation set scoring 3,4 or 5 on the NEWS. For those scoring 3 or 4, risks are split by whether the score included a single component score of 3.

When investigating which components most frequently contribute a NEWS value of 3 (and their associated risks), the authors found that a score of 3 for a single vital sign in NEWS is too low by itself to indicate imminent risk of adverse effect (with the exception of temperature ≤35°C). An alternative NEWS protocol would be to increase frequency of observation within these patients, but not to escalate care only on one vital sign score of 3. An individual score of 3 for low temperature (≤35°C) was the only single vital sign that significantly increased risk of adverse outcomes above that of an aggregate score of 5. But this was rare therefore loss of consciousness as a single vital sign was a better measure of risk; however risk was not significantly higher that an aggregate score of 5 (Figure 18). [55] level II-2

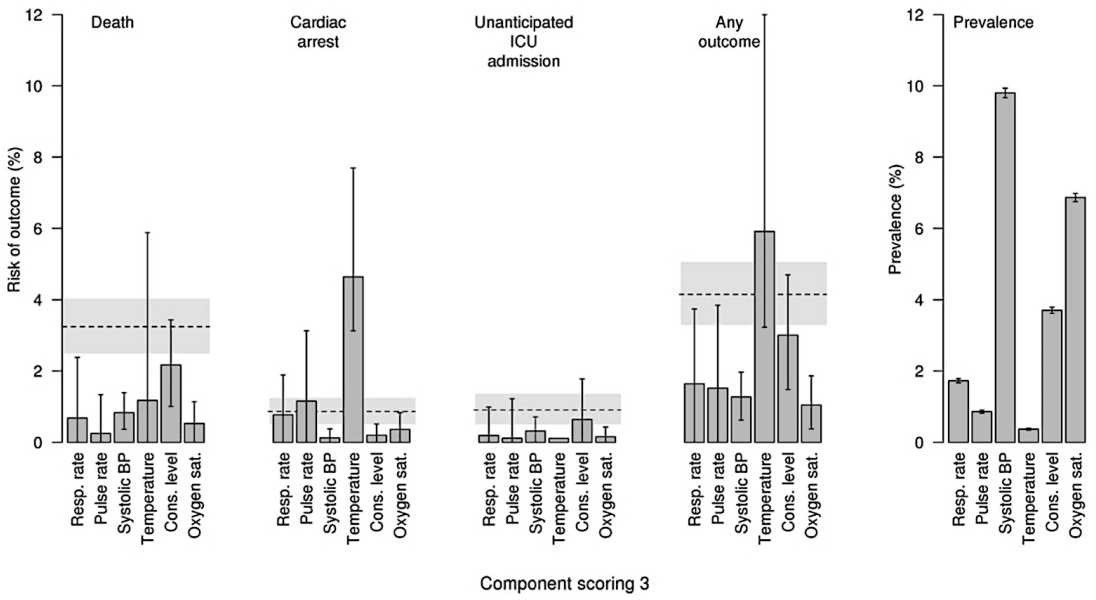


Figure 18: Prevalence of and risks associated with vital sign measurements responsible for the single component score of 3 in observation sets with NEWS values of 3 or 4, for a range of outcomes. Dashed horizontal lines indicate the risk associated with an aggregate NEWS score of 5 (shaded area is the 95% CI).

The ability of NEWS to discriminate death, cardiac arrest and unanticipated ICU admission within 24 hours for surgical and medical patients was compared by Kovacs C et al. (2016) in a prospective cohort study.[56] level II-2 The analysis of 2,017,455 observation sets (792 889 surgical observation sets and 1,174,574 medical observation sets) revealed that NEWS performed equally well, or better, for surgical as for medical patients. For death within 24 hours the AUROC for surgical admissions was 0·914 (95%CI 0·907, 0·922), compared with 0·902 (95%CI 0·898, 0·905) for medical admissions. For the combined outcome of any of death, cardiac arrest or unanticipated ICU admission, the AUROC was 0·874 (95%CI 0·868, 0·880) for surgical admissions and 0·874 (95%CI 0·871, 0·877) for medical admissions. NEWS is a poorer discriminator of cardiac arrest, compared with the other outcomes studied [medical: AUROC 0·747 (95%CI 0·857, 0·870), surgical: AUROC 0·762 (95%CI 0·853, 0·868)].[56] level II-2 EWS efficiency curve for NEWS using the combined outcome, within 24 hours of an observation set had shown that a NEWS value of 5 would trigger urgent assessment of the medical patients which would result in the detection of 70·2% (NEWS of at least 7: 48·7%t) of combined outcomes. A NEWS value of 4 would have a similar efficiency (detection of 70·9% of combined outcomes) for admissions to surgical specialties. Based on the findings, it was suggested a NEWS value of at least 5 should trigger an urgent assessment by a clinician with core competencies to assess acutely ill patients, and a NEWS value of 7 or more should prompt emergency assessment by a clinical team with critical care competencies.[56] level II-2

A prospective cohort study of adult medical admissions to a single-centre was conducted by Abbott TEF et al. (2016) reported outcomes of composite mortality or critical care escalation within 48 hours of hospital admission (n=322) and hospital length of stay (LOS) (n=310) associated with predictive ability NEWS versus combination of NEWS and blood gas variables (lactate, glucose and base-excess).[36] level II-2 This study represented ward-based care patients with a broad spectrum of medical presentations. NEWS alone was more strongly associated with death or critical care unit escalation within 48 hours of hospital admission (OR 1.46,p<0.01) (as shown in Table 5) and a reasonable predictor of the mentioned outcomes (AUROC 0.74, p<0.01). The authors indicated that NEWS was a poor predictor of hospital LOS

as no association between NEWS alone or any combination of NEWS and blood gas variables with hospital LOS was identified. Hence, data from this study did not support using blood gas variables in combination with NEWS for risk stratification as neither method increased the strength of association of NEWS with either outcome measure.[36] level II-2

Table 5: Association between the sum of NEWS and biomarkers, with primary outcome measure (critical care admission or death within 48 hours)

	Odds ratio	p-Value	H–L	p-Value
Univariable logistic regression without adjustment for covariates				
NEWS	1.48	<0.01	3.73	0.59
NEWS + lactate	1.19	<0.01	8.02	0.43
NEWS + glucose	1.02	0.62	3.56	0.89
NEWS + base excess	1.13	0.02	3.73	0.88
Multivariable logistic regression with adjustment for age and gender				
NEWS	1.46	<0.01	5.59	0.69
Age	1.01	0.59		
Gender	1.46	0.50		
NEWS + lactate	1.18	0.01	5.46	0.71
Age	1.01	0.52		
Gender	1.37	0.57		
NEWS + glucose	1.02	0.70	13.70	0.09
Age	1.01	0.54		
Gender	1.62	0.37		
NEWS + base excess	1.13	0.03	6.04	0.46
Age	1.01	0.57		
Gender	1.56	0.42		

* H-L Hosmer-Lemeshow statistic for goodness of fit, presented with p-value

The results of two studies indicate that the NEWS risk classification can be used to predict in-hospital mortality in a mixed patient population. Spangfors M et al. (2019) using a retrospective cohort study, demonstrated the NEWS risk classification has good predictive capabilities on mortality.[57] level II-2 The sum of points is then related to the level of risk for the patient: low-risk = 0-4 points, medium-risk = 5-6 points or 3 points in one individual parameter and high-risk = ≥7 points. The NEWS risk classification was significantly higher among those who died before hospital discharge and within 30 days of discharge compared to those who did not. Medium (NEWS 5-6) and high-risk (NEWS≥7) was significantly associated with a 2.11 (95%CI 1.27, 3.51, p=0.004) and 3.40 (95%CI 1.90, 6.01, p<0.001) increase in odds of in-hospital death compared to low-risk (0-4), respectively. For 30-day mortality, medium and high-risk was significantly associated with a 1.98 (95%CI 1.32, 2.97, p=0.001) and 3.19 (95%CI 1.97, 5.18, p<0.001) increase in odds of death compared to low-risk, respectively.[57] level II-2 Spagnolli et al. (2017) in a prospective cohort single centre study have shown that medical patients, classified as NEWS medium-risk (NEWS 5-6) upon hospital ward admission had a more than three-fold increase in odds of in-hospital mortality and a nine-fold increase, if classified as NEWS high-risk (NEWS ≥7).(Figure 19)[58] level II-2 Spangfors M et al. acknowledged the difference in odds ratio between the two studies was due to the variation in patients' distribution across three NEWS risk categories. Spagnolli et al. had fewer medium-risk patients (11%) than high-risk patients (17 %) compared to medium (27 %) and high-risk patients (11 %) in the study by Spangfors M et al.[57, 58] level II-2

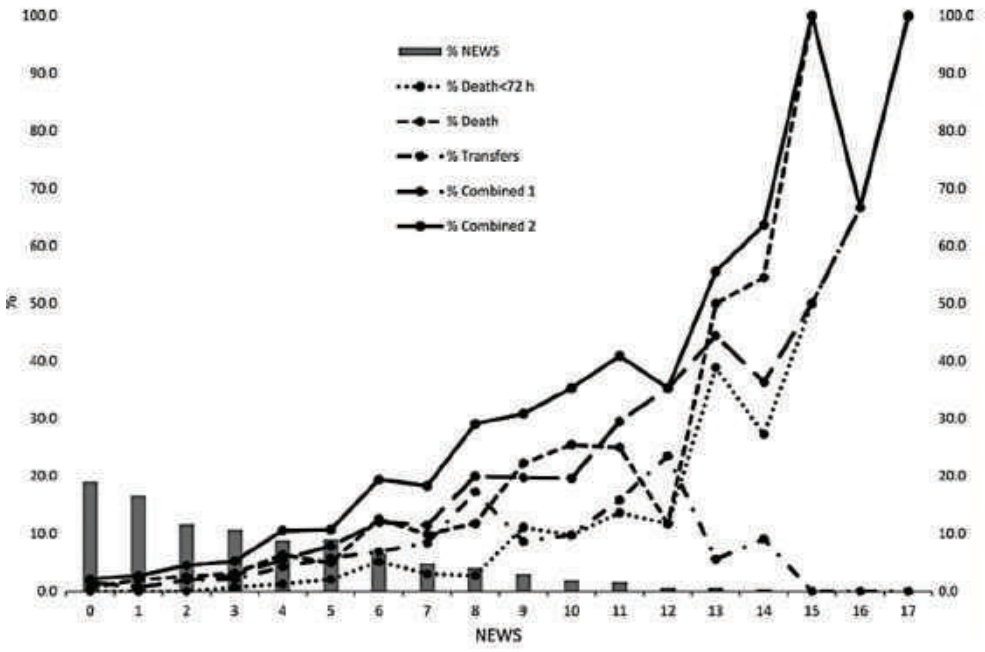


Figure 19: Relative distribution of the NEWS on admission and relationship with evaluated outcomes

Another study conducted in a single Korean medical centre by Lee YS et al. (2018) using retrospective cohort design also showed that the NEWS was effective in predicting in-hospital mortality (AUROC 0.765; 95%CI 0.659, 0.846) among general wards patients via risk stratification at the time of admission.[59] level II-2 Based on the Kaplan Meier survival curves, the survival time of patients who are at high risk according to NEWS was significantly shorter than that of patients who are at low risk ($p<0.001$). Results of the multivariate Cox proportional hazards regression analysis showed that the hazard ratios of patients who are at medium and high risk based on NEWS were 2.6 and 4.7, respectively ($p<0.001$). In addition, the study showed that the predictive performance of NEWS can be further improved with combination model that used other factors, such as age and diagnosis. (NEWS: 0.765; combination model: 0.861; $p<0.005$) (Table 6).[59] level II-2

Table 6: Prognostic capabilities of NEWS and other factors for in-hospital mortality

Models	AUC value (95%CI)	p value[a]	p value[b]	p value[c]
I	0.765 (0.659–0.846)	reference		
II	0.821 (0.735-0.888)	0.046	reference	
III	0.837 (0.756-0.900)	0.020	0.182	reference
IV	0.861 (0.793-0.917)	0.005	0.138	0.138

Model I : trigger thresholds for the NEWS only; Model II : trigger thresholds for the NEWS and age
Model III: trigger thresholds for the NEWS, age and medical reason for admission
Model IV: trigger thresholds for the NEWS, age, medical reason for admission and cancer
Comparison of AUCs between [a]Model I and other models, [b]Models II,III and IV, [c]Models III and IV were tested using the Boot-strap method.

A retrospective cohort study conducted by Roberts D et al. (2017) assessed the preceding NEWS [within 12 hours before in-patient cardiac arrest (IHCA)] and its association with 30-day survival after an IHCA.[60] level II-2 In all 358 patients suffered an IHCA during one year study period, the overall 30-day survival rate was 30%. Lower survival rates was associated with higher NEWS [survival rates were 47% among those with low NEWS (NEWS 0-4), 20% among those with medium NEWS (NEWS≥5) and 10% among those with high NEWS (NEWS≥7)]. Combinations with ≥90% mortality ratio, were found for patients with at least 2 points on two of the

following parameters in any combination: high respiratory rate, oxygen saturation <90%, high heart rate and low systolic blood pressure. Further, a ≥2-point score on at least three of the four above mentioned parameters formed a lethal triad with 100% mortality. Patients with a medium NEWS had a more than fourfold chance of dying in their IHCA compared to those with a low NEWS (adjusted OR 4.43, 95% CI 1.81, 10.83). Likewise, patients with a high NEWS had tenfold chance of dying of their IHCA compared to those with a low NEWS (adjusted OR 9.88, 95%CI 2.77, 35.26). [60] level II-2

Tirkkonen J et al. (2014) in a point prevalence study using data of patients on general wards (n=615) found that NEWS score ≥ 5 or if the weighted score for any individual vital sign was 3 was associated with an increased odds of mortality at 30 and 60 day: NEWS score ≥5 30-day mortality: OR 11.8 (95%CI 4.26, 32.6); NEWS score ≥7 30-day mortality: OR 11.4 (95%CI 4.40, 29.6); NEWS score ≥5 60-day mortality OR 5.55 (95%CI 2.91–10.6); NEWS score ≥7 60-day mortality: OR 6.42 (95%CI 2.92, 14.1).[61] level III A score of 7–8 increased the risk for death at 30 days independently 25-fold; a score of 9–10 increased the risk 45-fold. (Figure 20) The risk of serious adverse event (medical emergency team activation, cardiac arrest, emergency ICU admission or death): NEWS score ≥5 OR 14.7 (4.32–50.2); NEWS score ≥7 OR 7.45 (2.39–23.3). Following adjustment of confounding factors [age, gender, admission type (elective/emergency), background (surgical/medical), surgery within 48 hours of assessment, preceding intensive care unit admission and Charlson comorbidity index], NEWS cumulative score was able to detect high risk ward patients regardless of multiple factors affecting patient outcome in a population without treatment limitation.[61] level III

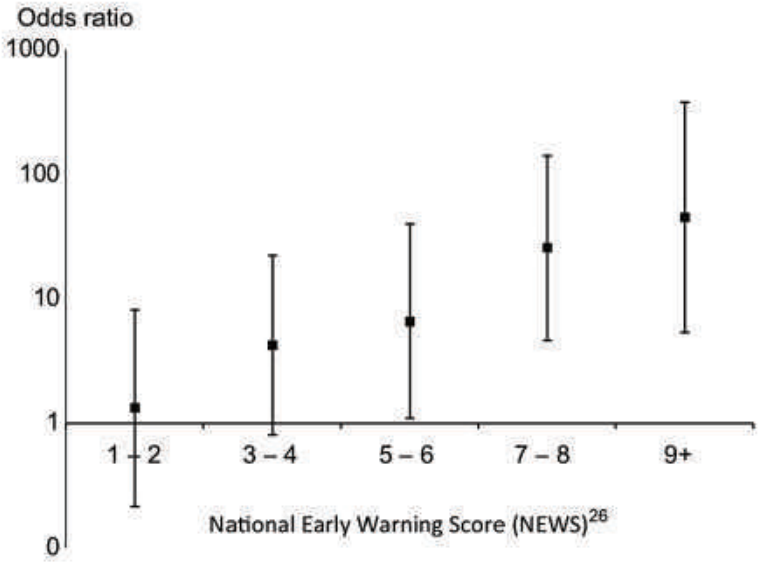


Figure 20: Odds ratios of different National Early Warning Score values with 95%CI for 30-day mortality as compared with patients with a total score of 0. All odds ratios are adjusted for patient age, gender, admission type (elective/emergency), background (surgical/medical), surgery within 48 hours of assessment, preceding intensive care unit admission and Charlson comorbidity index. The scale of odds ratios (left) is logarithmic.

NEWS and respiratory disease

Eccles SR et al. (2014) in prospective cohort study showed that patients with chronic hypoxaemia (CH), defined as those with target oxygen saturations of 88–92%, had persistently high NEWS during stability/at discharge causing unnecessary triggers and alarm fatigue for this patient group, whilst identifying the sickest patients.(Figure 21)[62] level II-2 It was observed that NEWS lacked specificity for chronic hypoxaemia patients. This is likely to be due to the respiratory variables in NEWS. Chronic hypoxaemia patients, in whom lower oxygen saturations are acceptable and indeed desirable, it is not logical to score highly on NEWS for oxygen saturations when these are within the target range. However, NEWS had a good predictive value for 30-day mortality for chronic hypoxaemia patients during stability/at discharge [AUROC 0.876 (95%CI 0.788, 0.963)]. [62] level II-2

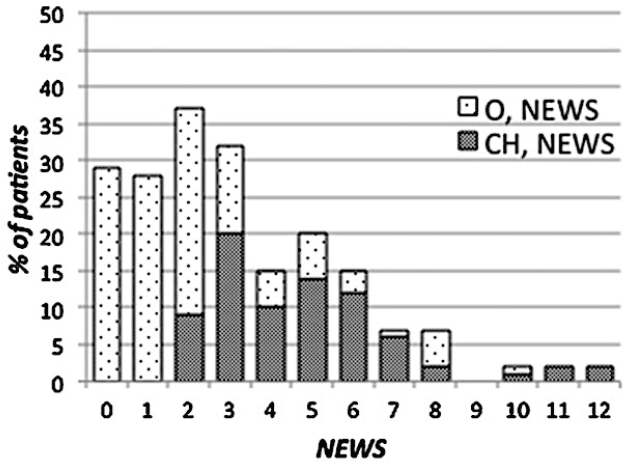


Figure 21: Distribution of NEWS scores for chronic hypoxaemia (CH) and other (O) patients during stability/at discharge

Validation study of the NEWS for patients with acute exacerbation chronic obstructive pulmonary disease (AECOPD) was performed by Hodgson LE et al. (2017) using retrospective cohort design.[63] level II-2 Prognostic prediction of NEWS for in-patient mortality was compared between AECOPD patients and general acute medical unit (AMU) patients. The study reported modest discrimination of NEWS to predict mortality in AECOPD cohort. The study also demonstrated similar discrimination to an AMU cohort [AECOPD cohort: AUROC NEWS 0.74 (95%CI 0.66, 0.82) versus AMU cohort: AUROC NEWS 0.77 (95%CI 0.75, 0.78)]. However, at suggested cut-offs of 5 and 7 points in the AECOPD cohort specificity to predict mortality and positive predictive value (PPV) values of the NEWS were lower compared to the AMU cohort, though sensitivity at the same cut-offs was higher. (Table 7) [63] level II-2

Table 7: Prediction of in-patient mortality by admission score.

NEWS threshold	Cohort	Sensitivity (%) (95%CI)	Specificity (%) (95%CI)	PPV (%) (95%CI)	NPV (%) (95%CI)
≥5	COPD	76 (61-88)	57 (54-61)	8 (5-11)	98 (97-99)
	AMU	43 (40-46)	90 (90-91)	17 (16-19)	97 (97-97)
≥7	COPD	60 (43-74)	80 (77-83)	12 (8-18)	98 (96-99)
	AMU	25 (23-28)	96 (96-97)	25 (22-28)	96 (96-97)

Sensitivity, specificity, PPV, NPV (with 95% confidence intervals) at RCP suggested NEWS thresholds of 5 points & 7 points for 1st AECOPD admission (n=942) using NEWS, CREWS, Salford-NEWS scores & the NEWS for the AMU cohort (n=20,415). AMU - acute medical unit patients, PPV - positive predictive value, NPV - negative predictive value.

A single centre retrospective cohort study was conducted by Forster S et al. (2018), analysing the sensitivity and specificity of NEWS in predicting imminent in-hospital mortality in an unselected respiratory population and in a subgroup analysis of patients with COPD and the number of mandatory escalations generated.[64] level II-2 NEWS demonstrated higher sensitivity for predicting death within 24 hours, offset by reduced specificity, in comparison to locally adapted EWS. (Table 17) The result showed that at the scores' cut points for escalation, NEWS would have generated an eightfold increase in mandatory workload due to a lower specificity. (Figure 22) [64] level II-2

Table 8: Workload predictions and sensitivity and specificity in predicting death within 24 hours for NEWS and local EWS

Unselected respiratory population

NEWS band	Mandated escalation to:	% of observations in each band	Median no per day (range)	Sensitivity for predicting death within 24 hours	Specificity for predicting death within 24 hours
0	Nil	17.86	32 (3–75)	100.00	0.00
1–4	Nurse	67.34	180 (21–457)	99.44	15.09
5–6	Doctor	8.82	60 (10–184)	88.64	74.51
7 or more	Registrar	5.97	38 (2–158)	68.53	91.16

NUH EWS band	Mandates escalation to:	% of observations in each band	Median no per day (range)	Sensitivity for predicting death within 24 hours	Specificity for predicting death within 24 hours
0	Nil	56.11	174 (20–409)	100.00	0
1–2	Nurse	31.83	99 (16–300)	95.49	56.32
3	Nurse/doctor	5.39	16 (1–116)	76.65	88.24
4–5	Doctor	4.74	14 (1–55)	63.33	93.58
6 or more	Registrar	1.94	5 (0–41)	41.91	98.24

Chronic Obstructive Pulmonary Disease

NEWS band	Mandated Escalation	% of observations in each band	Median no (range)	Sensitivity for death within 24 hours	Specificity for death within 24 hours
0	Nil	7.96	5 (0–23)	100.00	0.00
1–4	Nurse	59.3	43 (4–112)	100.00	7.99
5–6	Doctor	22.2	16 (1–59)	89.85	67.47
7 or more	Registrar	10.54	6 (0–47)	71.07	89.68

NUH EWS band	Mandated Escalation	% of observations in each band	Median no (range)	Sensitivity for death within 24 hours	Specificity for death within 24 hours
0	Nil	53.89	39 (1–101)	100.00	0.00
1–2	Nurse	35.05	26 (4–90)	92.39	54.06
3	Nurse/doctor	5.46	3 (0–30)	70.56	88.50
4–5	Doctor	4.31	2 (0–18)	58.38	94.20
6 or more	Registrar	1.28	0 (0–19)	38.07	98.75

NUH, Nottingham University Hospital.

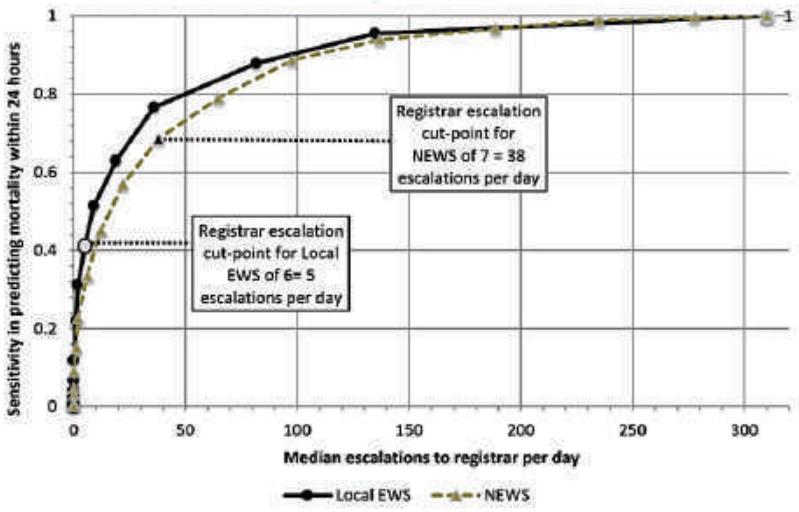


Figure 22: Graph of sensitivity versus alerts created for NEWS and local EWS

Grudzinska FS et al. (2019) sought to evaluate whether NEWS, pneumonia-specific (CURB65, Lac-CURB-65) or generic sepsis (qSOFA) were most accurate at predicting adverse outcomes among hospitalized community acquired pneumonia (CAP) patients.[65] level II-2 At admission, NEWS≥5 identified 79% of those who died within 30 days while for CURB65 ≥2, Lac-CURB-65 ≥moderate (CURB65=2 and/or lactate 2.0–4.0 mmol/L) and qSOFA ≥2 identified 85.0%, 96.4% and 40.3% of patients with CAP, respectively. Pneumonia-specific tools provide better discrimination of patients at high risk of adverse outcome than NEWS or generic sepsis tools [AUROC CURB65 0.69, Lac-CURB-65 0.68, NEWS 0.63 and qSOFA 0.62. Lac-CURB-65, using 'moderate' as the cut-off, had the greatest sensitivity and negative predictive value (NPV), 96.4% and 95.6%, respectively. While having acceptable sensitivity to predict 30-day mortality, NEWS≥5 had a low specificity (39.9%) for mortality prediction among CAP patients (PPV 23.4%, NPV 89.1%).[65] level II-2

NEWS and liver disease

Hydes TJ et al.(2018) demonstrated in their retrospective cohort study, NEWS as accurate discriminator of short-term (less 24 hours) deterioration of inpatients with liver disease with its performance being highest in alcohol-related(ARLD).[66] level II-2 The short term deterioration occurring within 24 hours of an observation set were in-hospital mortality, unanticipated ICU admission or cardiac arrest. The NEWS identified patients with primary, non-primary and no diagnoses of liver disease (control group-patients not allocated any liver disease codes during their episodes of care during or prior to the study) with AUROC values of 0.873 (95%CI 0.860, 0.886), 0.898 (95%CI 0.891, 0.905), and 0.879 (95%CI 0.877, 0.881), respectively. High AUROC values were also obtained for all clinical subgroups; the NEWS identified patients with ARLD with an AUROC value of 0.927 (95% CI, 0.912–0.941).[66] level II-2

NEWS prediction in oncology

A retrospective cohort study was performed by Cooksley T et al. (2012) at a specialist oncology hospital in UK.[67] level II-2 Data on 840 oncology patients were analysed to assess the effectiveness of two early warning scores, NEWS and MEWS in predicting critical care admission and 30-day mortality. The 30-day mortality data include patients who were transferred to the hospice or for terminal care at home and died within this period. The reason for admission during the study period ranging from admission for chemotherapy or radiotherapy treatment, unwell after recent treatment, receiving other treatment to surgery. Both NEWS and MEWS had poor discriminatory value in identifying oncological patients at risk of deterioration and requiring critical care admission. The AUROC value of NEWS to predict critical care admission was 0.59 ($p<0.001$) and for MEWS was 0.55 ($p<0.05$). The 30-day mortality AUROC value of NEWS equaled 0.62 ($p<0.001$) and for MEWS 0.60 ($p<0.05$).[67] level II-2

NEWS prediction at post-intensive care unit discharge

A prospective cohort study conducted by Uppanisakorn S et al. (2017) aimed to determine the ability of NEWS at ICU discharge ($NEWS_{dc}$) to predict the development of clinical deterioration (acute respiratory failure or circulatory shock) within 24 hours.[68] level II The NEWS was immediately recorded before discharge. The incidence of early clinical deterioration after ICU discharge was 14.8%. The findings indicated that $NEWS_{dc}$ was an independent predictor for early clinical deterioration after ICU discharge (OR 2.54; 95%CI 1.98, 3.26; $p<0.001$). The AUROC of $NEWS_{dc}$ was 0.92 3 0.01 (95%CI 0.89, 0.94, $p<0.001$). A $NEWS_{dc}$ > 7 showed the best sensitivity (93.6%) and specificity (82.2%) to detect early clinical deterioration 24 hours after ICU discharge.[68] level II

Another retrospective cohort study with similar interest conducted by Klepstad PK et al. (2019), involving population of gastrointestinal patients transferred from ICU/

high dependency unit (HDU) to general ward.[69] level II-2 In this study, the NEWS values were collected during patients' stay in general ward and the clinical deterioration of interest were death or readmission to ICU. No patients died unexpectedly at the ward and ICU/HDU readmission was 16%. The NEWS values increased by a mean of 0.15 points per hour (intercept 3.7, p<0.001) before ICU/HDU readmission according to the linear mixed effect model. NEWS at transfer from ICU was the only factor that predicted readmission (OR 1.32; 95%CI 1.01, 1.72; p=0.04) at the time of admission to the ward.[69] level II-2

Evaluation of NEWS as predictor of post-ICU respiratory failure in older ICU patients (≥60 years) who were successfully weaned from mechanical ventilation (MV) and discharged to the general ward from ICU was conducted by Chen YC et al. (2019) by utilising retrospective cohort design.[70] level II-2 The present study had 8.5% of the older patients with successful liberation from MV and ICU (ICU_{mv-lib}) developing post-ICU respiratory failure before day 14 (PIRF-14). The post-ICU in-hospital mortality rates were 47.8% and 6.8% in patients with and without PIRF-14 (adjusted OR 12.597, 95%CI 4.368, 36.331). National Early Warning Score on discharge was identified as independent predictor of PIRF-14 in this studied population. Patient with escalating NEWS levels had increasing rates of PIRF-14. Those with a NEWS of ≥10 had 2.6 fold increased risk of PIFR-14 (adjusted OR 2.642, 95%CI 1.001, 6.976). Patients with a NEWS of <10 and PIRF-14 had a sevenfold increased risk of mortality as compared with the reference group without both factors (adjusted OR 7.729, 95%CI 1.155, 51.703). Patients with a NEWS of ≥10 and subsequent PIRF-14 had a 15-fold elevated risk of mortality as compared with the reference group (adjusted OR 15.418, 95% CI 4.344, 54.720).[70] level II-2

Zaidi H et al. (2019) in a retrospective cohort study utilising a large vital signs database (n = 2, 723, 055) collected from 28,523 critical care admissions from surgical (SICU), coronary (CCU), cardiac surgery recovery (CSRU), medical (MICU) and trauma surgical (TSICU) intensive care patients with a single complete admission (patient was admitted to ICU and later discharged without returning to another ICU), demonstrated that the NEWS was able to discriminate a patient by discharge location (home; hospital ward; nursing facility; hospice and death) within 24 hours of admission to any ICU specialty.[71] level II-2 A reasonable discriminative ability of NEWS across five different ICU specialties for any discharge location was reported. The NEWS has greater ability to discriminate patients in the Coronary Care Unit (CCU) and Cardiac Surgery Recovery Unit (CSRU) compared to other ICU specialties.(Figure 23 and 24) The NEWS AUROC (95%CI) at 24 hours following admission: all patients 0.727 (0.709, 0.745); Coronary Care Unit (CCU) 0.829 (0.821, 0.837); Cardiac Surgery Recovery Unit (CSRU) 0.844 (0.838, 0.850); Medical Intensive Care Unit (MICU) 0.778 (0.767, 0.791); Surgical Intensive Care Unit (SICU) 0.775 (0.762, 0.788); Trauma Surgical Intensive Care Unit (TSICU) 0.765 (0.751, 0.773). The authors did not report on NEWS cut off values for different type of discharge locations.[71] level II-2

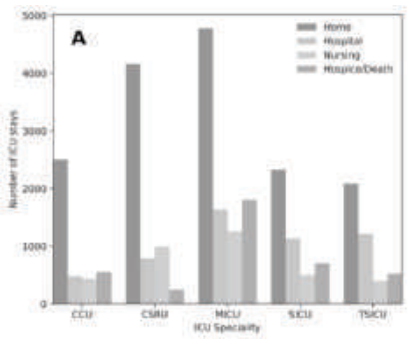


Figure 23: ICU specialty and discharge

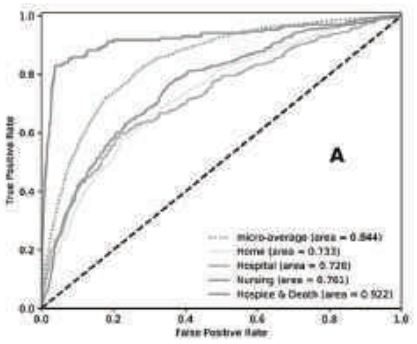


Figure 24: NEWS discrimination within Cardiac Surgery Recovery Unit

Comparison with other established EWS or track and trigger system (TTS)

Based on published findings from validation study conducted Smith et al. (2013), NEWS had greater discriminatory ability compared to other 33 EWSs that were in use at the time of the study to predict unanticipated ICU admission or death but not cardiac arrest within 24 hours of a vital signs dataset among medical admissions.[53] level II-2 [NEWS: AUROC (95%CI) 0.894 (0.887, 0.902) for death, 0.857 (0.847, 0.868) for unanticipated ICU admission, 0.722 (0.685, 0.759) cardiac arrest, 0.873 (0.866, 0.879) for combined outcome] [AUROCs (95% CI) for the other 33 EWSs were 0.813 (0.802, 0.824) to 0.858 (0.849, 0.867) for death, 0.570 (0.553, 0.568) to 0.827 (0.814, 0.840) for unanticipated ICU admission, 0.611 (0.568, 0.654) to 0.710 (0.675, 0.745) for cardiac arrest and 0.736 (0.727, 0.745) to 0.834 (0.826, 0.842) for combined outcome]. [53] level II-2

Jarvis et al. (2015b) also found that NEWS performed the best of all 35 EWSs when predicting risk of death within 24 hours.[72] level II-2 The top three EWS (using all observation data) were NEWS AUROC=0.898; MEWS AUROC=0.862; Worthing AUROC=0.861 and the lowest was Centiles AUROC=0.783. [72] level II-2

Abbott et al. (2015) using a prospective, observational cohort study design (n=445; n=16 met the primary outcome) found that NEWS was more strongly associated with the composite endpoint of critical care admission or death within the first 48 hours of the hospital stay compared to Patient at Risk Score (PARS); NEWS OR 1.54, (95%CI 1.26, 1.91, p <0.001); PARS OR 1.42 (95%CI 1.00, 2.05, p = 0.056).[73] level II-2 Every one point increase in NEWS was associated with a 55% increased risk. Analysis of individual NEWS thresholds identified that a score of ≥3 was associated with the composite end point (OR 8.12, p<0.001). Both NEWS and PARS were poor predictors of hospital length of stay. Neither score was correlated with hospital length of stay. [73] level II-2

Yu et al. (2014) using retrospective nested case-control design, examined and compared the ability of nine prediction scores (SOFA), Predisposition/ Infection/ Response/Organ Dysfunction Score (PIRO), ViEWS-National Early Warning Score System, SCS, MEDS, MEWS, SAPS II, APACHE II and REMS) to estimate the risk of clinical deterioration.[74] level II-2 NEWS ranked third behind SOFA and PICO in predicting clinical deterioration in non-ICU patients in general medical wards, during 0 and 12 hours prior to the deterioration. Although SOFA performed the best, this was not significantly higher than PIRO, NEWS, SCS, MEDS or MEWS. At the 0- to 12-hour interval before clinical deterioration, all scores except REMS performed with acceptable discrimination (AUROC ≥0.70) and had almost similar AUROC. However, at the 12- to 72-hour intervals, all scores, with the exception of MEDS, no longer performed with acceptable discrimination for mortality (AUROC <0.70). For all models, average scores of cases increased closer to time of clinical deterioration (p <0.05). For the MEWS, SAPS II, APACHE II and REMS scoring models, this increase was detected as early as 12 to 24 hours before deterioration (p <0.05). (Table 9) [74] level II-2 A subgroup analysis, using mortality as the endpoint had shown at the 0- to 12-hour interval, seven of the eight scores performed similarly and had an AUROC of greater than 0.80 (SOFA AUC 0.83, NEWS 0.81, PIRO 0.87, SCS 0.83, MEDS 0.85, MEWS 0.82, SAPS II 0.83 and APACHE II 0.80). However, at the 12- to 72-hour intervals, only MEDS continued to predict for mortality with excellent discrimination (AUC >0.80). In this subgroup analysis, the clinical decision rule performed even better, with a sensitivity of 79% and a specificity of 72% when predicting for mortality. Even after baseline differences between cases and controls were adjusted for, patients who met the clinical decision rule criteria are much more likely to die during hospitalization compared with patients who did not (adjusted OR 13.3, 95%CI 5.3, 33.3) (Table 10).[74] level II-2

Table 9: Comparison of AUROC for nine scoring systems

Score	0-12 hours	12-24 hours	24-48 hours	48-72 hours
SOFA	**0.78[a] (0.74-0.81)**	**0.68[a] (0.63-0.73)**	0.66 (0.60-0.71)	0.64 (0.57-0.71)
PIRO	0.76 (0.72-0.79)	0.66 (0.61-0.71)	0.66 (0.61-0.72)	0.68 (0.61-0.75)
ViEWS (NEWS)	0.75 (0.71-0.79)	0.67 (0.62-0.72)	0.64 (0.58-0.69)	0.66 (0.59-0.73)
SCS	0.74 (0.70-0.78)	0.67 (0.62-0.72)	0.63 (0.57-0.69)	0.63 (0.56-0.71)
MEDS[b]	0.74 (0.70-0.78)	0.68 (0.63-0.73)	**0.69[a] (0.63-0.74)**	**0.71[a] (0.64-0.78)**
MEWS	0.73 (0.69-0.77)	0.66 (0.61-0.71)	0.59 (0.53-0.65)	0.60 (0.52-0.67)
SAPS II	0.73 (0.69-0.77)	0.67 (0.61-0.72)	0.61 (0.55-0.67)	0.60 (0.53-0.68)
APACHE II	0.72 (0.68-0.76)	0.66 (0.61-0.71)	0.61 (0.55-0.67)	0.60 (0.52-0.67)
REMS	0.67 (0.62-0.71)	0.63 (0.57-0.68)	0.55 (0.49-0.61)	0.59 (0.52-0.66)

[a]Denotes best performing score at each time interval. [b]Scores where AUC at 0 to 12 hours is NOT significantly higher than AUC at 12 to 24 hours, 24 to 48 hours, and 48 to 72 hours. APACHE II, Acute Physiology and Chronic Health Evaluation Score II; MEDS, Mortality in Emergency Department Sepsis; MEWS, Modified Early Warning Score; PIRO, Predisposition/Infection/ Response/Organ Dysfunction Score; REMS, Rapid Emergency Medicine Score; SAPS II, Simplified Acute Physiology Score II; SCS, Simple Clinical Score; SOFA, Sequential Organ Failure Assessment; ViEWS, VitalPac National Early Warning Score.

Table 10: Comparison of AUROC for the nine scoring systems when using mortality as the endpoint.

Score	0-12 hours	12-24 hours	24-48 hours	48-72 hours
SOFA	0.83 (0.77-0.88)	0.76 (0.69-0.83)	0.75 (0.67-0.83)	0.74 (0.64-0.83)
PIRO	0.87 (0.82-0.92)	0.79 (0.73-0.86)	0.76 (0.68-0.84)	0.78 (0.69-0.86)
ViNEWS	0.81 (0.76-0.87)	0.77 (0.70-0.84)	0.72 (0.64-0.81)	0.78 (0.70-0.87)
SCS	0.83 (0.78-0.89)	0.78 (0.71-0.85)	0.74 (0.66-0.83)	0.74 (0.65-0.84)
MEDS	0.85 (0.79-0.90)	0.81 (0.74-0.87)	0.81 (0.74-0.89)	0.82 (0.74-0.90)
MEWS	0.82 (0.77-0.88)	0.77 (0.70-0.84)	0.70 (0.62-0.79)	0.73 (0.64-0.83)
SAPS II	0.83 (0.77-0.89)	0.77 (0.70-0.84)	0.74 (0.65-0.82)	0.74 (0.65-0.84)
APACHE II	0.80 (0.74-0.86)	0.75 (0.67-0.82)	0.73 (0.64-0.81)	0.74 (0.64-0.83)
REMS	0.75 (0.65-0.79)	0.70 (0.63-0.78)	0.63 (0.53-0.72)	0.64 (0.54-0.75)

Areas under the receiver operating characteristic curves along with 95% confidence intervals are displayed. Analysis was applied to the subgroup of cases that died during hospitalization (n = 110) along with their corresponding controls (n = 110)

Based on retrospective cohort study conducted by Hydes TJ et al. (2017), a direct comparison made between NEWS with 34 other EWS systems revealed that NEWS was the most discriminating for 24 hours risk of death, ICU admission and cardiac arrest in patients with primary or non-primary diagnostic codes for liver disease. (Table 11) [66] level II-2

Table 11: The top five EWS based on AUROC values for adverse outcomes for patients with a primary or non-primary diagnosis of liver disease

EWS	Primary diagnosis of liver disease		Non-primary diagnosis of liver disease	
	AUROC	95% CI	AUROC	95% CI
NEWS	0.873	0.860 - 0.886	0.898	0.891 - 0.905
PARS	0.843	0.829 - 0.857	0.862	0.853 - 0.871
Worthing	0.840	0.826 - 0.855	0.844	0.835 - 0.854
LEWS	0.839	0.825 - 0.853	0.860	0.851 - 0.869
SEWS	0.836	0.822 - 0.851	0.860	0.851 - 0.870

PARS=Patient-at-Risk Score;LEWS=Leeds Early Warning Score;SEWS= standardised early warning scoring system

Khwannimit B et al. (2019) did a comparison of prediction accuracy between three EWS (NEWS, MEWS, SOS) with both the qSOFA and SOFA for adverse outcomes among sepsis patients admitted to the ICU.[75] level II-2 This retrospective cohort study showed that the SOFA presented the best predictive ability for in-hospital and 30-day mortality as well as multiple organ failures among sepsis patients admitted to the ICU. The NEWS provided the lowest AUROC value. For predicting ICU mortality, SOS presented the highest AUROC, followed by SOFA, MEWS, NEWS and qSOFA. The results established that only SOS has comparable accuracy as a SOFA score to predict mortality in ICU sepsis patients. (Table 12) [75] level II-2

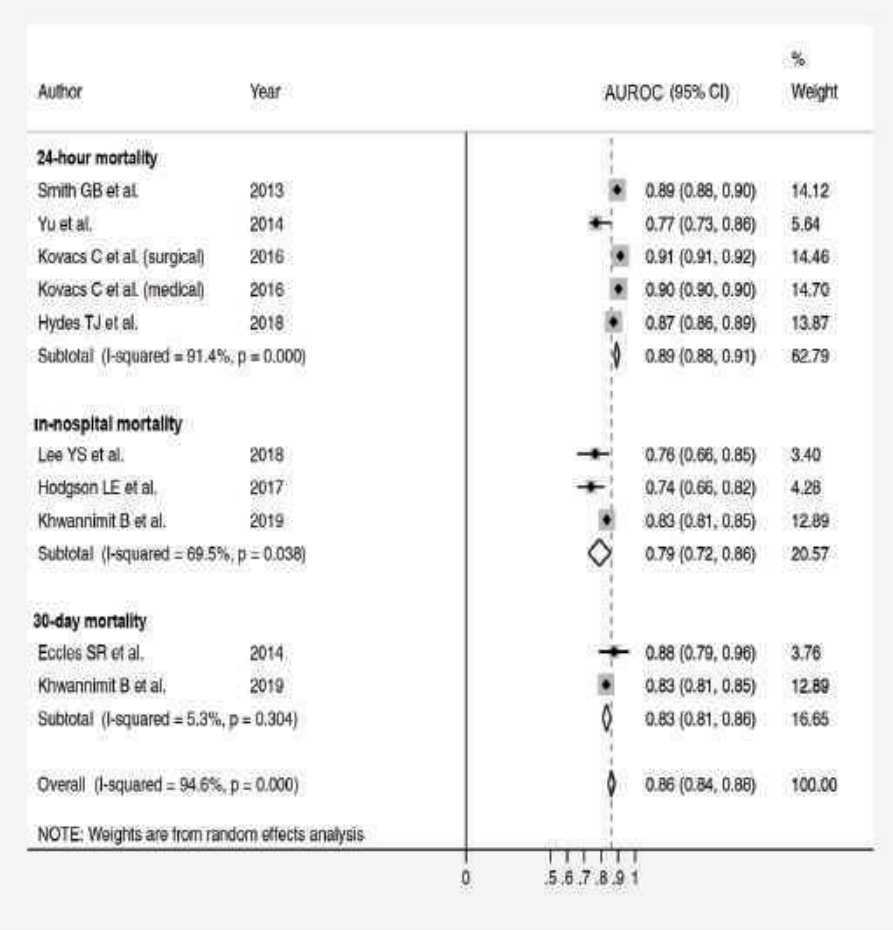
Table 12: The area under the receiving operating characteristic curve with 95% CI of early warning scores, qSOFA and SOFA score to predict hospital, ICU and 30-day mortality and multiple organ failures

Scores	Hospital mortality	ICU mortality	30-day mortality	Multiple organ failures
SOFA	0.880 (0.863-0.896)	0.867 (0.849-0.885)	0.876 (0.859-0.893)	0.978 (0.972-0.984)
SOS	0.878 (0.861-0.894)	0.875 (0.858-0.892)	0.873 (0.856-0.889)	0.831 (0.807-0.855)
MEWS	0.858 (0.840-0.876)	0.861 (0.842-0.879)	0.854 (0.835-0.872)	0.779 (0.752-0.805)
qSOFA	0.847 (0.829-0.864)	0.812 (0.794-0.830)	0.842 (0.825-0.860)	0.776 (0.748-0.803)
NEWS	0.833 (0.813-0.852)	0.825 (0.805-0.846)	0.829 (0.809-0.848)	0.799 (0.771-0.827)

ICU: intensive care unit; MEWS: Modified Earning Warning Score; NEWS: National Early Warning Score; qSOFA: quick Sequential Organ Failure Assessment; SAPS: Simplified Acute Physiology Score; SOFA: Sequential Organ Failure Assessment; SOS: Search Out Severity.

Weighted pooled result for mortality outcomes

In a pooled AUROC analysis of NEWS in general ward population, there was a trend of AUROC showing good to excellent prognostic performance for short and long term mortality outcomes [AUROC for 24-hour mortality 0.77-0.90 (95%CI 0.73-0.90, 0.86-0.90), AUROC for in-hospital mortality 0.79 (95%CI 0.72, 0.86)) and AUROC for 30-day mortality 0.83 (95%CI 0.81, 0.86)]. However, pooling of studies for 24-hour mortality outcome produced statistically significant heterogeneity (I^2 91.4%, $p<0.001$). Sensitivity analysis showed this highly heterogenous outcome was associated with combining the results from studies conducted in different type of highly specified subpopulation of ward patients, attributed to significant physiological differences between each subpopulation. (Figure 25)



Test for overall effect Z=85.87, p<0.001

Figure 25: The pooled estimate of AUROC values for 24-hour mortality, in-hospital mortality and 30-day mortality for general ward patients

Pre-hospital setting

A retrospective cohort study conducted by Silcock DJ et al. (2015) sought to evaluate the validity of the NEWS in unselected prehospital patients.[76] level II-2 The calculation of NEWS was done using parameters recorded prior to ambulance transfer to hospital. The study demonstrated that the discriminative performance of NEWS was good for 24 hours mortality [AUROC 0.855 (95%CI 0.69,1)], 48 hours mortality [AUROC 0.871 (95%CI 0.75, 0.98)] and 30 day mortality [AUROC 0.740 (95%CI 0.661, 0.819)], ICU admission [AUROC 0.774 (95%CI 0.657, 0.890)] and a combined outcome of 48 hours mortality or ICU admission [AUROC 0.815 (95%CI 0.730, 0.990)]. For the combined endpoint of death in the Emergency Department (ED) or admission directly to ICU from the ED, the AUROC was 0.889 (95%CI 0.823, 0.957). Elevated NEWS was associated with a higher incidence of adverse outcomes. Across the whole range of patient presentations, patients with a NEWS≥7 had 11% chance of death or ICU admission within 48 hours. The medium-risk NEWS group was associated with a statistically significant increase in ICU admission (RR=2.466, 95%CI 1.0, 6.09), but not in-hospital mortality relative to the low risk group. The high risk NEWS group had significant increases in 48 hours mortality [RR 35.32 (95%CI 10.08, 123.7)], 30 day mortality [RR 6.7 (95%CI 3.79, 11.88)] and ICU admission [RR 5.43 (2.29–12.89)]. [76] level II-2

Abbott TEF et al. (2018) performed a retrospective cohort study of adult patients admitted to a single UK teaching hospital with acute medical presentations, brought to hospital by ambulance.[77] level II-2 The authors aimed to determine the association of pre-hospital NEWS with the combined outcome of death or critical care unit escalation within 48 hours of hospital admission and hospital length of stay. Pre-hospital NEWS and admission to hospital NEWS were both associated with the combined outcome of death or critical care unit escalation within 48 hours of hospital admission (OR 1.25; 95%CI 1.04, 1.51; p = 0.02 and OR 1.52; 95%CI 1.18, 1.97, p < 0.01 respectively). Patients with a pre-hospital NEWS of 7 or more had a four-fold increase in the odds of death or critical care unit admission compared to patients with a pre-hospital NEWS of 4 or less. Neither pre-hospital nor admission NEWS were associated with hospital length of stay (r^2=5.1%, p=0.48 and r^2=5.2%, p=0.92 respectively). This study identified a moderate correlation between ambulance NEWS and admission NEWS – in 83% of cases NEWS at both time points was the same (r = 0.44, p < 0.01). Where the scores were different, ambulance NEWS was greater in the majority of cases suggesting an improvement in clinical condition between pre-hospital assessment and medical ward admission. [77] level II-2

In a retrospective cohort study conducted by Pirneskoski J et al. (2019), the prognostic accuracy of pre-hospital NEWS for predicting 24 hours mortality of Emergency Medical Services (EMS) dispatch was assessed using large population based database.[78] level II-2 The primary outcome of death within 24 hours of EMS dispatch occurred in 378 (1.1%) cases. The secondary outcomes of death within 7 and 30 days occurred in 857 (2.4%) and 1607 (4.5%) of cases respectively. The AUROC for primary outcome of death within 24 hours was 0.840 (95%CI 0.823, 0.858). Subgroup analysis suggested that NEWS had better prognostic accuracy in cases where the initial dispatch code was specified as trauma [AUROC 0.901 (95%CI 0.859, 0.942)]. Prehospital NEWS score has a good specificity (77.1%) and sensitivity (77%) for prediction of death within 24 hours of EMS dispatch with highest Youden's index for 24 hours mortality at a threshold of 7 points (increase in mortality for patients with higher NEWS scores of >7). For secondary outcomes of death within 7 and 30 days, the AUROCs were 0.809 (95%CI 0.795, 0.823) and 0.758 (95%CI 0.747, 0.770) respectively. Based on logistic regression model of performance of NEWS parameters in predicting 24 hours mortality of EMS despatch, the most significant single NEWS parameter was heart rate ≤40 min [1] with OR 5.41 (95%CI 1.78, 13.9; p< 0.001).[78] level II-2

A prospective cohort study by Hoikka M et al. (2018) reported twofold accuracy of using NEWS in the prehospital patient population to predict 24 hours mortality.[79] The high risk NEWS category could predict 8 in 10 early deaths within 24 hours, but failed to acceptably predict 30-day mortality due to a high rate of false negatives. (Table 13) The increase in 24 hours mortality occurred with NEWS value greater than 12.(Figure 26) The study did not report on AUROC value.[79] level II-2

Table 13: Mortality (24 hours and 30-day) at high, medium and low risk classes categorized according to the pre-hospital NEWS.

		NEWS class	
	n	**High** 718	**Medium** 2550
24 hours mortality	Sensitivity (95%CI) Specificity (95%CI) PPV NPV PLR NLR	80.1% (73.7%, 85.5%) 95.4% (95.0%, 95.8%) 21.3% 99.7% 17.36 0.21	89.0% (83.7%, 93.1%) 80.6% (79.8%, 81.3%) 6.7% 99.8% 4.58 0.14
30-day mortality	Sensitivity (95%CI) Specificity (95%CI) PPV NPV PLR NLR	42.4% (38.3%, 46.6%) 96.0%(95.6%, 96.3%) 33.2% 97.2% 10.49 0.60	63.0%(58.8%, 67.0%) 81.5%(80.8%, 82.2%) 13.8% 97.9% 3.40 0.46

95% CI 95% confidence interval, PPV positive predictive value, NPV negative predictive value, PLR positive likelihood ratio, NLR negative likelihood ratio

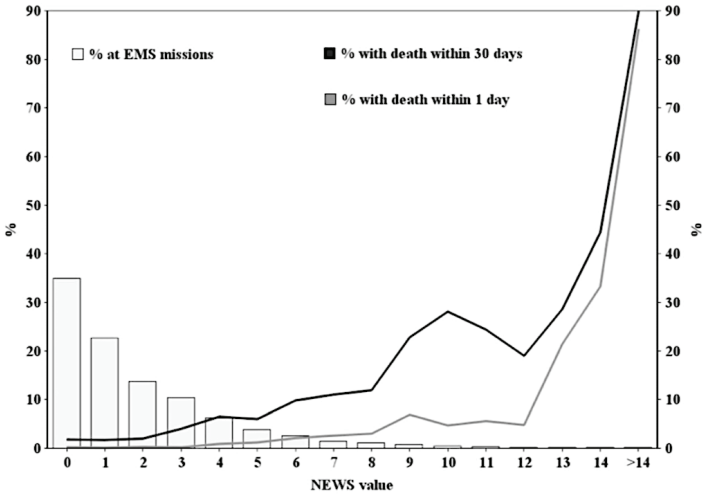


Figure 26: The distribution of pre-hospital NEWS values and the relation with 24 hours and 30 day mortality

Shaw J et al. (2017) conducted a retrospective cohort study involving 287 patients who were treated by ambulance service and transported to hospital, to determine the association between pre-hospital NEWS derived from ambulance service clinical observations and hospital ED disposition.[80 level II-2] The authors found strong associations between NEWS calculated from ambulance service clinical records and the severity of the patient's condition as indicated by a proxy measure of patient disposition. Those with a higher NEWS risk category were more likely to be admitted to the ICU or die, whereas those with a low risk category were more likely to be discharged from the ED. (Table 14) [80 level II-2]

Table 14: Patient disposition by NEWS clinical risk level

	Patient disposition			
NEWS clinical risk level	**Discharged from ED**	**Admitted to ward**	**Admitted to ICU**	**Died in ED**
Low (score 0-4)	81(81%)	65 (65%)	8 (14%)	4 (13%)
Medium (score 5-6)	16 (16%)	25 (25%)	19 (33%)	7 (24%)
High (score ≥7)	3 (3%)	10 (10%)	30 (53%)	19 (63%)
Total	**100**	**100**	**57**	**30**

A comparison was made between the effectiveness of NEWS and MEWS in pre-hospital setting by Mitsunaga T et al. (2019) in the retrospective cohort study.[81 level II-2] The authors sought to evaluate the predictive ability of pre-hospital NEWS (pNEWS) and the pre-hospital MEWS (pMEWS) for admission to ward or ICU and in-hospital mortality in elderly patients (age 65 years old and older) presented to the ED by ambulance. The study demonstrated the low utility of the pNEWS and the pMEWS as predictor of admission to ward or ICU and in-hospital mortality in elderly patients. The value of the pNEWS was also compared with that of the ED NEWS (eNEWS) and ED MEWS (eMEWS). The eNEWS and the eMEWS predicted admission and in-hospital mortality more accurately. The AUROC of the eNEWS was significantly greater than that of the eMEWS for predicting admission and in-hospital mortality ($p < 0.001$). (Table 15) [81 level II-2]

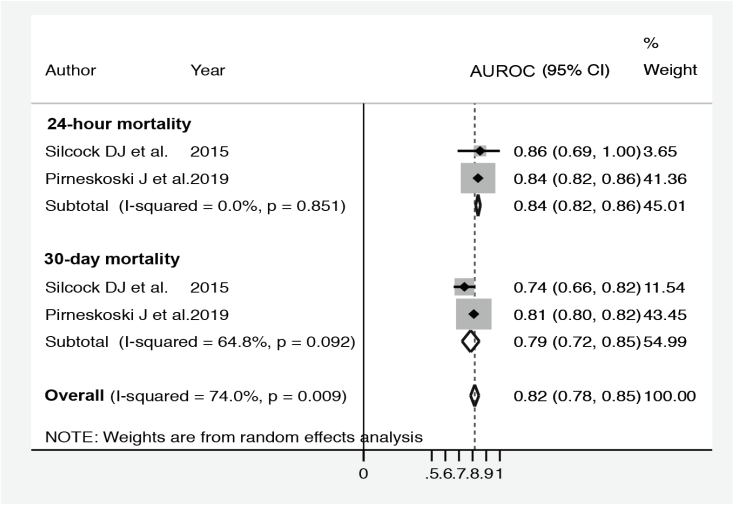
Table 15: AUROC, Sensitivity and Specificity values for prediction of the need for admission and in-hospital mortality.

Score	Admission to ward or ICU			In-hospital mortality		
	AUROC (95%CI)	Sensitivity	Specificity	AUROC (95%CI)	Sensitivity	Specificity
Pre-hospital						
pNEWS	0.559 (0.536–0.583)	54%	54,8%	0.678 (0.633–0.720)	65.4%	59.7%
pMEWS	0.547 (0.525–0.572)	54.9%	50.6%	0.652 (0.609–0.695)	57.5%	64.5%
Emergency Department						
eNEWS	0.628 (0.605–0.652)	55.3%	63.1%	0.789 (0.747–0.829)	78.7%	64.0%
eMEWS	0.591 (0.569–0.616)	41.2%	75.7%	0.720 (0.671–0.765)	69.3%	67.6%

The analysis of data of 1713 pre-hospital patients in a retrospective cohort study by Silcock DJ et al. (2018) aimed to compare the ability of NEWS and qSOFA to predict adverse outcomes in a prehospital population with suspected infection.[82] level II-2 The study revealed that among unselected pre-hospital patients, an elevated qSOFA much like NEWS, was associated with increased levels of adverse outcomes, namely, ICU admission within 48 hours of presentation and/ or 30-day mortality. The aggregated total NEWS score was, however, significantly superior to qSOFA at identifying patients at combined risk of either ICU admission within 48 hours of presentation and/or 30-day mortality. The relative discriminatory value of NEWS and qSOFA for the combined outcomes of ICU admission within 48 hours of presentation and/or 30-day mortality were AUROC 0.740 (95%CI 0.685, 0.795) and AUROC 0.679 (95%CI 0.624, 0.733); p=0.011. Comparison of the AUROC curves between NEWS and qSOFA showed no statistically significant difference between NEWS and qSOFA at predicting ICU admission within 48 hours [AUROC NEWS 0.798 (95%CI 0.693, 0.902); AUROC qSOFA 0.689 (95%CI 0.571, 0.808), p=0.057] and at predicting 30-day mortality [AUROC NEWS 0.731 (95%CI 0.671, 0.791); AUROC qSOFA 0.682 (95%CI 0.623, 0.740), p=0.647]. Therefore, the authors suggested that rather than qSOFA, a NEWS of medium or high clinical risk be used to fulfil the requirement of the Sepsis-3 UK definitions namely 'to prompt clinicians to further investigate for organ dysfunction, to initiate or escalate therapy as appropriate, and to consider referral to critical care or increase the frequency of monitoring'. [82] level II-2

Weighted pooled result for mortality outcomes

In pre-hospital setting, the pooled AUROC values for NEWS in predicting short term (24 hours) and long term (30 days) mortality outcomes were 0.84 (95%CI 0.82, 0.86) and 0.79 (95%CI 0.72, 0.85), respectively. (Figure 27)



Test for overall effect Z=51.87, p<0.001

Figure 27: The pooled estimate of AUROC values for 24-hour mortality and 30-day mortality for patients in pre-hospital setting

NEWS2

Pimentel MAF et al. (2019) undertook a multicenter retrospective cohort study to compare the ability of the NEWS and NEWS2 to predict in-hospital mortality, unanticipated ICU admission and cardiac arrest within 24 hours of a vital sign observation in three risk groups: those with documented type 2 respiratory failure (T2RF), those at risk of T2RF and patients in neither of these groups.[83] level II-2 For the in-hospital mortality within 24 hours of an observation, NEWS2 demonstrated no improvement in discrimination over NEWS for patients with documented T2RF, but at the suggested Royal College of Physicians of London (RCPL) cut-offs of 5 and 7 points, the positive predictive values (PPV) were higher for NEWS2 than NEWS [AUROC NEWS 0.862 (95%CI 0.848, 0.875); NEWS2 0.841 (95%CI 0.827, 0.855); PPV NEWS 2.5%; NEWS2 3.0%]. However, for patients at risk of T2RF, NEWS had superior discrimination and higher PPV compared to NEWS2 [AUROC NEWS 0.881 (95%CI 0.878, 0.884); NEWS2 0.860 (95%CI 0.857, 0.864); PPV NEWS 3.2%; NEWS2 2.7%]. When applied to patients not at risk of T2RF (to simulate the impact of using NEWS2 in error in such patients) NEWS2 discriminated less well than NEWS and had lower PPV. NEWS2 did not improve discrimination for unanticipated ICU admission, cardiac arrest or combined outcomes compared to NEWS (Table 16). The efficiency curves comparing the efficiency of NEWS and NEWS2 demonstrated that, for the few patients with documented T2RF, the use of NEWS2 at the suggested RCPL cut-offs of 5 and 7 points reduced absolute staff workload by approximately 11% and 5% respectively, but at the expense of reduced sensitivity of approximately 10% and 14%, respectively. For patients at risk of T2RF, the use of NEWS2 at the suggested RCPL cut-offs of 5 and 7 points did not significantly decrease staff workload, but reduces sensitivity by 5–6%. Finally, if used in error for patients not at risk of T2RF at the suggested RCPL cut-offs, NEWS2 was slightly more sensitive than NEWS but, to achieve this, risks doubling the workload.[83] level II-2

Table 16: Performance metrics of the two scoring systems (NEWS and NEWS2) for predicting unanticipated ICU admission, cardiac arrest and combined outcome in the three risk groups: AUROC, with 95% confidence interval (CI). NEWS– NEWS2 indicates the mean difference (95% CI) between the AUROCs of NEWS and NEWS2.

	Documented T2RF	At risk T2RF	Not at risk T2RF
Unanticipated ICU admission			
NEWS	0.806 (0.786 - 0.826)[a]	0.814 (0.808 - 0.821)	0.841 (0.837 - 0.845)
NEWS2	0.816 (0.796 - 0.836)[a]	0.815 (0.808 - 0.821)	0.833 (0.829 - 0.837)
NEWS – NEWS2	-0.010 (-0.023 - 0.003)[a]	0.000 (-0.004 - 0.004)	0.008 (0.007 - 0.010) ∝
Cardiac arrest			
NEWS	0.701 (0.654 - 0.749)[a]	0.756 (0.744 - 0.769)	0.785 (0.776 - 0.794)
NEWS2	0.706 (0.658 - 0.753)[a]	0.741 (0.728 - 0.754)	0.768 (0.760 - 0.777)
NEWS – NEWS2	-0.004 (-0.046 - 0.037)[a]	0.015 (0.008 - 0.022)∝	0.016 (0.012 - 0.020) ∝
Combined outcome			
NEWS	0.835 (0.824 - 0.847)	0.858 (0.855 - 0.861)	0.881 (0.879 - 0.884)
NEWS2	0.830 (0.818 - 0.841)	0.843 (0.840 - 0.847)	0.867 (0.864 - 0.869)
NEWS – NEWS2	0.006 (-0.003 - 0.014)	0.015 (0.013 - 0.016) ∝	0.015 (0.014 - 0.016) ∝

[a] Where number of adverse outcomes is under 100. ∝ Denotes significant difference in AUROC ($p < 0.05$).

A study by Hodgson LE et al. (2018) using retrospective cohort design, aimed to assess the performance of NEWS and NEWS2 in acute exacerbation of chronic obstructive pulmonary disease (AECOPD) cohort.[84] level II-2 The study reported that among the non-survivors, median NEWS was 7 (IQR 3–9) compared to 4 (IQR 2–8) using NEWS2 ($p<0.001$). Of patients who died, 50% had an admission NEWS ≥7 points; rescoring using NEWS2 SpO2 parameters, 44% of these patients would have been placed in a lower call-out threshold, reducing sensitivity. Of cases with NEWS>7 who survived (false positives for mortality) 66% (n=291/440) would have been similarly placed in a lower threshold, increasing specificity. The NEWS2 at admission did not outperform the original NEWS. [84] level II-2

Another study by Echevarria C et al. (2019) using prospective cohort design also aimed to compare prognostic performance of NEWS and NEWS2 for in-hospital mortality and the impact on alert frequency in patients with COPD.[85] level II-2 Findings revealed that NEWS2 showed superior discrimination for mortality to NEWS, but only reclassified 3.1% as not requiring a review, based on an alert trigger of 5 or more. $NEWS2_{All\ COPD}$, adopting target saturations of 88%–92% and scale 2 of the NEWS2 tool for all patients, led to an absolute reduction in alert frequency of 12.6%. The performance of $NEWS2_{All\ COPD}$ was similar to NEWS2, with no increased risk of death in the low-risk group. $NEWS2_{All\ COPD}$ was a stronger mortality predictor than NEWS (AUROC $NEWS2_{All\ COPD}$=0.72, 95%CI 0.68, 0.76, versus NEWS=0.65, 95%CI 0.61, 0.68; p<0.001). $NEWS2_{All\ COPD}$ showed a trend towards superiority compared with NEWS2 (AUROC $NEWS2_{All\ COPD}$=0.72, 95%CI 0.68, 0.76 versus NEWS2=0.70, 95%CI 0.67, 0.74; p=0.090). The percentage of patients classified as requiring an urgent review (score of 5 or more) for $NEWS2_{All\ COPD}$, NEWS2 and NEWS was 62.1%, 71.6% and 74.7% $NEWS2_{All\ COPD}$ resulted in a shift of total scores towards the lower risk range compared with NEWS2. $NEWS2_{All\ COPD}$ identified fewer patients requiring medical review relative to NEWS2 (9.5% absolute reduction), but the risk of death in the low-risk group was similar (3.5% and 3.1%, p=0.686).(Figure 28)[85] level II-2

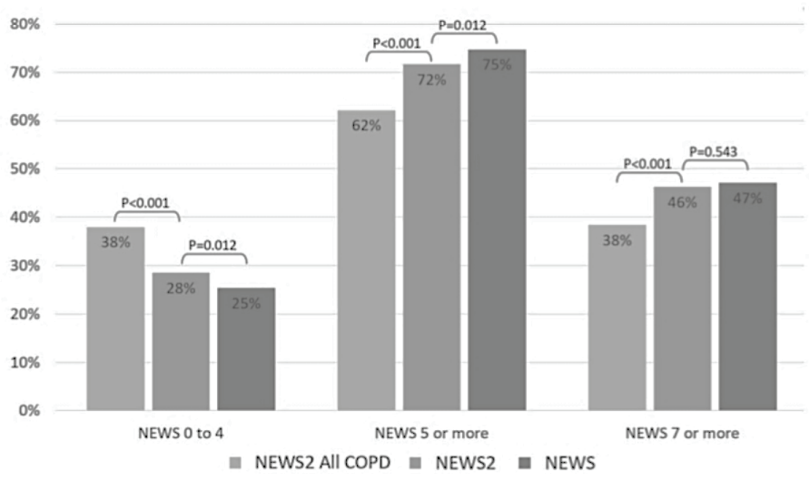


Figure 28: Frequency of alerts for NEWS2All COPD, NEWS2 and NEWS. Figure shows the percentage of patients in each risk category, grouped together by early warning score

Fernando SM et al. (2019) through retrospective cohort study, sought to evaluate the prognostic accuracy of NEWS2 among hospitalized patients with acute deterioration, requiring Rapid Response Team (RRT) assessment.[86] level II-2 The authors found that NEWS2 accurately predicted in-hospital mortality particularly among patients with suspected infection. For the entire RRT cohort, the AUROC was 0.72 (95%CI 0.71, 0.74) and for patients with suspected infection only, NEWS2 had an AUROC of 0.75 (95%CI 0.73, 0.78). At the critical threshold (≥ 5), the NEWS2 had sensitivity of 84.5% (95%CI 82.8, 86.2) and specificity of 49.0% (95%CI 47.4, 50.7). The number needed to examine (NNE) was 2.20 (95%CI 2.16, 2.25). For prediction of ICU admission, sensitivity of NEWS2 was 83.4% ((95%CI 81.4, 85.3) and specificity 64.5% (95%CI 62.7, 66.2). The study did not report AUROC value of NEWS2 for ICU admission.[86] level II-2

Mellhammar L et al. (2019) conducted a retrospective cohort study to compare the prognostic accuracy of qSOFA and NEWS2 for a composite outcome of sepsis with organ dysfunction, infection-related mortality within 72 hours or intensive care due to an infection.[87] level II-2 Retrospective analysis of data was done for two ED patient cohorts. Cohort A consisted of 526 patients with a diagnosed infection, 288 with the composite outcome. Cohort B consisted of 645 patients, of whom 269 had a diagnosed infection and 191 experienced the composite outcome. In Cohort A and B,

NEWS2 had significantly higher AUROC , 0.80 (95%CI 0.75, 0.83) and 0.70 (95%CI 0.65, 0.74), than qSOFA, AUROC 0.70 (95%CI 0.66, 0.75) and 0.62 (95%CI 0.57–0.67) p < 0.01 and, p = 0.02, respectively for the composite outcome. NEWS2 was superior to qSOFA for screening for sepsis with organ dysfunction, infection-related mortality or intensive care due to an infection both among infected patients and among undifferentiated patients at emergency departments.[87] level II-2

A multi centre prospective cohort study by Martin-Rodriguez F et al. (2019a) aimed to evaluate the ability of the prehospital NEWS2 to predict early mortality (within 48 hours) after the index event based on the triage priority assigned for any cause in the emergency department.[88] level II-2 A total of 1054 patients were included in the study and early mortality within the first 48 hours after the index event affected 55 patients (5.2%), of which 23 cases (41.8%) had causes of cardiovascular origin. Mortality at 7 days from the index event increased to 81 cases (7.7%) and up to 119 cases (11.3%) at 30 days. The predictive power of the NEWS2 scale to discriminate mortality at 2, 7, and 30 days was evidenced by an AUROC of 0.88 (95%CI 0.82, 0.94), 0.86 (95%CI 0.81, 0.91) and 0.82 (95%CI 0.77, 0.87), verifying how its capacity to assess mortality fell by 6% between the AUC at 2 days and the AUC at 30 days. Early mortality according to the assigned Spanish Triage System priority in the ED, in level I (resuscitation) the mortality rate was 24.4%, in level II (emergency) 5.5%, and in level III (urgency) 0.9%. The combined use of the NEWS2 and hospital triage can help to identify patients with a high risk of early death, including those that a *priori* were not emergencies or resuscitation cases. When stratified by triage levels, the AUCs of the NEWS2 obtained for short-term mortality varied between 0.77 (95%CI 0.65, 0.89) for level I and 0.94 (95%CI 0.79, 1) for level III. (Figure 29) A NEWS2 score greater than or equal to 7 among patients with priority III had a sensitivity of 100% (95%CI 56.6, 100) and a specificity of 78.7% (95%CI 75.1, 81.9) with a PPV of 4.1% (95%CI 1.8, 9.3) and a NPV of 100% (95%CI 99.1, 100). Meanwhile, in patients with priorities I and II, the cutoff point with better sensitivity and joint specificity rose to 9 points in both cases, with associated NPV of 92.5% (95%CI 82.1, 97.0) for level I and 98.4% (95%CI 96.2, 99.3) for level II. [88] level II-2

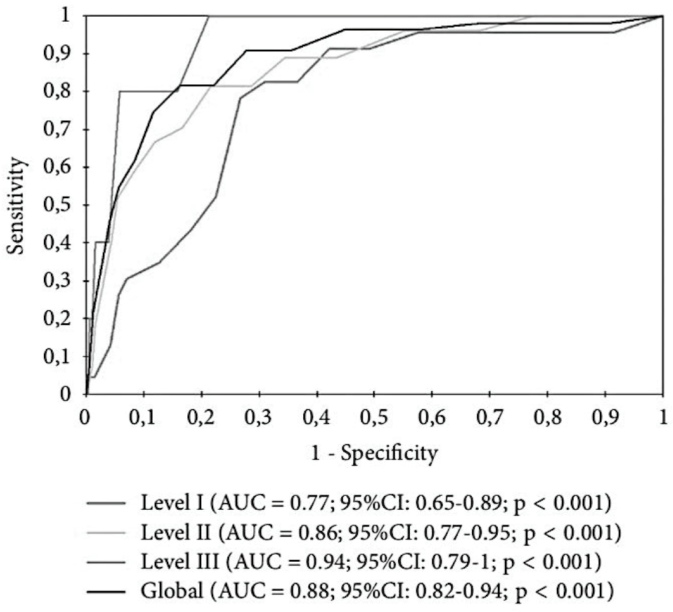


Figure 29: Diagnostic performance curves and areas under the curve with 95%CI for NEWS and Spanish triage system. Mortality less than 2 days.

Another prospective cohort study was conducted by Martin-Rodriguez F et al. (2019b) in adult patients who were treated by the advanced life support unit and transferred to the emergency department in order to evaluate six different EWS [Early Warning Score (EWS), National Early Warning Score 2 (NEWS 2), Modified Early Warning Score (MEWS), Vital- PAC Early Warning Score (ViEWS), Hamilton Early Warning Score (HEWS), Scottish Early Warning Score (SEWS)] that can be used in the pre-hospital setting to predict mortality in the first 48 hours.[89] level II-2 NEWS2 and the ViEWS had the best prognostic performance with an AUROC of 0.896 (95%CI 0.82, 0.95) and 0.894 (95%CI 0.82, 0.96), respectively. When comparing both scales, no statistically significant differences are observed (p = 0.919). The MEWS scale obtained the lowest AUROC of 0.848 (95%CI 0.76, 0.93). The NEWS2 and the ViEWS presented the same sensitivity and specificity for scores of more than 8 and a positive likelihood ratio of 3.36 (95%CI 2.69, 4.22) and 3.29 (95%CI 2.63, 4.11) respectively. For scores greater than or equal to 10, the specificity increased to 0.88 (95% CI 0.84–0.91) in the NEWS2 and 0.87 (95% CI 0.83–0.90) in the ViEWS with a probability ratio of 7.09 and 6.85, respectively. (Figure 30) [89] level II-2

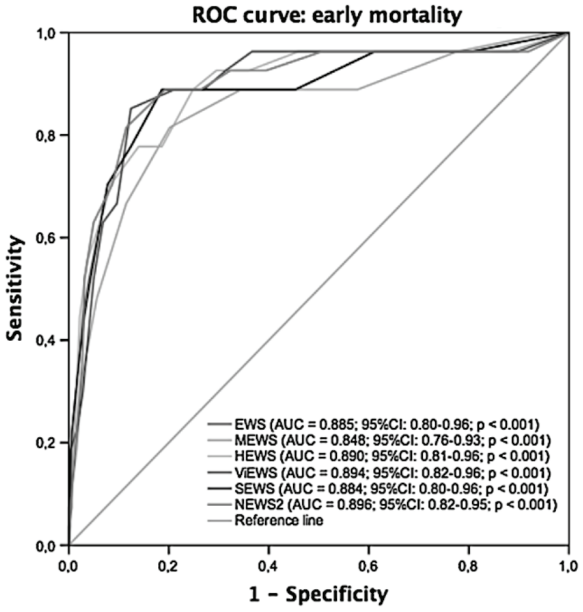


Figure 30: Diagnostic performance curves and areas under the curve with 95% confidence intervals for six EWS. Analysis of early mortality. EWS Early Warning Score, MEWS Modified Early Warning Score, HEWS Hamilton Early Warning Score, ViEWS VitalPAC Early Warning Score, SEWS Scottish Early Warning Score, NEWS2 National Early Warning Score-2.

6.1.2 Impact on clinical outcomes

Haegdorens F et al. (2019) conducted a post-hoc data analysis of a stepped wedge cluster randomized controlled trial in six Belgian hospitals to study the impact of NEWS implementation on cardiac arrest event, unexpected death rate and unplanned ICU admission.[90] level II-1 The intervention comprised of an observation protocol using NEWS combined with a pragmatic medical response strategy implemented in two medical wards and two surgical wards for each participated hospitals. The control group standard care was provided where nurses observed patients according to local protocols or standard practice. The cardiac arrest rate was 1.0 per 1000 admissions versus 1.3 per 1000 admissions (control), the unexpected death rate was 0.6 per 1000 admissions versus 1.5 per admissions (control) and the unplanned ICU admission was 10.7 per 1000 admissions versus 6.5 per 1000 admissions (control). However, the differences between control and intervention groups were not seen to be statistically

significant. Based on analysis of aggregrated ward level data, compliance to NEWS protocol was negatively associated with patient mortality adjusted for comorbidity and age (correlation coefficients, r = -0.452, p=0.027).[90, 91] level II-1

The pre-post intervention study conducted by Farenden S et al. (2017) in a tertiary UK hospital did not observed any change in mortality at different time points six months following the introduction of NEWS.[92] level II-2 However, the finding of this study reinforced the fact that there was a positive correlation (r^2=0.854) between higher NEWS scores and hospital mortality.[92] level II-2

In another pre-post intervention study, Sutherasan Y et al. (2018) sought to evaluate the impact of NEWS protocol six months post implementation, in response to patient deterioration in general medical wards.[93] level II-2 The NEWS was compared with traditional hierarchy of stepwise approach of assessment (4-hourly observation) and management. The study found that higher NEWS on admission was associated with increased in-hospital mortality and ICU transfer rates. Implementing NEWS did not change overall patient outcomes [in-hospital mortality; 2.6% (pre-NEWS) versus 2.0% (NEWS group), p=0.47 and ICU admission; 5.7% (pre-NEWS) versus 3.9% (NEWS group), p=0.16].[93] level II-2

An evaluation of the impact of a NEWS or NEWS-based track and trigger system (TTS) on the rate of in-patient cardiac arrests (IHCAs) and patients' survival in 106 UK hospitals was carried out by Hogan H et al. (2019).[94] level III Based on cross-sectional interrupted time-series and difference-in-difference analyses of 13 millions hospital admissions data with 34 202 identified cardiac arrest events between 2009 and 2015, there was a downward trend in the rate of IHCAs attended by the resuscitation team and improvement in the survival of IHCA patients. The use of a NEWS or NEWS-based TTS, when compared with a non-NEWS TTS, was associated with an additional reduction above pre-existing trends of 8.4% in the rate of IHCAs [Incidence rate ratio, IRR 0.925 (95%CI 0.890, 0.961;p<0.001)]. A conversion from paper to electronic TTS use was associated with an additional 7.6% decrease in the rate of IHCAs [IRR 0.923 (95%CI 0.873, 0.976;p=0.005)]. Restricting IHCAs to ward-based arrests increased the reduction to 9.9% for NEWS [IRR 0.901 (95%CI 0.858, 0.944; p < 0.001)] or NEWS-based TTSs and to 13.1% for electronic TTSs [IRR 0.869 (95%CI 0.809, 0.933; p<0.001)]. There was no evidence of an association between the type of TTS and survival of all hospital admissions, or on any of the measures of survival of patients who had an IHCA. [94] level III

6.2 Safety

A prospective cohort study of 370 medical patients conducted by Kolic I et al. (2015) revealed a high rate of NEWS score calculated incorrectly (18.9%) which adversely affected clinical response (25.9% of inappropriate response); a trend towards increased mortality for patients who received an incorrect response to a NEWS score was observed.[95] level II-2 The authors highlighted an important patient safety concern whereby accuracy of NEWS scoring decreased significantly with increasing score or worsening physiological derangement. (Table 17). Inappropriate or inadequate response was associated with increasing NEWS (Table 18) and day of admission. Patients admitted at the weekend had a worse clinical response [adjusted OR 4.15 (95%CI 2.24, 7.69), p<0.0001]. Clinically there was a significant difference in mortality between patients who has an adequate response to the score (6%) compared to patients who had an inadequate clinical response (8.5%), but the results did not reach statistical significance (p=0.573).[95] level II-2

Table 17: Univariate analysis of factors associated with a NEWS scoring error

Factor		Correct score	Incorrect score	Univariate analysis	
				Crude OR (95%CI)	p value
Age		77 (18–102)	77 (23–97)	1.01 (0.99–1.02)	0.160
Time of day	Day (9am-9pm) Night (9pm-9am)	149 (79.7) 151 (82.5)	38 (20.3) 32 (17.5)	0.83 (0.49–1.40)	0.487
Day of week	Weekday Weekend	237 (80.3) 63 (84.0)	58 (19.7) 12 (16.0)	0.78 (0.39–1.54)	0.471
NEW score	NEWS 0 NEWS 1–4 NEWS 5–6 NEWS 7	131 (87.9) 156 (78.0) 9 (69.2) 4 (50.0)	18 (12.1) 44 (22.0) 4 (30.8) 4 (50.0)	1.0 2.05 (1.13–3.72) 3.24 (0.90–11.60) 7.28 (1.67–31.68)	 0.018 0.072 0.008

Data is presented as median (range) or number (percent).
OR, Odds Ratio; CI, Confidence Interval; NEW score, National Early Warning Score. Binary logistic regression analysis with score error as the indicator dependent variable.

Table 18: Univariate and multivariate analysis of factors affecting the adequacy of the clinical response to NEWS score

Factor		Adequate response	Inadequate response	Univariate analysis		Multivariate analysis	
				Crude OR (95%CI)	p value	Adjusted OR (95% CI)	p value
Age		78 (18–102)	75 (21–97)	1.01 (0.99–1.02)	0.358		
Time of day	Day (9am-9pm) Night (9pm-9am)	142 (75.9) 132 (72.1)	45 (24.1) 51 (27.9)	1.22 (0.77–1.94)	0.404		
Day of week	Weekday Weekend	234 (79.3) 40 (53.3)	61 (20.7) 35 (46.7)	3.36 (1.97–5.73)	<0.0001	4.15 (2.24–7.69)	<0.0001
NEW score	NEWS 0 NEWS 1–4 NEWS 5–6 NEWS 7	137 (92.0) 135 (67.5) 0[a] 2 (25.0)	12 (8.0) 65 (32.5) 13 (100.0) 6 (75.0)	1.0 5.50 (2.84-10.64) 297 (16.64-5302) 34.25 (6.22-188.6)	 <0.0001 <0.0001 <0.0001	1.0 6.13 (3.08-12.16) 177 (20.72–1510) 40.64 (7.04–234.7)	 <0.0001 <0.0001 <0.0001

Data is presented as median (range) or number (percent).
OR, Odds Ratio; CI, Confidence Interval; NEW score, National Early Warning Score.
Binary logistic regression analysis with adequate response as the indicator dependent variable.
a A contingency factor of 0.5 was used to enable logistic regression calculations.

Petersen JA et al. (2014) utilising a prospective cohort study design, aimed to investigate the occurrence of serious adverse events (unexpected death, cardiac arrest and unanticipated ICU admission) and the attributable NEWS related factors to this incidents.[96] level II-2 The authors found a concerning number of serious adverse events (144 events) whereby in 92% of the events, non-adherence to the escalation protocol occurred at one or several levels. Patients were monitored at least twice daily in 88% of the cases, but in only 19% the minimal observation interval according to the escalation protocol was followed and patients with higher NEWS were less likely to be monitored adequately. Patients were monitored according to the escalation protocol only in 13% of unanticipated ICU admission, 31% of cardiac arrest and 13% unexpected death. Nurses escalated care and contacted physicians in 64% and 60% of events of unanticipated ICU admission and the corresponding proportions for combined were 58% and 55%. On call physicians provided adequate care (defined as attended the patient immediately and implemented an appropriate treatment) in only 49% of cases of unanticipated ICU admission and 29% of cases of the combined outcome. Out of 106 events with EWS ≥ 6 of which 58% were not treated by the attending physician, 27 of these, there was no documentation that the attending physician had been alerted by nursing staff. Senior staff (specialists) was involved according to protocol (with

NEWS ≥ 9), only in 53% and 36% of cases of unanticipated ICU admission and cardiac arrest, respectively. The authors identified poor compliance with the escalation protocol was commonly found when serious adverse events occurred, however level of care provided by physicians was also a problem in a hospital with implemented early warning system.[96] level II-2

A HTA on the use of information technology for early warning system found that no adverse events or negative effects on patient safety were reported as a result of the introduction of electronic early warning systems. [29] level I Adverse event reporting was minimal. One study documented a technical problems with the device prevented complete recording for the whole monitoring period for 33 of 257 monitored patients. In 30 of these episodes, motion artifact gave a spurious abnormal reading. [29] level I

6.3 Economic Evaluation

The economic evidence from the literature on NEWS was limited. The search of the economic literature did not produce any full economic evaluation. There were one health technology assessment (HTA) (HIQA, 2015) and two budget impact analyses (BIA) (NCEC, 2013 and NCEC, 2014) included in this review. These studies were Irish studies previously commissioned by the Department of Health. The HTA described the electronic implementation of NEWS, whilst one BIA was for original guideline on NEWS (NCEC, 2013) and another BIA on the additional cost implications from the implementation of the Sepsis Management Guideline (NCEC, 2014).

The HTA conducted by Irish Health Information and Quality Authority (HIQA) (2015) estimated resources gains and the investment required to implement an electronic early warning system into a representative Irish teaching hospital (530 bed occupancy).[29] level I Benefits were estimated using extrapolated results from the systematic review and measured as resource gains. Using Irish average LOS data and evidence from Jones et al. (2011) estimated potential reductions in general average LOS was 28.9% and ICU average LOS was 40.3%. It was estimated that these reductions in LOS translated into just over 802,000 bed days per annum in general wards and 30,628 ICU bed days per annum. However, this was considered as an efficiency rather than a monetary saving. Other potential benefits presented were efficiencies owing to a reduction in vital sign recording time (up to 1.6 times faster than the paper system). [29] level I

In terms of the investment required to move from paper based to an electronic EWS, a core model without continuous monitoring was included in the analysis. Resources considered over a five-year period were classified as technology based (software, hardware and integration fees) and implementation (project management staff, staff education and clinical leadership). Note that two different licensing agreements were considered in the analysis. Type 1 involved a fee for a definitive time period plus additional hardware and maintenance costs per annum. Whereas, type 2 required a one-off license payment, but maintenance and hardware costs were on-going. Prices were estimated using indicative costs from suppliers and hospitals in the UK. Total cost for type 1 (including implementation costs) over five years was €1.0 million and type 2 was €1.3 million per site. The authors highlighted that this amounted to a national cost of €40.1 million for type 1 and €51.4 million for type 2 over five years. [29] level I

The Irish National Clinical Guideline for NEWS (NCEC, 2013) included a BIA to assess the economic impact of introducing NEWS and the COMPASS education programme.[97] In assessing the budget impact of employing NEWS and COMPASS two cost categories were considered, those that applied to the initial implementation phase and the on-going intervention costs. Initial costs, included staff costs (trainers and trainees), which amounted to €7.47million and non-staff costs of €18,000 for materials. On-going intervention costs, which included staff and non-staff costs, were estimated to be €425,000 per annum. The report acknowledged that additional resources were likely due to the expected increase in the response rate to triggers; however an estimate for this was not provided. In addition, efficiency savings were

likely owing to reduced ICU days (estimated at € 4.2 million using Irish ICU LOS data and cost per diem and assumptions regarding reduction in ICU admissions informed by Mitchell et al. 2010). Other efficiency savings were gained from replacing the previously used ALERT system with COMPASS, realising a saving of approximately € 6,000 in annual licence fees per annum, also disability treatments avoided due to the reduction in cardiac arrest were expected but the potential value attributed to this saving was not given.[97]

The Sepsis Management Guideline of the National Clinical Effectiveness Committee (NCEC), published by the Department of Health in 2014 highlighted the significance of the timely recognition of sepsis and incorporated the NEWS system as part of a suite of guidelines to detect the acutely deteriorating in-patient in the correct management of sepsis.[98] The report included evidence from a UK study, conducted by the Sepsis Trust, who found that compliance with the sepsis protocol reduced the relative risk of sepsis by 46.6% (Richards, 2013). The study also showed that patients in receipt of the protocol reduced their LOS by an average of two days in critical care with a total reduction of 3.4 hospital days, which equated to a cost saving of € 4,500 per patient (Richards, 2013). The NCEC (2014) also conducted a BIA which considered the additional cost implications that could arise further to implementation of the guideline. They outlined the costs involved in introducing point of care lactate testing, and, in their BIA considered the costs of the device, education and staff. The BIA showed an estimated cost of € 1.9 million (€ 1.4 million incurred in the initial set-up and on-going annual costs of € 0.5 million) leading to a saving of € 12 million per annum.[98]

Local costing analysis

Based on cost analysis of local costing data, there is a potential long-term cost saving in NEWS implementation if NEWS is integrated into existing electronic medical record (EMR) system. (Table 19)

Table 19: Cost comparison between local paper- and electronic-based EWS

Paper-based Implementation – Medical Department , Hospital Sg Buloh, Selangor

11 medical wards; 213 beds

Initial Implementation Cost :

Promotion – roadshow, launching and awareness events, posters	**RM 750**
Training - material ie manuals, NEWS charts,food * **(**Trainers – matron , medical specialists – FOC)	**RM 800**
Total	**RM 1550**

Ongoing Intervention Cost :

Training –CMEs (12 session/year)(20 nurses/session)	**RM 1500**
NEWS charts (10 000pc/3mthly) (0.28cents/pc)	**RM 11 200**
Total Annual Cost	**RM 12 700**

Electronic-based Implementation – Integration into Existing EHR system ; UMMC

12 wards (medical and surgical based wards); 804 beds

Initial Implementation Cost :

Promotion – roadshow, launching and awareness events	**RM500**
Training – NHS online training module	**Free**
Project management fees (5 staffs)	**30 man hours at RM100 per hour**
System Integration Fee Additional hardware-handheld devices etc	**Negligible** (In-house) **Existing**
Total	**RM 3500**

Ongoing Intervention Cost :

Training – free online NHS training module	**Free**
Total Annual Cost	**Minimal**

Source of costing data from Medical Department, Hospital Sg Buloh and Faculty of Medicine, University Malaya

6.4 Organisational implications

6.4.1 Impact on resources

a) Length of hospital stay

A systematic review by Smith ME et al. (2014) (n=21) reported four studies evaluated length of hospital stay before and after EWS implementation and found mixed results.[17] level 1 In a good-quality trial and a pre–post observational study, no differences in length of hospital stay were detected 1–2 years after EWS implementation. A study with a shorter observation period (47 days before and 38 days after EWS implementation) found a significantly reduced length of stay (median [IQR] 9.7 days [4.70-19.8] vs. 6.9 days [3.3–13.9]; p=0.001). An increase in length of hospital stay from 4.0 (1.8–8.3) days to 4.8 (2.2–9.8) days was observed in a fourth study comparing data four months before with those four months after EWS implementation. Variation in study populations (patients with an unplanned ICU admission or medical emergency vs all ward patients) and follow-up time make it difficult to assess the overall effect of EWS on length of stay across studies. [17] level 1

Alam N et al. (2015) in a cohort study evaluating the NEWS performance in emergency department found that LOS was significantly correlated with NEWS, at all measured time points (p<0.05). Median LOS more than doubled for a NEWS score >7 compared with a score of 0–4. [40] level II-2

b) Admission to the intensive care

Smith ME et al. (2014) also reported mixed results on the impact of the EWS on ICU utilization also reported mixed results.[17] level 1 Two studies found a significant increase in the number of ICU admissions after implementing EWS and accounting for differences in overall hospital admission rates, whereas a third study found no difference in the proportion of patients transferred from the general medicine wards to the ICUs. One study involving two hospitals found increases of 24.5% and 14% in the annual ICU admission rates, but a significant decrease in the proportion of patients admitted to the ICU after having undergone cardiopulmonary resuscitation (pre-EWS 3% vs. post-EWS 2%, p=0.004; and pre-EWS 6.65% vs. post-EWS 2.63%, p= 0.001). One study found the proportion of clinically unstable patients who were on the ward for six hours or longer had decreased from 41.2% to 24.5% after implementing EWS. [17] level 1

c) Use of rapid response or code team

Smith ME et al. (2014) found at least a 50% increase in the number of RRT or ICU liaison team calls in all studies assessing the impact of EWS on RRTs and code teams. Code blue calls decreased by 6–33% in three studies. [17] level 1 One study found that the number of code blue calls for a patient still breathing and with a pulse increased from 47.9% to 64.4%, suggesting that response teams were activated before the patient's condition deteriorated to the point of cardiac or respiratory arrest. [17] level 1

6.4.2 Impact on work process

a) Workload

Jarvis S et al. (2015a) revealed that escalation of care to a doctor when any component of NEWS scores 3 compared to when aggregate NEWS values ≥5, would have increased doctors workload by 40% with only a small increase in the number of detected adverse outcomes from 2.99 to 3.08 per day (a 3% improvement in detection).[55] level II-2

In a study by Kovacs C et al. (2016) involving surgical and medical patients, the analysis of NEWS efficiency curve showed that using a NEWS threshold of 5 generates different workload and detection rates for the two patient groups (medical: workload 12·3%, detection 70·2%; surgical: workload 6·1%, detection 60·6%); and similarly for a NEWS value of 7 (medical: workload 4·4%, detection 48·7%; surgical: workload 1·8%, detection 36·9%).[56] level II-2

A result from study by Forster S et al. (2018) in COPD population showed that NEWS would have generated an eightfold increase in mandatory workload due to a lower specificity in this population.[64] level II-2

b) Level of adherence (documentation/clinical response)

Documentation

Pedersen NE et al. (2017) in a cross-sectional study performed assessment on NEWS data recorded manually and stored electronically over 12 months period in an inpatient hospital service.[99] Of 2,835,333 NEWS records from 168 496 patients, 10% were incomplete with one or more variable missing and 0.2% of records containing implausible values. Body temperature was the most frequently missing single NEWS variable, missing in 66% (n=79,991) of incomplete records. Artefacts or extreme value were detected in 0.2% (n=5,361) of records indicating that entry of wrong values and entry of values in wrong fields were sources of error. The most common extreme value was 0. Digit preferences were identified for respiratory rate, supplementation oxygen flow, pulse rate, and systolic blood pressure. Respiratory rate and pulse rate showed a digit preference for even numbers. The distribution indicated an overrepresentation of values for respiratory rates divisible by 4 (16, 20, 24 and 28). A preference for numbers divisible by 10 was seen in both pulse rate and systolic blood pressure records. A distributional anomaly was found as an accumulation was seen of records of pulse rate just below 91 beats per minute. Among complete NEWS records, 64% had NEWS≥1; 29% had NEWS≥3; and 8% had NEWS≥6. Staff practice influenced the recorded values in a system where data were manually entered into the EMR.[99]

Utilising cross-sectional study design, Clifton DA et al. (2015) sought to investigate factors associated with errors using an established paper-based early warning score (EWS) system.[100] Based on analysis of 6 795 observation sets, from 200 postsurgical patients, 34.5% of all observation sets were incomplete. Temperature was the most commonly missing vital sign, being absent in 11.4% of observation sets. An incomplete observation sets were more likely to contain observations which should have led to an alert than complete observation sets (15.1% vs 7.6%, $p<0.001$), but less likely to have an alerting score correctly calculated (38.8% vs 30.0%, $p<0.001$). In a complete observation sets, type of error that occurred were errors in the assignment of weights to vital sign measurements (16.2%), error in the aggregate score(15.9%) and composite error in the assignment of weights and the aggregate score (16.9%). Mis-scoring was much more common when leaving a sequence of three or more consecutive observation sets with aggregate scores of 0 (55.3%) than within the sequence (3.0%, $p<0.001$). Observation sets that 'incorrectly' alerted were more frequently followed by a correctly alerting observation set than error-free non- alerting observation sets (14.7% vs 4.2%, $p<0.001$). Observation sets that 'incorrectly' did not alert were more frequently followed by an observation set that did not alert than error-free alerting observation sets (73.2% vs 45.8%, $p<0.001$).The authors concluded that missed alerts were particularly common in incomplete observation sets and when a patient first became unstable. Observation sets that 'incorrectly' alert or 'incorrectly' do not alert were highly predictive of the next observation set, suggesting that clinical staff detect both deterioration and improvement in advance of the EWS system by using information not currently encoded within it. [100]

Clinical response

Poor compliance with the NEWS protocol and level of care was observed when faced with a deteriorating patient as described by Petersen JA et al. (2014). [96] level II-2

Based on the finding reported by Kolic I et al. (2015), clinical response to NEWS scores was significantly worse at weekends compared to weekdays, which has implications for standards of care for patients out of hours. [95] level II-2

In a mixed method study by Lydon S et al. (2015) revealed many of the barriers to the implementation of NEWS were related to sociocultural aspects of introducing a new system into current practice.[101] It was highlighted that these sociocultural issues may affect non-compliance and must be addressed in order to improve detection of the clinical deterioration of patients.[101]

6.4.3 Education and training

Liaw SY et al. in a randomised control trial sought to evaluated the effect of an educational programme on improving the nurses' knowledge and performances in recognising and responding to clinical deterioration.[102, 103] level II-1 The interactive web-based educational programme addressed three areas: (1) early detection of changes in vital signs; (2) performance of nursing assessment and interventions using airway, breathing, circulation, disability and expose/examine and (3) reporting clinical deterioration using identity, situation, background, assessment and recommendation (ISBAR) communication tool. The experimental group underwent a 3 hours programme while the control group received no intervention. Pretests and post-tests, a mannequin-based assessment and a multiple-choice knowledge questionnaire were conducted. The authors evaluated the participants' performances in assessing, managing and reporting the deterioration of a patient using a validated performance tool. A significantly higher number of nurses from the experimental group than the control group monitored respiratory rates (48.2% vs 25%, $p<0.05$) and pulse rates (74.3% vs 37.5%, $p<0.01$) in the simulated environment, after the intervention. The post-test mean scores of the experimental group was significantly higher than the control group for knowledge (21.29 vs 18.28, $p<0.001$), performance in assessing and managing clinical deterioration (25.83 vs 19.50, $p<0.001$) and reporting clinical deterioration (12.83 vs 10.97, $p<0.001$). There was a significant increase in knowledge and performance in assessing, managing and reporting clinical deterioration following participation in a web-based educational programme developed for hospital nurses one week post-intervention. [102, 103] level II-1

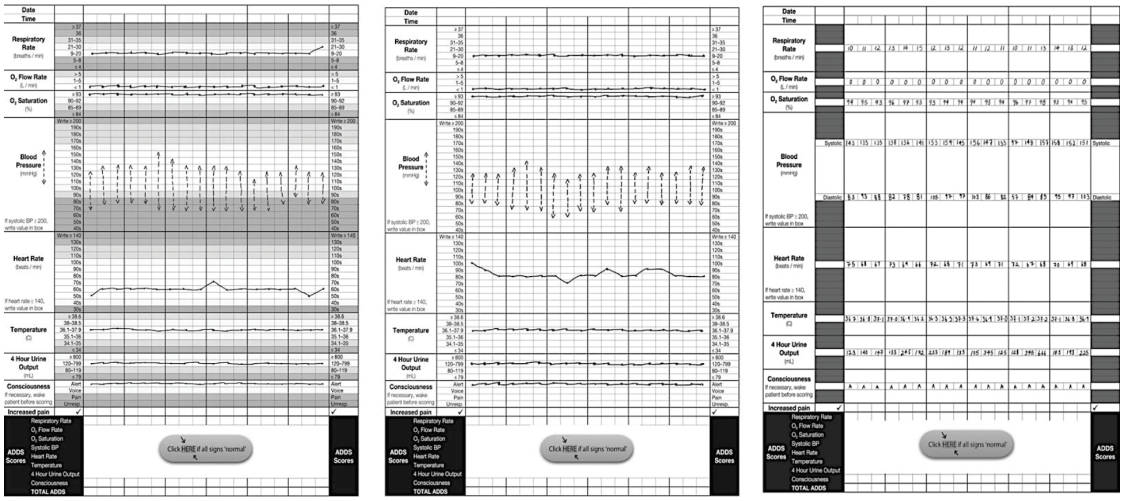
A before and after study was undertaken by Merriel A et al. (2015) to establish whether a short multidisciplinary training intervention can improve recognition of the deteriorating patient using an aggregated physiological parameter scoring system EWS.[104] level II-2 Nursing, medical, and allied nursing staff participated in an hour-long training session, using real-life scenarios with simple tools and structured debriefing. After training, staff were more likely to calculate EWS scores correctly [68.02% vs 55.12%; risk ratio (RR) = 1.24 (95%CI 1.07, 1.44], and observations were more likely to be performed at the correct frequency [78.57% vs 68.09%; RR = 1.20 (95% CI 1.09,1.32)]. Multidisciplinary training, according to core principles, can lead to more accurate identification of deteriorating patients, up to 6 months post-intervention, with implications for subsequent care and outcome. [104] level II-2

6.4.4 EWS Implementation

a) Observation Tool : The impact of chart design

Using eye-tracking technology to study search efficiency and cognitive workload, Cornish L et al. (2019) demonstrated that a chart that incorporated both graphically

displayed observations and an integrated colour-based scoring-system yielded faster, more accurate responses and fewer, shorter eye fixations to detect abnormal patient observations.[105] A comparison was made between three chart designs: (a) graphically-displayed observations and a colour-based scoring system (b) graphically-displayed observations without a colour-based scoring system (c) tabular chart (neither graphically-displayed observations nor a colour-based scoring system). (Figure 31) The graphically-displayed observations and a colour-based scoring system produced responses 8.34 seconds faster (CI 6.68,10.00) than the graphical-only chart and responses 29.39 seconds faster (CI 26.30,32.49) than the tabular chart, had 5.09% (CI 1.10,9.07) fewer errors than the graphical-only chart and 23.60% (CI 19.76,27.62) fewer errors than the tabular chart. The resultant lowest fixation counts and the shortest average fixation durations suggest that both colour-based scoring-systems and graphically displayed observations improve search efficiency and reduce the cognitive resources required to process vital sign data.[105] level II-1



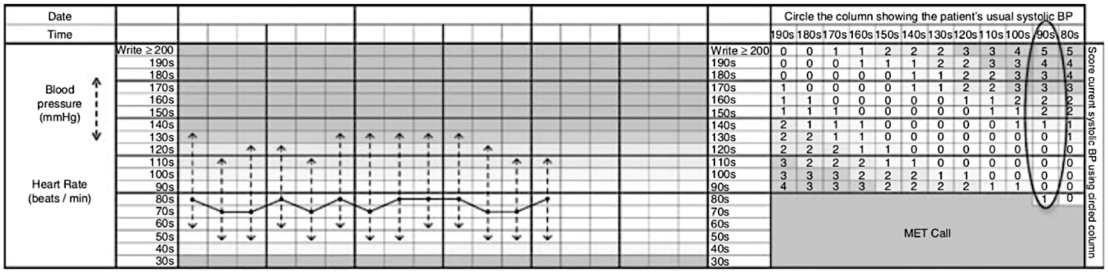
(a) (b) (c)

Figure 31: Examples of the three observation chart design extracts, as seen by participants during the experiment: (a) the graphically displayed observations and an integrated colour-based scoring-system; (b) the 'graphical-only chart' (graphically displayed observations without a colour-based scoring-system); and (c) the 'tabular chart' (neither graphically displayed observations nor a colour-based scoring-system).

A clinical trial conducted by Fung et al. (2014) also demonstrated that clinical staffs were better and faster at detecting abnormalities on EWS charts with graphical display of observation trends.106 One hundred healthcare professionals who used observation charts in their daily clinical activities were given six clinical scenarios to study on two type of charts: (a) chart with a graphic depiction of observations and (b) chart with numerically depicted observations. The speed and accuracy of data interpretation between the two charts were compared. Response to the chart with graphic portrayal of data was 1.6 times faster ($p<0.0001$) and 15% more accurate (90% versus 75%, $p<0.0001$) than the chart with numerical display. [106] level II-1

Christofidis MJ et al. (2013) investigated whether overlapping blood pressure and heart rate graphs improve chart-users' ability to recognise derangements the vital signs.(Figure 32) The result showed that charts where blood pressure and heart rate observations were plotted separately, produced fewer errors (effect size *d* 0.55) and faster response times (effect size *d* 0.57).[107] level II-1 *(effect size: small 0.20; medium 0.50; large 0.80)*

(a) Overlapping blood pressure and heart rate graph with colour based scoring EWS



(b) Separate blood pressure and heart rate graph with colour based scoring EWS

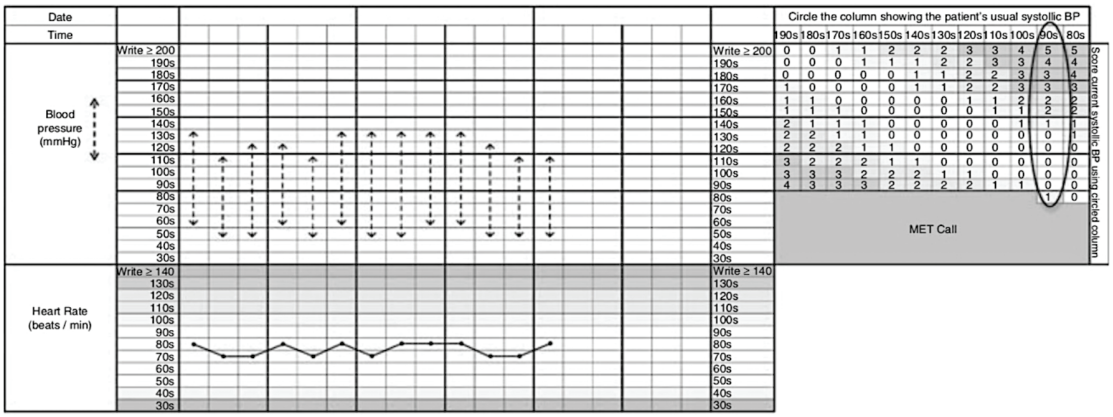
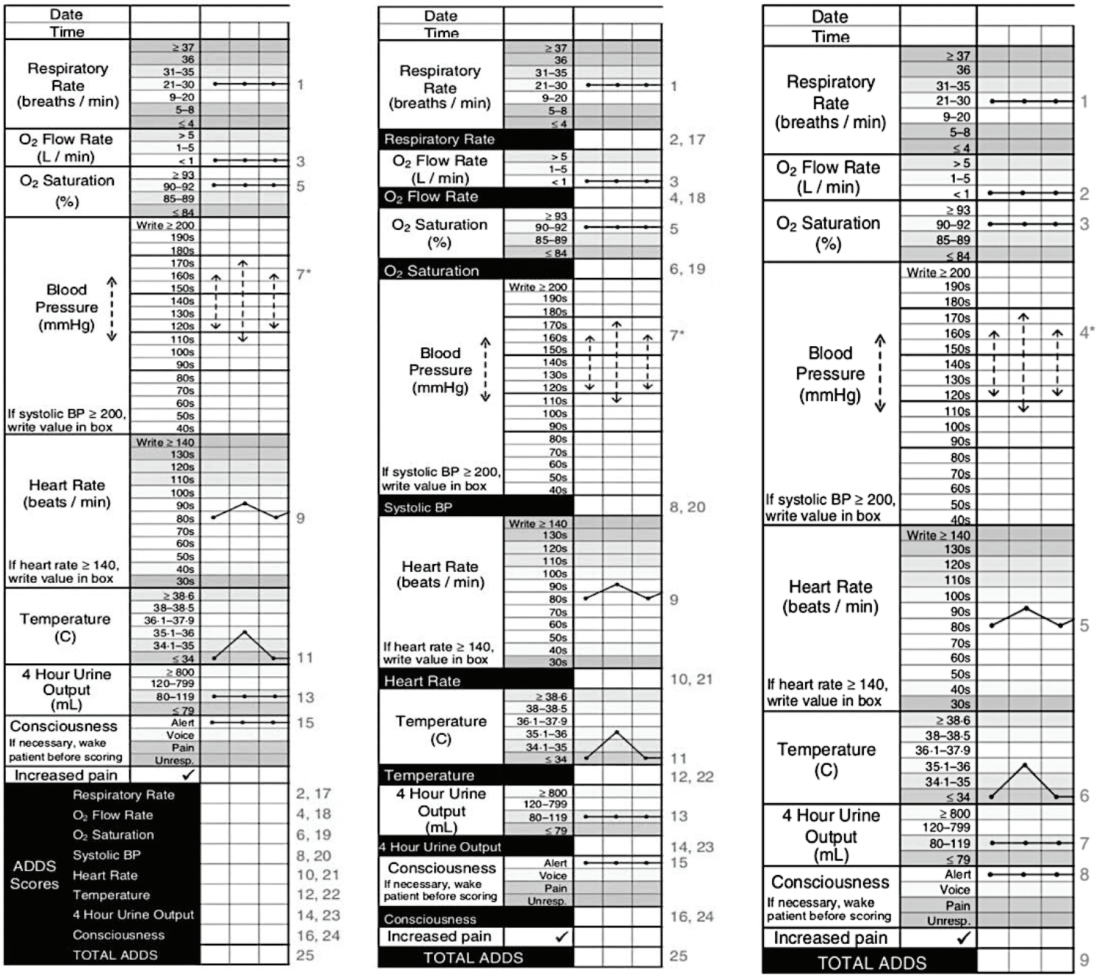


Figure 32: Chart design extracts used in the study

Christofidis MJ et al. (2015) sought to evaluate the effect of chart design on the speed and accuracy of scoring.108 Forty-seven novice chart-users were presented with three different observation chart designs for EWS. They varied according to their placement of individual vital sign scoring-rows: (a) grouped row (b) separate rows, with each row presented immediately below the corresponding vital sign row (c) no rows (excluded altogether). (Figure 33) The response time (the mean number of seconds to record an EWS) was 6.35 seconds faster when there was no row for scoring than when there were separate rows and 7.69 seconds faster when no row was compared to grouped rows. Participants responded 1.34 seconds faster with separated rows compared to grouped rows. Error rates (the number of incorrect EWS as a percentage) were 2.48% and 2.76% less with no row compared to separate rows and grouped rows respectively. There was no significant difference between the separated and grouped rows conditions. Data for patient in the worse state was associated with prolonged response time and higher chance of error.[108 level II-1]



(a) Grouped row (b) Separated rows (c) No row

Figure 33: The three chart designs which varied according to placement of scoring rows. Red numerals indicate the potential order in which a chart user typically attend to vital sign observation rows and scoring-rows when determining scores.

Another study by Christofidis MJ et al. (2016) further evaluated the impact of chart design on chart-users' detection of patient deterioration by examining different design features.109 The evaluation was done using a 2 x 2 x 2 x 2 mixed factorial design by random assignment. The following design features were assessed as shown in Figure 34;

i. data-recording format (drawn dots vs. written numbers)
ii. scoring-system integration (integrated colour-based system vs. non-integrated tabular system)
iii. scoring-row placement (grouped vs. separate) varied within-participants
iv. scores (present vs. absent) varied between-participants

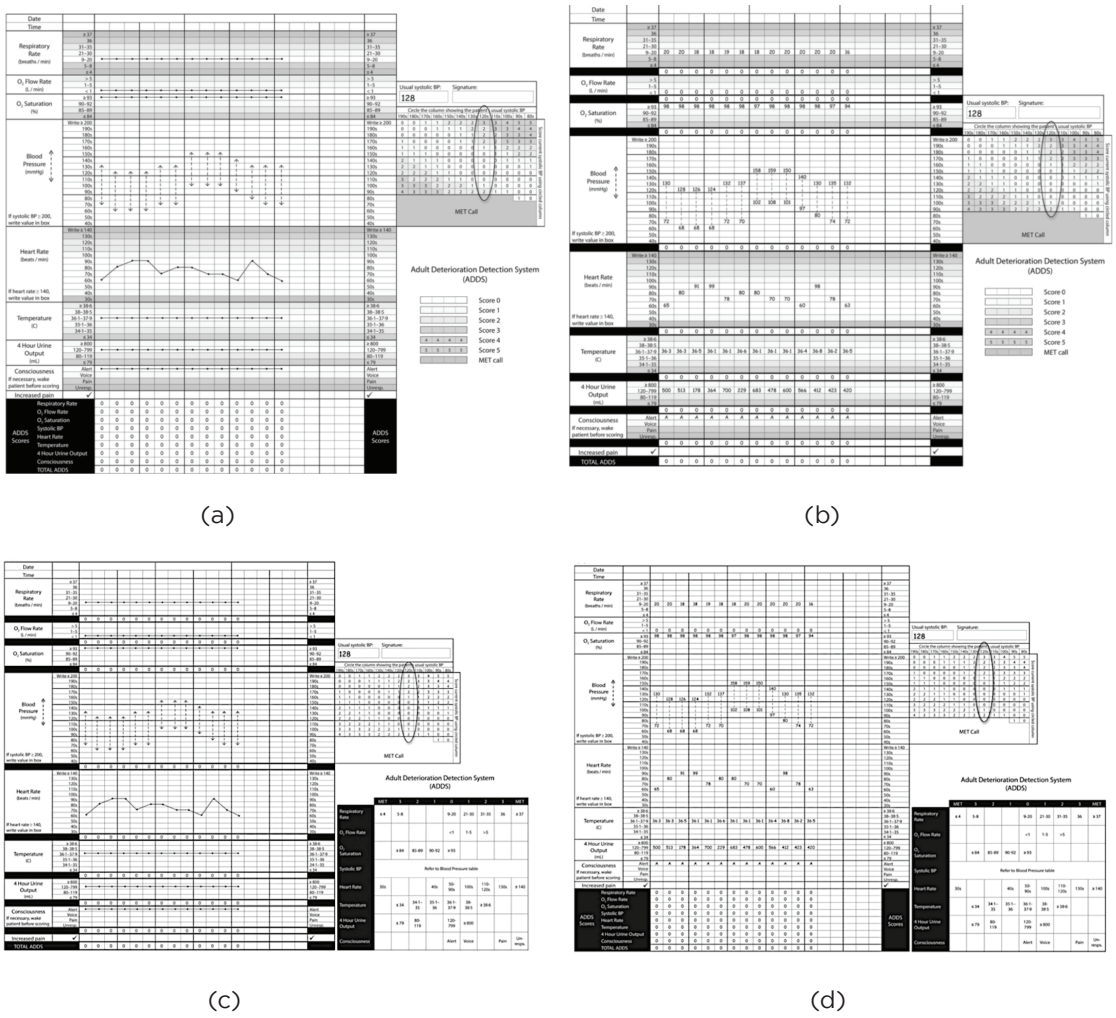


Figure 34: Examples of chart design used with EWS (a) an integrated colour-based scoring-system and grouped scoring rows (b) an integrated colour-based scoring-system and separate scoring-rows (c) a non-integrated tabular scoring-system and separate scoring-rows (d) a non-integrated tabular scoring-system and grouped scoring-rows. The remaining four designs were identical, except that each used the alternative data-recording format option.

Based on the responses of 205 novice chart-users for the given eight clinical scenarios (four containing abnormal observations) on each of eight designs (64 cases of genuine de-identified patient data), chart-users detected patient deterioration faster and more accurately using designs with a drawn-dot data-recording format (as opposed to written numbers) [2.24 seconds faster (CI 1.76,2.72) and 2.57% fewer errors (CI 1.19,3.94)] and an integrated colour-based scoring-system (rather than a non-integrated tabular one) [3.94 seconds faster (CI 3.40,4.48) and 2.24% fewer errors (CI 0.75,3.73)]. Charts were manipulated to whether or not EWS scores available to participants, to give a broader range of real-world clinical situations. There was a main effect of scores, indicating that participants for whom scores were present (versus absent) responded faster overall, $F(1, 186) = 194.80$, $p < 0.001$, effect size $\eta^2 = 0.52$. Again, fewer errors was made overall by the participants for whom scores were present (versus absent), $F(1, 186) = 51.99$, $p < 0.001$, effect size $\eta^2 = 0.22$. The optimal arrangement of scoring-rows may depend on the clinical context and compliance culture. Participants were faster at determining and recording early-warning scores when the scoring-rows were separate, rather than grouped if scores were present.[109]
level II-1

b) Electronic Tool: Opportunity For Automation

The HTA conducted by Irish Health Information and Quality Authority (HIQA) (2015) identified eight studies (one RCTs, two randomised controlled cross-over studies, one controlled before and after study, four before and after studies) that investigate the role of automation in improving detection of deteriorating patients with early warning scores. 29 level I The early warning systems that were examined in this HTA included the review of a move from a paper-based to electronic early warning systems, the comparison of a new electronic alerting system to no alerts and continuous monitoring systems either with or without the integration of an automated electronic early warning. The results indicated that there were evidences that the implementation of electronic early warning systems has contributed to reduced mortality rates. The change in general and intensive care unit (ICU) length of stay (LOS) varied from a minimal reduction up to 29% and 40% reductions, respectively. Improved efficiency and accuracy of recording vital sign parameters and compliance with escalation protocols were also reported. However, the authors noted the limitation to generalise the results as the quality of studies of effectiveness was variable and the interventions performed in a number of healthcare jurisdictions with a range of outcomes measured. 29 level I The summary of the studies included in the review and the outcome reported, grouped according to type of comparison is shown below in Table 20. 29 level I

Table 20: Summary of the included studies and the outcome reported according to type of comparison

Type of comparison	Study	Outcome reported
Manual versus electronic data input	**Prytherch 2006, UK (Randomised Crossover Study, classroom setting.)** [Handheld personal digital assistant, VitalPAC versus paper-based generic early warning score]	1. Fewer errors in computer-based systems 2. Recording efficiency gains ❖ Incorrect entries/omissions decreased from 29% to 10% using the VitalPAC method. ❖ Fewer incorrect clinical actions were indicated (14% to 5%) and mean time taken for participants to calculate and chart the early warning score was 1.6-times faster with VitalPAC
	Mohammed 2009, UK (Before and after study) [Handheld personal digital assistant, VitalPAC versus paper-based generic early warning score]	❖ **Accuracy:** Paper based 58% vs. electronic classroom 96% CI 95% 31-44% (P<0.0001), Phase 3: Electronic classroom 96% vs. Electronic Ward 88% p=0.006 ❖ **Efficiency:** Paper based 37.9s vs. Electronic classroom 35.1s (p=0.016) vs. Electronic Ward 24.0s (p<0.0001)
Electronic alerts versus no electronic alerts	**Kollef 2014, US (RCT)** [Realtime alert]	**Length of stay (LOS)** ❖ Reduction in LOS in general ward [9.4 days (control) v. 8.4 days (intervention) p=0.038] **Unplanned ICU admission/transfer** ❖ No difference in ICU admission/transfer between intervention and control groups.
	Bailey 2013, US (Cross- over study)	**Mortality outcome** ❖ Patients with alerts were at 8.9-fold greater risk of death than those without alerts (244 of 2353 [10.4%] vs. 206 of 17678 [1.2%]). ❖ Among patients identified by the early warning system, there were no differences in the proportion of patients who died in the intervention group as compared with the control group. Alerts occurred a median of 8 hours prior to death (interquartile range, 4.09-15.66). **Length of stay** ❖ No difference in LOS between intervention and control group (specific data not reported)

Type of comparison	Study	Outcome reported
Continuous monitoring versus no continuous monitoring	**Bellomo 2012, Multi US, UK, Sweden, Australia (Controlled before and after study)** **[Automated advisory vital signs monitors]**	❖ The intervention was associated with an increased proportion of calls secondary to abnormal respiratory vital signs (from 21% to 31%). ❖ Survival immediately after rapid response team treatment, to hospital discharge or 90 days increased from 86% to 92%. ❖ Median length of stay and time to record observations were also significantly reduced. ❖ The time required to complete and record a set of vital signs decreased from 4.1 3 1.3 mins to 2.5 3 0.5 mins (difference [95% CI] 1.6 [1.4–1.8]; p < 0.0001) ❖ Significant reduction in LOS 4(before) [2– 6.7] and 3[2–6] (after) p<0.0001, Hospital length of stay (days)
Paper versus Electronic Early Warning System	**Schmidt 2014, UK (Controlled before and after study)** **[VitalPAC]**	**Mortality outcome** ❖ Crude mortality reduction in the 5 year study period Hospital 1: 7.75% to 6.42% (p<0.001) (estimated 397 fewer deaths) Hospital 2: 7.57% to 6.15% (p<0.001) (estimated 372 fewer deaths). ❖ Seasonally-adjusted mortality was predominantly above the 7- year mean [Hospital 1, 30/47 (63.8%) months; Hospital 2, 45/57 (78.9%)], whereas afterward introduction, it was seldom so [Hospital 1, 4/37 (10.8%) months; Hospital 2, 2/27 (7.4%)]
	Dawes 2014 (Before and after study) **VitalPAC system linked with EWS**	**Mortality outcome** ❖ Reduction of observed mortality rate; 8.3% to 5.2% over 5 years (p=0.29 post adjustment for disease severity) **Length of stay** ❖ No significant reduction in length of stay post adjustment for patient severity on admission.
	Jones 2011, UK (Before and after study) **Patientrack**	**Mortality outcome** ❖ Deaths in study population [baseline 67 (9.5%) vs. alert 59 (7.6%) p=0.19] **Length of stay** ❖ statistically significant decrease in LOS post intervention by 2.8 days ❖ statistically significant reduction in ICU LOS during the study periods: (pre-intervention) 14 patients (51 critical care bed-days) and (post intervention) 5 patients (26 critical care bed-days) (p=0.04) **Unplanned ICU admission/transfer** ❖ Reduced critical care bed days 14 admissions to 5 admissions p=0.04 **Cardiopulmonary arrest** ❖ Reduced Cardio-Pulm arrest 3 (0.4%) to 0, p=0.21) **Changes in work process** ❖ Accuracy of recording improved 81% to 100%, ❖ Clinical attendance improved (EWS 3, 4, and 5) 29% to 79%; EWS level >5 from 67% to 96% (p<0.001). Complete compliance with the early warning score protocol for EWS 3, 4 or 5 (i.e., recheck EWS within 1 hour and if still EWS 3, 4 or 5 then clinical response within the next hour) could not be determined in the baseline group due to poor documentation of attendance times in the medical record.

A before and after study by Mestrom E et al. (2019) compared non-automated with automated EWS, evaluating operational outcomes (number of recorded assessments, number of complete EWS assessment, adherence rate to related EWS protocol) and clinical outcomes (hospital length of stay, mortality, ICU readmission rate) for surgical high dependency unit patients.110 level II-2 The automated EWS comprised of electronic device that automatically measured the physiological parameters, calculate the EWS values and showed them on the screen of the device as well as on a monitor at the central nurse station. A short advice was displayed on the screen for further monitoring such as the recommended time until the next assessment, or recommended actions, such as alerting a physician or the RRT. The adherence to EWS hospital protocol improved from 1.1% to 25.4% and the number of complete EWS recorded improved significantly by 43%. However, there were no significant differences in clinical outcomes. 110 level II-2

6.4.5 Clinical Guidelines Published Internationally

a) NICE Guideline: Acutely ill adults in hospital: Recognising and Responding To Deterioration[111]

The National Institute for Health and Care Excellence (NICE) UK (2007) in their clinical guidance requires that, hospitals must have (i) a clear written monitoring plan specifying which vital signs should be recorded (and at what frequency for all adult hospitalised patients), (ii) a physiological EWS for documenting vital signs and (iii) a graded response strategy. The graded response strategy according to NICE for patients identified as being at risk of clinical deterioration should be agreed and delivered locally (low score group -increased observations, charge nurse alerted; medium score group- urgent call to team with primary medical responsibility for the patient and simultaneous call to personnel with core competencies for the management of acute illness which can be delivered by a variety of means; high-score group- emergency call with immediate response to team with critical care competencies and diagnostic skills). The updated version of the guideline 2019 included details of the NEWS2 tool.111

b) NCEC National Clinical Guideline No. 1: National Early Warning Score[112]

In December 2013, the first National Clinical Guideline of National Early Warning Score was published by the Irish National Clinical Effectiveness Committee (NCEC). The NEWS guideline is part of a suite of National Clinical Guidelines on Clinical Deterioration for Irish health system. It was updated in August 2014 to ensure alignment with National Clinical Guideline No. 6 Sepsis Management. The guideline focuses on ensuring that a 'track and trigger' system is in place for adult patients whose condition is deteriorating, and outlines the clinical processes and organisational supports required to implement the guideline. It describes the essential features of the systems of care required to implement the NEWS System, (using the VitalPACTM Early Warning Score (ViEWS) Parameters) and the NEWS escalation protocol, to recognise and respond to clinical deterioration.112

c) SIGN 139 Guideline: Care of Deteriorating Patients[113]

The Scottish Intercollegiate Guideline Network (SIGN) (2014) developed consensus recommendations to underpin a national approach to the care of adult deteriorating patients. Similarly, the SIGN system makes reference to patients with high NEWS score requiring immediate action from staff with an emergency call to the team with critical care competencies and diagnostic skills. SIGN noted that as a first step in implementing any new recommendation an understanding of current clinical practice is required. In addition, acute hospitals should consider the introduction of electronic track, trigger and alert systems.113

d) AUSTRALIAN COMMISSION ON SAFETY AND QUALITY IN HEALTH CARE. 2017. National Consensus Statement: Essential Elements for Recognising and Responding to Clinical Deterioration.[114]

AUSTRALIAN COMMISSION ON SAFETY AND QUALITY IN HEALTH CARE. 2012. Safety and Quality Improvement Guide Standard 9: Recognising and Responding to Clinical Deterioration in Acute Health Care.[115]

In 2010 the National Consensus Statement relating to the "Recognising and Responding to Clinical Deterioration" was endorsed by Health Ministers as the national approach for recognition and response systems in Australian acute care facilities. The purpose of the Consensus Statement is to describe the elements that are essential for prompt and reliable recognition of, and response to, physiological deterioration of patients in acute healthcare facilities in Australia. The evidence base regarding recognition and response systems for clinical deterioration has matured since the Consensus Statement was originally released in 2010. This revision reflects the agreed views of experts in the field and the Australian Commission on Safety and Quality in Health Care, and the findings of a rapid review of the literature from 2010-2016. The current version of the document includes eight essential elements. Four relate to clinical processes that need to be locally delivered (measurement and documentation of observations, escalation of care, rapid response system and clinical communication), and are based on the circumstances of the health service in which care is provided. Four relate to the structural and organisational prerequisites that are essential for recognition and response systems to operate effectively (leadership and governance, education and training, evaluation and audit, support system for high quality care).[114] An Australian guidance document was particularly concerned regarding implementation strategies and noted that governance arrangements need to be in place "to support the development, implementation, and maintenance of organisation-wide recognition and response systems" (Standard 9.1).115 Such a governance system includes: the identification of a suitable individual, group or committee to take responsibility for governance; development and implementation of processes for collecting, analysing and reporting feedback from the workforce; identification of system failures through data collection systems which review deaths and cardiopulmonary arrest; routine and timely provision of relevant data about recognition and response systems to the clinical workforce; utilisation of the data from evaluation of recognition and response systems to inform quality improvement activities.[115]

6.5 Ethical and legal issues

Risk prediction models and algorithms have long been utilized in healthcare to support decision-making. There are well-established frameworks that provide guidance to the development and utilization of these algorithms and models. A well-known framework is the one proposed jointly by the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) and the Society for Medical Decision Making (SMDM) through their ISPOR-SMDM modeling good research practices task force.[116, 117] The implementation of electronic health care predictive analytic (e-HPA) applications such as electronic NEWS on a wide scale to aid in real-time, point-of-care decision-making brings a new set of challenges and opportunities that are not covered by earlier frameworks. As a result of rapid development, many ethical, legal, regulatory, methodological and technical challenges are emerging; consequently, the existing frameworks in these areas are not well equipped to provide sufficient guidance for addressing these new challenges. Seventeen international experts with diverse expertise including methodology, ethics, legal, regulation and health care delivery systems were assembled to identify emerging opportunities and challenges of e-HPA and to propose a framework to guide the development and application of e-HPA.[118]

The framework proposed by the panel includes three key domains where e-HPA differs qualitatively from earlier generations of models and algorithms (Data Barriers, Transparency, and Ethics) and areas where current frameworks are insufficient to address the emerging opportunities and challenges of e-HPA (Regulation and Certification; and Education and Training). The following list of recommendations summarizes the key points of the framework:[118]

1. **Data Barriers:** Establish mechanisms within the scientific community to support data sharing for predictive model development and testing.
2. **Transparency:** Set standards around e-HPA validation based on principles of scientific transparency and reproducibility.
3. **Ethics:** Develop both individual-centered and society-centered risk-benefit approaches to evaluate e-HPA.
4. **Regulation and Certification:** Construct a self-regulation and certification framework within e-HPA.
5. **Education and Training:** Make significant changes to medical, nursing, and paraprofessional curricula by including training for understanding, evaluating, and utilizing predictive models.

A systematic review of applied analytics and qualitative/conceptual papers (n=117) on healthcare analytics identified four papers that highlighted healthcare privacy and fraud detection of major concern.119 The traditional technique of security for healthcare information system which uses de-identification or anonymization technique leaves healthcare data vulnerable to re-identification. One paper analyzed the major policy, ethical, and legal challenges of performing predictive analytics on health care big data. The proposed recommendations for overcoming challenges raised in the four-phase life cycle of a predictive analytics model (i.e., data acquisition, model formulation and validation, testing in real-world setting and implementation and use in broader scale) included developing a governance structure at the earliest phase of model development to guide patients and participating stakeholders across the process (from data acquisition to model implementation). It was also recommended that model developers strictly comply with the federal laws and regulations in concert with human subject research and patients information privacy when using patients' data.[119]

According to Cohen IG et al., among legal and ethical concerns that could arise from using predictive analytics are the the liability issue whereby clinicians who are early users of predictive analytics models may face increased risks of liability or at least litigation.[120]

Potential liabilities are;

1. **Failure to properly study patient's medical record from existing electronic health record**
   - ❖ The case law on electronic health records establishes that "physicians can be held liable for harm that could have been averted had they more carefully studied their patients' medical records." [121] Use of the predictive models could cause clinicians to reduce the time they spend with those medical records and thus increase their liability.

2. **Overriding an alert or recommendation**
   - ❖ Plaintiffs might use evidence that a doctor overrode an alert or recommendation from the model as proof that he or she was negligent. It is clinically appropriate to override many computerized alerts in the practice of medicine. However, there is a significant risk that "a doctor who is accustomed to overriding alerts may become desensitized to them and occasionally ignore a critical one," and evidence of a doctor's overriding alerts may prove damaging in litigation.[121]

3. Following the recommendations of faulty predictive analytic model

- Doctors may also face liability if they follow the recommendations of a predictive analytics model that contains an error. In the case of computer decision support software more generally, some legal scholars suggest that courts are likely to fault a physician for failing to question bad advice given by the software—even if the error was in the software—because courts would assume that physicians would ultimately rely on their own judgment and professional knowledge.[122]

The ethical challenge of predictive analytics is its potential impact on the role of the physician. Predictions of adverse clinical events by the models can promise greater accuracy than prognostication by clinicians.120 Hence, physicians' clinical expertise and self-esteem may be called into question. Physicians will need to master new skills, including how to communicate effectively with patients or their families about the trade-offs involved in different clinical outcomes. The role of the physician in the delivery of care across inpatient and outpatient settings may need to be reconfigured. The separation of hospitalists from ambulatory care providers, the frequent handoffs of responsibility for inpatients from one physician to another, and the rarity of long-term primary care relationships all mean that when a predictive analytics model identifies a patient as being at risk, the treating physician might not know the patient or his or her values and preferences. A model's predictions also raise novel questions about the doctor-patient relationship. Conventionally, a physician provided care to an individual patient based on the patient's best interests, as guided by his or her preferences and values. In the era of predictive analytics and team-based care, clinical decision making may be heavily influenced by default rules set by the health care organization. These rules may be driven by financial and administrative incentives and by a desire to maximize population-based health. It would appear to patients that the treating physician is no longer exercising clinical judgment and acting in their best interests.[120]

6.6 Social implications

Wood C et al. (2019) conducted a mixed method systematic review (n=23) to explore medical and surgical ward nurses' attitudes, perception and intention towards the use of early warning scoring systems.123 Three themes emerged from this review; barriers to following early warning score algorithms, inconsistent activation of the rapid response team and overreliance on scores. (Table 21) The review identified nurses aimed to use early warning score systems to detect deterioration and ensure patient safety, however cultures, confidence and past experiences impact on rates of afferent limb failure globally. The nurses had difficulty adhering to the easy to follow algorithms used in track and trigger charts due to heavy workloads and challenges in getting medical officers to review within recommended time frames. Nurses relied heavily on the scores generated by early warning score systems but unable to follow algorithms and undertake holistic physical assessments to detect deterioration earlier.[123]

Table 21: Thematic synthesis

Theme	Subtheme	Note on key findings
Barrier to following early warning score algorithms and rapid response team activation	Previous experiences with the rapid response team	❖ nurses confidence level - nurses had a fear of criticism and retribution for inappropriate referrals which directly contributed to afferent limb failure. ❖ ardous collaboration with the RRT- found RRT to be problematic when called if the patient wasn't critically unwell
	Workload	❖ a delay between a trigger being identified and a repeat set of observations or a review being undertaken ❖ adherence to monitoring frequency would be neglected during busy periods ❖ collaboration and communication with doctors about patients with elevated early warning scores was deemed to be unrealistic due to the high number of patients with elevated scores ❖ The incidence of falsely elevated scores was further compounded by nurses who miscalculated scores when undertaking observations, leading to both over and under reporting of vital sign changes, further increasing the workloads of both nurses and doctors
	Lack of knowledge / inadequate training	❖ doctors need more training in the tool as they had a lack of understanding and therefore poor response times when called to review patients with elevated scores. ❖ continuous disagreement on the scores for nurses - identified that patients often have elevated scores due to treating teams neglecting to chart modifications on the track and trigger charts for chronic diseases such as chronic obstructive pulmonary disease
Inconsistent activation of the rapid response team	Culture	❖ some nurses called the RRT when they were unhappy with the treating team plan ❖ others didn't call the RRT when patients met criteria but didn't look unwell
	Confidence in inter-professional collegiality	❖ some nurses prefer to call treating teams before activating the rapid response team whilst others called the rapid response team if the treating team are not responding appropriately ❖ nurses didn't often feel confident enough to activate the rapid response team but felt more confident in calling the intensive care outreach nurse. ❖ as familiarity and agreement with rapid response team activation criteria increased, clinicians were more likely to activate the rapid response team than those who were unfamiliar or believed the criteria to be incorrect. ❖ nurses and junior doctors feared calling the rapid response team in case the patient was not found to be critically unwell. ❖ RRT was activated when criteria were met or when communication between professionals broke down such as when nurses could not reach doctors through normal lines of communication or when there were interprofessional disagreements surrounding decisions that affect patient care
Overreliance on scores	Privileging early warning score over own clinical assessments	❖ score generated by the early warning system was the most important indicator of referral to the rapid response team ❖ nurses often lack the knowledge and skills to recognise and respond to deterioration in patients ❖ nurses identified track and trigger scores were often miscalculated leading to delays in recognising deterioration and therefore, afferent limb failure.
	Lack of experience in identifying signs of early deterioration	❖ when assessing patients' nurses often neglected to consider their medical history which led them to call the rapid response team with little information, despite having an awareness that the rapid response team need background history when called to review deteriorating patients ❖ education programmes could improve nurses' knowledge and skills when performing a holistic assessment and handover of a deteriorating patient
	Increased sensitivity of detection with the computational equipment	❖ increased incidence of activation of RRT with the use computer aided technology

A qualitative study conducted by Hogan H et al. (2019) to explore staff perspectives on key factors that had been important in the effectiveness of the implementation of track and trigger systems (TTSs) and education initiatives, utilizing thematic analysis of semi-structure in depth interview with 60 healthcare staff from 13 NHS hospitals.[124] The interviews principally assessed service configurations for the NEWS, education provision and any contextual factors such organizational culture, staff engagement and communication. Within the two domains of the thematic framework, the authors identified and mapped themes and subthemes as shown in Table 22. The NEWS had been well received and was seen as straightforward to use and the standard tool was helpful in an environment where staff turnover is high. The utility of the NEWS across the whole spectrum of patients was questioned, both from the point of view of the scope of the physiological measures included and its under/ oversensitivity in particular groups. Many clinicians viewed it as a basic building block and had added additional measures when they felt that the additions added value. These alterations of a validated tool may threaten its reliability. Electronic versions of the NEWS, were viewed as important mechanisms in improvement of care around deteriorating patients. Benefits cited included removing barriers to escalation and decreasing the possibility of 'human error', as calculation of scores and triggering a response were done automatically. Issues highlighted for electronic NEWSs including issues of sensitivity and additional issues, such as the need to help staff get over their fears of new technology, as well as the requirement to update and maintain hardware and software systems. Education and training were perceived to have a role in empowering nurses to speak to clinicians and helping to overcome challenges of communication across different disciplines and seniorities. Staff shortages and high staff turnover were felt to be detrimental to maintaining a suitably trained workforce.[124]

Table 22: Themes and subthemes from data analysis organised by thematic framework domains

Domain 1: Service configuration for NEWS		
Theme	**Subthemes**	**Note on key findings**
Benefits of NEWS	User friendly	❖ simple design, easy to use ❖ require minimal training and supervision
	Standardisation	❖ standardisation enabled a familiarity with a single tool and decreased the length of time required to train new or bank staff when they began working in a new ward or hospital
	Empowerment	❖ feeling empower to call a doctor if concerned about a patient by providing evidence that something was wrong
Limitations of NEWS	Miscalculation and missed escalation	❖ concern about adding up the score incorrectly even with the aid of colour coding; incomplete observations; possible missed escalation ❖ inexperience and skill deficit staffs making decision about escalation without consider individual patient's context as well.
	Lengthy implementation	❖ changeover to NEWS not an easy process, taken up 2 years for many NHS hospitals involving negotiations with different wards, trial periods and significant training for staff.
	'Deskilling' workforce	❖ perception of NEWS 'deskilling' NHS workforce: more 'less skilled' staff in patient caring roles than previously_ seeing the introduction of a'one-size-fits-all' TTS only solve patient caring issue but not really address the skill deficit issue
	Lack generalizability	❖ the score was too generic for use in certain specialties or in particular patients.
	Lack reliability as stand alone clinical decision tool	❖ the need to combine calculation of the NEWS with assessment of the patient's clinical context by an experienced health-care professional; differing perceptions _lack of sensitivity for detecting early deterioration and deterioration in certain patient groups vs oversensitive & resulted in unnecessary escalation.

Domain 2: Electronic system		
Themes	**Subthemes**	**Note on key findings**
Benefits	Barrier removal	❖ viewed as important mechanisms in improvement of care around deteriorating patients ; removing barriers to escalation
	Minimising error	❖ removing barriers to escalation and decreasing the possibility of 'human error'; calculation of scores & triggering a response done automatically
	Increase compliance	❖ omissions of certain observations were decreased as the electronic systems forced staff to enter a full set of observations.
Limitations	Technophobia	❖ the need to get over fears of new technology
	System maintenance	❖ the requirement to update and maintain hardware and software system Suggestion: further digitisation, such as electronic patient records or Wi-Fi access throughout the hospital to enable tablets to be used to collect observations, would make jobs easier and free up time for patient care.
Domain 3: Education and Training Programmes		
Themes	**Subthemes**	**Notes on key findings**
Benefits	Knowledge enhancement	❖ valued bedside teaching, especially when provided by outreach teams, as a way of improving their knowledge in identifying and responding to deteriorating patients
	Courage to speak up	❖ role that education and training can have in empowering nurses to speak to clinicians
	Bridging communication	❖ helped overcome challenges of communication across different disciplines and seniorities.
Barriers	Sceptism	❖ sceptical of the value of formal courses
	Lack of sustainability due to trainer shortage	❖ staff shortages and high staff turnover were felt to be detrimental to maintaining a suitably trained workforce
	Time constraint for educator	❖ the difficulty of maintaining the role of educator while at the same time being increasingly called on to fill other roles, such as providing overnight cover in place of junior doctors ❖ prioritisation of risk assessments and paperwork that they could not spend as much time as they wanted on teaching at the bedside.

Jensen JK et al. (2019) using a qualitative approach, explored hospital nurses' perceptions and reactions to the NEWS during an introduction programme. In total, nine seminars with 79 nurses and 23 simulation sessions with 52 nurses were included.[125] The findings revealed four tensions related to the working context: (a) tension between using a standardized tool and relying on clinical judgement (the tool could be either an aid or a barrier to patient assessment); (b) tension in the community of practice (the tool could be beneficial or increase stress and anxiety); (c) tension related to rules and compliance (the tool could be perceived as optional or compulsory); and (d) tension related to the division of labour (nurses feared more work). The nurses underlined the particular utility value of NEWS for new and inexperienced nurses and described it as a tool that could enable them to more readily identify deteriorating patients. However, it is interesting to note the contradictory feelings that the nurses displayed towards NEWS. On the one hand, they welcomed the tool as a helpful aid in the assessment of patients and as a reminder of the importance of vital signs in clinical practice. On the other hand, they seemed concerned that using a standardized tool like NEWS would affect and somehow hamper their ability to rely on and use their professional competence in the assessment of patients. The nurses seemed to perceive the situation in a somewhat less harmonious light. It seems that some nurses' experiences with other tools, such

as SOFA, influenced their ambivalence towards using standardized tools in general and their reaction to the implementation of NEWS in particular. Their reactions were partly linked to the possibility that nurses might somehow become too dependent on numeric tool scores and hence undervalue their own clinical judgement of a situation. The nurses also said that they feared that doctors would emphasize measurements at the expense of nurses' observations and clinical judgements.[125]

Another qualitative study conducted by Jensen JK et al. (2019) applying a hermeneutic design aimed to explore general hospital ward nurses' experiences with the NEWS and to determine its impacts on their professionalism.[126] It consisted of semi-structured, in-depth interviews with 14 hospital nurses. Four themes were identified: (a) the National Early Warning Score and clinical judgement in patient assessment, (b) responding to the National Early Warning Score standard, (c) involving the professional community and (d) adjusting the tool. Nurses were aware of the importance of incorporating all of their professional competence, comprising clinical judgement, discretion and accountability, with the NEWS to accurately assess patients' conditions. Findings indicated that the NEWS was beneficial to nurses' professional practice; however, accountability to this standard alone does not ensure quality care and patient safety.[126]

Brangan E et al. (2019) in a qualitative study sought to explore staff experiences of using NEWS outside acute hospital setting (primary care, ambulance, referral management/acute interface, community, mental health services and service commissioning).[127] Thematic analysis of qualitative semi-structured interviews with 25 healthcare staff was conducted. Four themes were highlighted; (1) NEWS and communication, (2) NEWS in prioritization of care, (3) NEWS and clinical judgement (4) integrating NEWS into clinical practice. Participants reported that NEWS could support clinical decision-making around escalation of care, and provide a clear means of communicating clinical acuity between clinicians and across different healthcare organisations. Challenges with implementing NEWS varied—in primary care, clinicians had to select patients for NEWS and adopt different methods of clinical assessment, whereas for paramedics it fitted well with usual clinical practice and was used for all patients. In community services and mental health, modifications were 'needed' to make the tool relevant to some patient populations.[127]

McClelland G et al. (2016) sought to explore the thoughts and opinions of North East Ambulance Service NHS Foundation Trust (NEAS) paramedics about the NEWS system, and to explore the presence of barriers and/or facilitators to the use of NEWS in the pre-hospital setting. Three overarching themes emerged from the data: applying NEWS, decision making and external influences. (Table 23) [128]

Table 23: Themes and subthemes that emerged from paramedics' interview

Themes	Subthemes	Notes on key findings
Applying NEWS	To support discharge decision	❖ Discharging patients from their care without transporting them to hospital ❖ a NEWS of 0 was a good support for their decision
	Sepsis screening	❖ A high NEWS did not always lead to checking for sepsis but a patient with sepsis was thought to often have a high NEWS
	More use to non-paramedic roles in terms of being used to trigger decisions such as summoning paramedic backup.	❖ Some comments about non-paramedics not seeing it as part of their role or not being aware that they can use tools like NEWS
Decision making	To support or check decisions that had already been made rather than perceived as a threat to paramedic autonomy	❖ NEWS was used at the end of decision making process ❖ To guide non-paramedics in decision making process
External influences	The influence of other health care professionals (HCPs) and institutions.	❖ Negative reception at hospital, or lack of perceived value to handing over NEWS, acted as a disincentive to continued use by the paramedics

A mixed method study was conducted by Brimblecombe N et al. (2019) to assess the attitudes and views of staff and patients on the use of electronic NEWS. A total of 82 staff and 26 patients participated in the study.[129] Two themes emerged from the patients focus group discussion; security of the digital system and concern about personal information, increased physical observations and delayed leave. In a staff focus group discussion, three particular themes were highlighted namely risks associated with using handheld devices, the impact of digital recording of observation on staff time as well as workload and concern about system reliability and fit with existing information technology systems. Patients expressed concerns about data confidentiality. Most staff were neutral or positive about moving NEWS to the electronic platform, but raised possible safety risks and the risk of electronic recording being misinterpreted by patients.[129]

6.7 An overview of NEWS: the Malaysian Context

Early warning score has not been widely used in hospitals in Malaysia. However, there are public and private healthcare facilities through their individual initiative for quality improvement of care to their patients, have implemented early warning score in their settings. An organisational survey was conducted during the process of this review to determine the distribution and use of EWS in hospitals under Ministry of Health (MOH) as well as the presence of variation in EWS application among these hospitals. The survey was sent to 135 hospitals within Ministry of Health and 110 (81.5%) responded. Out of 110 hospitals, 12 hospitals responded to the use of EWS in one or more locations within their facilities.The implementation of EWS happened as early as 2012. The most commonest location for the use of EWS was general medical ward (67% of the hospitals), followed by emergency department (33%) and surgical ward (33%). Other locations were paediatric ward, labour room, obstetric and gynaecological ward and outpatient clinic (mental health service). (Figure 35) The majority of Ministry of Health hospitals operated a paper-based EWS system (91.7%). There were a variety of different EWS used across Ministry of Health hospitals including the NEWS, Modified Early Warning score (MEWS), Paediatric Early Warning Score (PEWS) and a hospital's own scoring systems. The most popular choice of EWS was MEWS (used by 7 hospitals) followed by NEWS (by two hospitals). (Table 24) The findings on the individual characteristics of different type of EWS used revealed that all EWS had included heart rate, respiratory rate, blood pressure and temperature as a measured parameters in their scoring system. Only six EWS included measurement of oxygen saturation in their scoring model and 3 EWS had assigned separate aggregate score for use of supplemental oxygen. Other physiological parameters used in the system score were level of consciousness/mental status and urine output. (Table 25) The survey had shown that the use of EWS is limited among Ministry of Health hospitals. Variation of EWS practice could be seen between hospitals that utilised EWS from the choice of EWS used to the implementation process.

Table 24: List of MOH hospitals, type of EWS used and their implementation characteristic

Name	Type of EWS	Year of implementation	Setting	Type of implementation tool
1. Hospital Sg Buloh	MEWS	2014	❖ General medical ward	Paper-based
2. Hospital Taiping & the cluster hospitals	MEWS	2019	❖ General medical ward	Paper-based
3. Hospital Sarikei	MEWS	2011	❖ General medical ward	Paper-based
4. Hospital Kuala Kangsar	NEWS	2019	❖ General medical ward ❖ Emergency department	Paper-based
5. Hospital Yan	MEWS	2017	❖ General medical ward ❖ Emergency department	Paper-based
6. Hospital Selama	MEWS	2016	❖ General medical ward ❖ Emergency department	Paper-based
7. Hospital Kuala Krai	NEWS	2017	❖ Surgical ward ❖ Orthopaedic ward	Paper-based
8. Hospital Umum Sarawak	MEWS	2016 2017	❖ Surgical ward ❖ Orthopaedic ward ❖ Labour room ❖ Gynaecology ward	Paper-based
9. Hospital Labuan	MEWS	2017	❖ General medical ward ❖ Surgical ward ❖ Gynaecology ward	Paper-based
10.Hospital Sultan Hj Ahmad Shah, Temerloh	Tem OBGYN PaWS	2017	❖ Labour room, O+G wards	Electronic-based
11. Hospital Kapit	PEWS and KEWS	2012	❖ General medical ward ❖ Surgical ward ❖ Emergency department ❖ Paediatric ward	Paper-based
12. Hospital Mesra Bukit Padang	EWS	-	❖ Outpatient clinic (mental health service)	Paper-based

Tem OBGYN PaWS =Temerloh OBYSGYN Patient Warning System ; KEWS= Kapit Early Warning Score

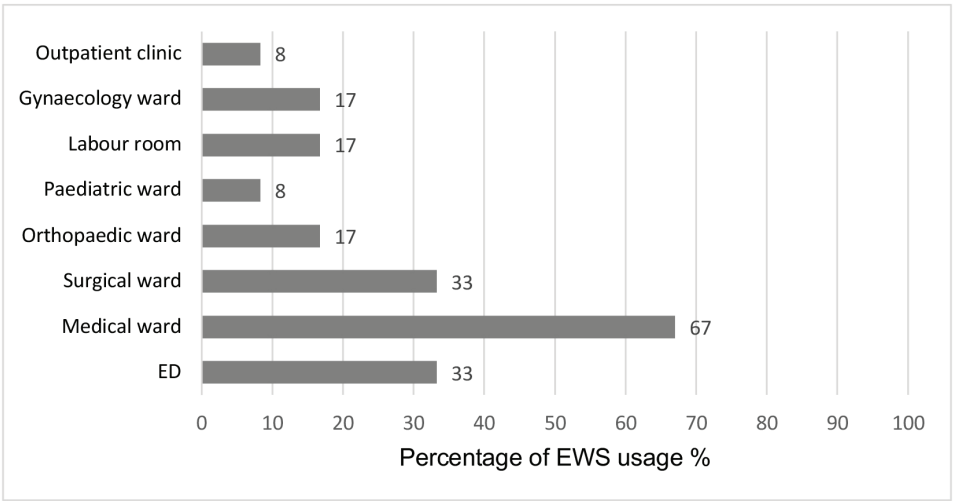


Figure 35: The percentage of EWS usage according to type of setting

Hospital	N parameters; EWS	Trigger level	Parameters used in the scoring model							
			BP	HR	RR	Temp	SpO2	Supp O2	Mental status (Level of consciousness)	Urine output
Hospital Sg Buloh	7-item MEWS	4	√	√	√	√	√	√	√	
Hospital Taiping & the cluster hospitals	7-item MEWS	4	√	√	√	√	√	√	√	
Hospital Sarikei	5-item MEWS	5	√	√	√	√	√	√		
Hospital Yan	5-item MEWS	5	√	√	√	√			√	
Hospital Selama	6-item MEWS	4	√	√	√	√	√	√		
Hospital Umum Sarawak	6-item MEWS	3	√	√	√	√			√	√
Hospital Kuala Kangsar	7-item NEWS	5	√	√	√	√	√	√	√	
Hospital Kuala Krai	7-item NEWS	5	√	√	√	√	√	√	√	
Hospital Labuan	6-item MEWS	4	√	√	√	√	√		√	
Hospital Temerloh	5-item TemOBGYN PaWS	4	√	√	√	√	√			
Hospital Kapit	6-item PEWS & KEWS	5	√	√	√	√	√		√	
Hospital Mesra Bukit Padang	6-item EWS	5	√	√	√	√	√		√	

Table 25: Parameters used in different type of EWS by MOH hospitals

An audit survey was conducted by Hospital Sungai Buloh MEWS team to evaluate the effectiveness of their MEWS training programme. The use of paper-based early warning score for early detection of clinical deterioration in medical inpatients of Sungai Buloh Hospital was first introduced in 2014. Since its implementation five years ago, a series of modification was done to the MEWS to improve its predictive accuracy and staff compliance level. Education and training programme was implemented to improve staff knowledge on MEWS and compentency in using MEWS. (Figure 36) There was a significant improvement in documentation and calculation of the scores (by 39%) and compliance rate to the escalation protocol (by 25%) following six months training programme. (Figure 37) This audit demonstrated the impact of education and training programme on the proficiency and adherence level of the staff in the utilisation of Hospital Sungai Buloh MEWS.

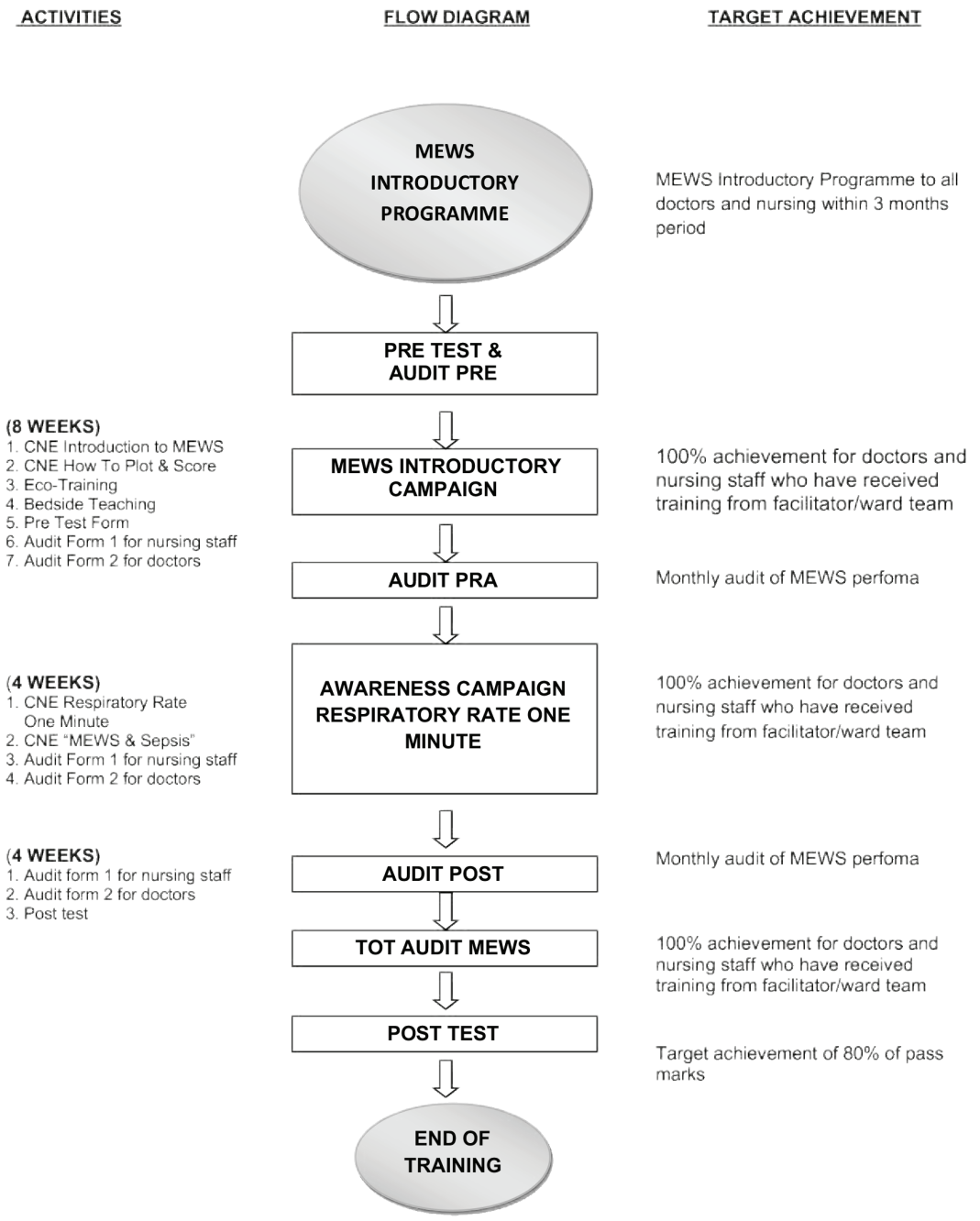


Figure 36: The flow chart of MEWS training programme for nursing staff and doctors in Hospital Sungai Buloh medical department

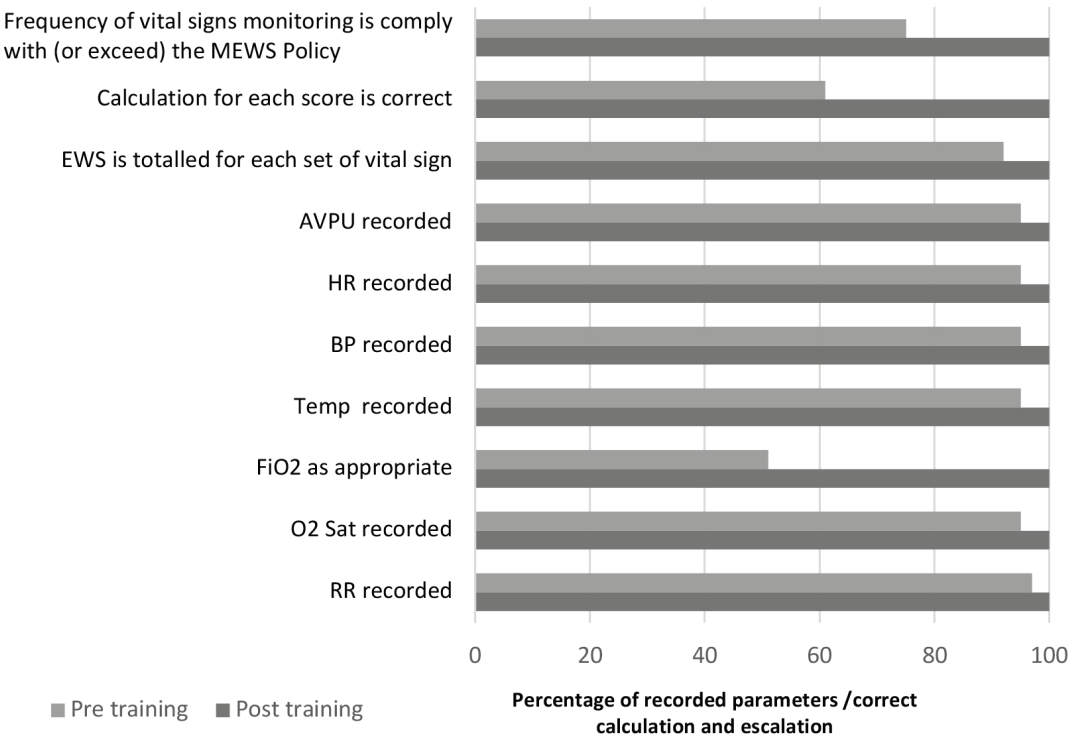
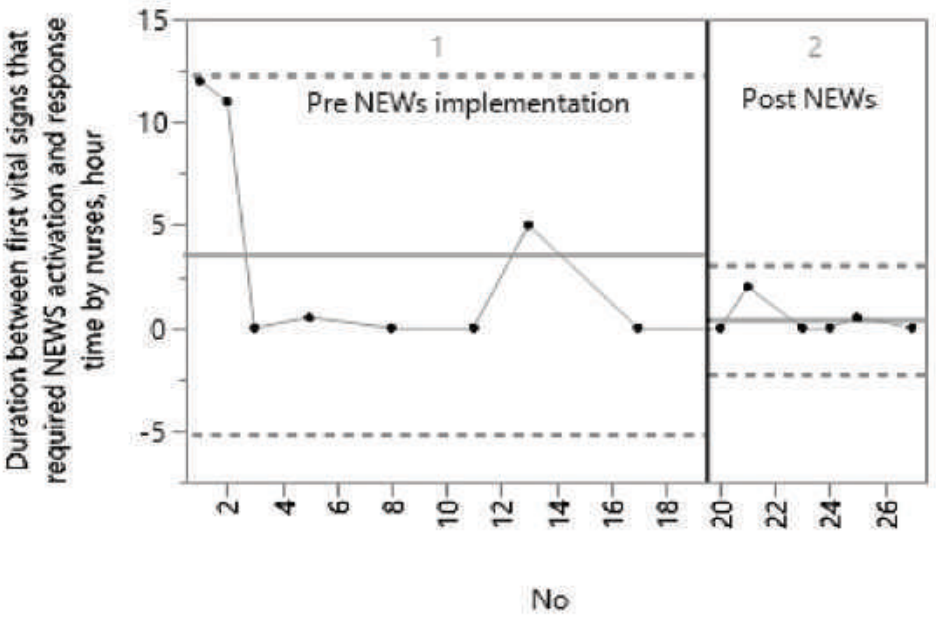


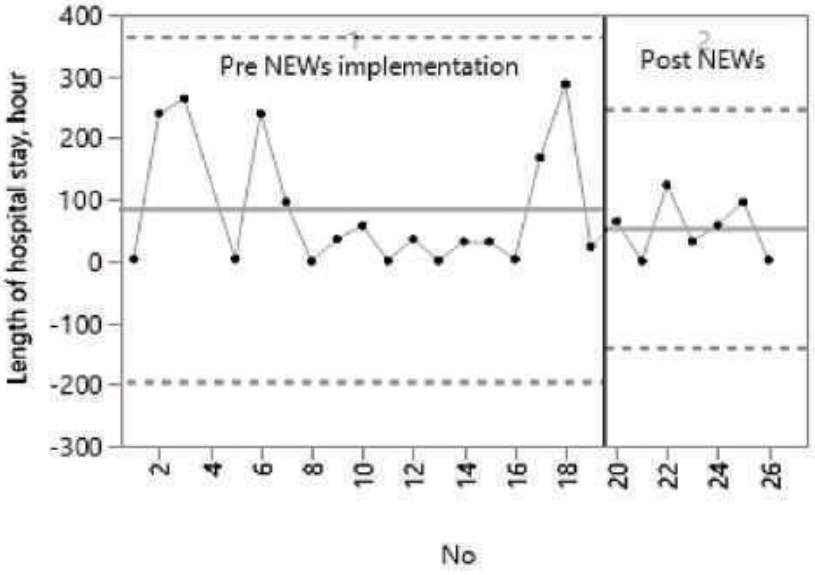
Figure 37: The percentage of documented MEWS parameters, correct calculation and monitoring compliance among nursing staff in 4D medical ward Hospital Sg Buloh before and after training programme.

In November 2017, University Malaya Medical Centre (UMMC) implemented NEWS system that has been fully integrated into its electronic patient management system. The process of planning and implementation was done over a six-month period by the UMMC quality department and the UMMC NEWS committee. Permission was obtained for unrestricted using of the original NEWS from the Royal College of Physicians, UK. The warning system is used by all the wards in the hospital except the intensive care unit, cardiac care unit, obstetric and gynaecology, paediatric and emergency departments. Three warning levels recommended by the original NEWS was adopted as the level of responses suitable for use locally. The first level of warning will trigger a response from the nursing team leader for the shift, while the second level will require the nurse to contact a medical officer, bypassing the houseman on call. The highest level of warning will prompt the nurse to call a specialist immediately. NEWS training workshops were provided for nurses which include introduction of NEWS, hands on training (how to use NEWS in EMR) with case scenarios and discussions. In addition, a roadshow was also conducted during which the NEWS committee training doctors in individual departments on the use of NEWS. Audits were conducted pre and post implementation of NEWS in a UMMC general medical ward to assess the impact of NEWS implementation. There was 63% reduction in the rate of patients with acute deterioration post-NEWS. Consequently, the number of unexpected deaths decreased with the relative risk reduction of 60%. The mean response time by nurse was found to be reduced from 3.56 hours to less than one hour (0.4167) indicating that improvement on nurses' response. (Figure 38) In addition, there was a slight decrease in a patient's average of length of hospital stay post NEWs implementation. (Figure 39)



Source: Faculty of Medicine, University Malaya

Figure 38: The mean of response time by nurse in pre and post NEWs system Implementation



Source: Faculty of Medicine, University Malaya

Figure 39: The mean of length of hospital stay

The following are published research on EWS in the Malaysian context:

Jusoh A et al. (2019) in a prospective cohort study sought to determine the best in patient trigger level for NEWS in predicting occurrence of serious adverse events (death and unanticipated ICU admission).[130 level II-2] A total of 226 in-patients from surgical and orthopaedic wards of Hospital Kuala Krai, Kelantan was enrolled in the study. The study revealed that there was an increased of serious adverse events with increasing NEWS scoring. National early warning score was able to independently predict death or unanticipated ICU admission with an excellent prognostic performance (AUROC 0.905, p<0.001). A score of 5 or more had the optimal sensitivity 87% and specificity (91.3) with PPV of 26.9% to predict serious adverse events in general ward (OR 2.828; 95%CI 1.632, 4.902). The number needed to screen at this threshold was 3.6.[130 level II-2]

Peng LS et al. (2018) conducted a prognostic accuracy study involving 259 patients from emergency department of Hospital Tuanku Ja'afar, Seremban to evaluate the ability of MEWS to risk stratify critically ill patients.[131] The MEWS in this study composed of five physiological parameters namely blood pressure, heart rate, respiratory rate, temperature and mental status (AVPU) for scoring. Modified early warning score with cut-off value of 4 was found to be most effective in detecting patients who require lifesaving intervention in the emergency department with the AUROC value of 0.959 (95% CI: 0.91–1.00, p<0.001), sensitivity 95% and specificity of 81%.[131 level III]

7.0 DISCUSSION

This review was undertaken in order to assess the effectiveness of NEWS in early detection of deteriorating patients from the available evidence and to identify key determinants to support effective robust implementation of NEWS in Malaysia. The evidence to support the introduction of NEWS is of variable quality with certain methodological limitations. There are 47 studies included in this review that focus on evaluating the performance of NEWS as a predictor of mortality, unanticipated ICU admission and cardiopulmonary arrest as well as its role in risk stratification of patients (prognosis prediction and disease progression evaluation). Most of the studies employed either retrospective or prospective cohort design. When using studies with historical controls, there is the risk of unmeasured confounding variables and temporal bias. For example, it is very likely that vital signs are not recorded at random but are instead measured after or because of a clinical change in the patient. Thus, all these studies likely suffer from a confounding by indication bias. Furthermore, these studies likely are limited by immortal time bias since patients without adverse events have more time available for vital sign measurement. Additionally, advances in medical care or other changes in practice cannot be ruled out as the cause of the outcomes. For example, adoption of a highly successful sepsis campaign might influence the outcome of mortality, independent of NEWS. There are numerous systematic review published on Early Warning Score (EWS). However, we decided not to include majority of them in this review as the findings were reported to represent the effectiveness and impact of EWS as a whole. Hence the findings might not be representative of true performance and impact of NEWS. We concluded it was best to report the individual NEWS studies. No formal comprehensive systematic review focussing solely on NEWS has ever been published to date.

National Early Warning Score has become prominent with the detection of the deteriorating patient. This review confirms that NEWS has good predictive value and has been found to influence patient outcomes in different healthcare settings [pre-hospital setting (ambulance service), general ward and emergency department]. All studies that included AUROC for one or more outcome measures found AUROCs which were far greater than 0.5, which is the cut-off for correlation that is reached by chance alone. The majority of the studies that objectified the performance of NEWS with either hazard ratio (HR), odd ratio (OR), risk ratio (RR) or p value found a strong significant correlation with their outcome variables. A higher ED-NEWS was associated with in-hospital mortality (OR 1.26, 95%CI 1.11,1.42; AUROC 0.75, 95%CI 0.64,0.86, p<0.001) and 30-day mortality (OR 1.27, 95%1.17,1.39; AUROC 0.78, 95%0.71,0.84, p<0.001) irrespective of age and comorbidity.[36]

For general ward patients, NEWS score ≥ 5 or if the weighted score for any individual vital sign was 3 was associated with an increased odds of mortality at 30 and 60 day: NEWS score ≥5 30-day mortality: OR 11.8 (95%CI 4.26, 32.6); NEWS score ≥7 30-day mortality: OR 11.4 (95%CI 4.40, 29.6); NEWS score ≥5 60-day mortality OR 5.55 (95%CI 2.91–10.6). Similarly in pre-hospital setting, the high risk NEWS group (NEWS≥7) had significant increases in 48 hours mortality [RR 35.32 (95%CI 10.08, 123.7)], 30 day mortality [RR 6.7 (95%CI 3.79, 11.88)] and ICU admission [RR 5.43 (2.29–12.89)].[73] Mortality was the most prevalent prognostic outcome, followed by ICU admission and the composite outcome of mortality and ICU admission. Most studies reported outcomes at multiple time points up to 30 days. Studies comparing NEWS with other EWS or single parameter system revealed that NEWS performance was comparable if not superior than the rest. While NEWS scores do have the ability to identify patients at risk of clinical deterioration, there is limited data on the impact of their implementation on patient outcomes. Similarly, NEWS may be predictive of important outcomes but their impact on clinically important outcomes such as mortality has not been established. Although some evidence on the impact of implementation on mortality and cardiac arrest were found, there was no evidence on additional outcomes such as other cardiac events, acute coronary syndrome, use of vasopressors, number of ventilator days, respiratory failure, or quality of life at discharge.

Patient population and time to follow-up greatly influenced the performance of NEWS, with some scores reaching good to excellent AUROC in some populations such liver disease patients, but only poor AUROC in others. However, it is important to recognize that they are more effective in certain patient groups, and care must be taken in the elderly and palliative populations. NEWS works with different prediction ability for various diseases. Liu et al. considered that NEWS enjoyed a relatively strong prediction ability on prognosis of respiratory diseases, with an area under ROC curve of 0.885; while the prediction ability on cardiovascular disease was weaker, with an area under ROC curve of 0.798. However, another study has obtained contrary results. It considered that NEWS should be weak in predicting chronic hypoxic respiratory diseases. The patient may be stable even at the warning threshold of NEWS. Because the patient has adapted to long-term hypoxia and the oxygen saturation has been in a low state, the uplifted NEWS score would not be fully correlated with the patient's condition. In December 2017, the RCPL published an update to NEWS - the National Early Warning Score 2 (NEWS2) - which includes several modifications to the NEWS vital sign weightings. To account for concerns about NEWS and type 2 respiratory failure (T2RF), NEWS2 includes a new SpO2 scoring scale for patients with/at risk of T2RF. Despite having slightly better performance if not similar to NEWS, Echevarria C et al. reported NEWS2 led to an absolute reduction in alert frequency of 12.6%.[82]

Whilst some papers report that the universal language of early warning scores improves communication between healthcare professionals, this is not always reflected in the reaction to the escalation. Concerns revolve around the resources needed to implement NEWS. Studies that compared nurses trained to those untrained in NEWS for recognizing signs of a simulated deteriorating patient and responses to their assessments, found that trained nurses were better able to identify and react but still missed multiple elements of the NEWS, failed to calculate the aggregate score and failed to take action informing the physician, which was part of their trained protocol. Other studies also revealed that accuracy and compliance of scoring decreased significantly with increasing score or worsening physiological derangement. Calculation errors are common and although improved with an electronic system, responses to the triggering score remain variable.

Training may improve staff engagement and the response to poor scores. Two interventions could improve the success of early warning scores to the benefit of patients. Firstly, the introduction of automated early warning score systems can minimize the risk of user error. Using a handheld computer device to document vital signs can highlight erroneous data, improve accuracy of calculations and prompt escalation. Scores can also be accessed remotely, which aids communication between healthcare professionals. Successful implementation of NEWS in the hospital however must go hand in hand with proper education of staff and increasing awareness of the necessity of structural patient monitoring. This will eventually lead to a change in the mindset of healthcare providers to collaborate as a team thereby leading to a better organization of patient care.

In local Malaysian context, there is a growing trend of utilising EWS both in private and public hospitals. A total of 12 hospitals within Ministry of Health has been using EWS. However, one drawback is that the approach is not standardized, as many hospitals use their own modified version of the EWS scorings system. This variation in methodology and approach can result in a lack of familiarity with local systems when staff move between clinical areas and hospitals, the various EWS systems are not necessarily equivalent or interchangeable. This diversity requires much effort to be put for standardisation of scoring system between hospitals.

8.0 CONCLUSION

Effectiveness

1. Discriminative Ability and Predictive Validity

NEWS

There was a substantial fair level of evidence to suggest;

Emergency department

- The NEWS was an effective assessment tool to identify and triage the patient for the most appropriate acute care assessments and interventions.
- The NEWS was a good predictor for serious adverse events (mortality and unanticipated ICU admission) in adult patients of varying severity of illness presenting to emergency department. It was able to rapidly predict prognosis and evaluate disease progression of critical patients in resuscitation room.
- The performance of NEWS was superior than quick Sequential Organ Failure Assessment (qSOFA), Systemic Inflammatory Response Sydrome criteria (SIRS) and Modified Early Warning score (MEWS), in risk-stratifying patients with suspected infection or sepsis and predicting death and unanticipated ICU admission in this subpopulation. Table-based aggregate weighted systems, such as NEWS, were more predictive and robust compared with tally-based single parameter scores such as qSOFA and SIRS.
- However, NEWS may not be the optimum scoring system for all patient subgroups. The NEWS showed moderate predictive ability for patient with community acquired pneumonia and low accuracy for in-hospital mortality in critically ill geriatric patients.

General wards

- The NEWS assessed on ward admission was able to risk stratify clinical deterioration and a good predictor of in-hospital serious adverse outcomes.
- NEWS discriminates high risk patients in a heterogenic general ward population independently of multiple confounding factors (age, gender, cumulative comorbidity, admission characteristic).
- The NEWS outperformed 33 other widely used Early Warning Scores (EWSs) for combined outcome of death, cardiac arrest and unanticipated ICU admission within 24 hours in the general population of patients.
- Between non-elective surgical patients and non-elective medical patients, NEWS had almost equal discriminative ability for prediction of serious adverse events.
- The NEWS accurately discriminates patients at risk of death, admission to the intensive care unit, or cardiac arrest within a 24-hour period for a range of liver-related diagnoses.
- A local study showed that NEWS was able to independently predict death or unanticipated ICU admission with an excellent prognostic performance (AUROC 0.905, $p<0.001$) in general surgical and orthopaedic wards. A score of 5 or more

had the optimal sensitivity (87%) and specificity (91.3%) with PPV of 26.9% to predict serious adverse events in general ward (OR 2.828; 95%CI 1.632, 4.902). The number needed to screen at this threshold was 3.6.

- National Early Warning Score was identified as independent predictor of early clinical deterioration 24 hours after ICU discharge and readmission to ICU or High Dependency Unit (HDU). A NEWSdc > 7 showed the best sensitivity (93.6%) and specificity (82.2%) to detect early clinical deterioration 24 hours after ICU discharge.
- The NEWS also had reasonable discrimination for any ICU patient's discharge location within 24 hours of admission to any ICU specialty. Hence, it could potentially be applied within a universal discharge planning tool for ICU, improving patient safety at the point of discharge (reduce the likelihood of both premature discharge and discharge delay by allowing care providers adequate time to plan accordingly).
- However, the NEWS system, whilst beneficial, lacks sensitivity and specificity in subpopulations of older adult patients (with/without comorbidity, high frailty index), patients with chronic obstructive pulmonary diseases (COPD) and oncology patients at risk of deterioration.

Pre-hospital setting

- In pre-hospital setting whereby NEWS was calculated using parameters recorded on the scene or prior ambulance transfer, NEWS showed good discriminative performance for both short term and long term mortality, and ICU admission from ED.
- A threshold level of 7 was associated with increased risk for the combined outcome of death or critical care unit escalation within 48 hours of hospital admission.
- Pre-hospital NEWS had better diagnostic accuracy in cases where the initial dispatch code was specified as trauma.
- Pre-hospital NEWS had poor prognostic performance for in-hospital mortality in elderly patients.
- Among pre-hospital patients with suspected infection, an elevated NEWS, was associated with increased levels of adverse outcomes (ICU admission within 48 hours of presentation and/ or 30-day mortality). The aggregated total NEWS score was, significantly superior to qSOFA at identifying patients at combined risk. A NEWS of medium or high clinical risk could be used according to sepsis guideline to prompt clinicians to further investigate for organ dysfunction, to initiate or escalate therapy as appropriate, and to consider referral to critical care or increase the frequency of monitoring.

NEWS2

- In predicting 24 hours mortality among patients with documented or at risk of type 2 respiratory failure, NEWS2 did not show superior performance to original NEWS. The NEWS2 did not improve discrimination for unanticipated ICU admission, cardiac arrest or combined outcomes compared to NEWS either.
- In acute exacerbation of chronic obstructive pulmonary disease (AECOPD) cohort, NEWS2 at admission did not outperform the original NEWS.
- In pre-hospital setting, NEWS2 had the best prognostic performance [AUROC of 0.896 (95%CI 0.82, 0.95)], in comparison with other EWS namely EWS [Early Warning Score (EWS), Modified Early Warning Score (MEWS), Vital-PAC Early Warning Score (ViEWS), Hamilton Early Warning Score (HEWS) and Scottish Early Warning Score (SEWS).
- The NEWS2 accurately predicted in-hospital mortality particularly among patients with suspected infection. At the critical threshold (≥ 5), the NEWS2 had sensitivity of 84.5% (95%CI 82.8, 86.2) and specificity of 49.0% (95%CI 47.4, 50.7). The number needed to examine (NNE) was 2.20 (95%CI 2.16, 2.25). NEWS2 was

superior to qSOFA for screening for sepsis with organ dysfunction, infection-related mortality or intensive care due to an infection both among infected patients and among undifferentiated patients at emergency departments.

2. Impact on clinical outcome (NEWS and NEWS2)

- Despite having good prognostic performance of death and ICU admission, the implementation of NEWS has not yet been reported to have any change in overall patient outcomes (survival rate, serious adverse events rate, ICU mortality rate).

Safety

There was fair level of evidence to suggest;

- Accuracy of NEWS scoring decreased significantly with increasing score or worsening physiological derangement and it had become a safety concern.
- The NEWS that were calculated incorrectly had implications for trigger actions and associated clinical care. Increased mortality trend was observed among patients who received an incorrect response.
- Patients admitted at the weekend had a worse clinical response [adjusted OR 4.15 (95%CI 2.24, 7.69), p<0.001].
- Non-adherence to NEWS escalation protocol at one or several levels was associated with the occurrence of serious adverse events.

Economic evaluation

There was no retrievable evidence on cost-effectiveness. However, there were one cost analysis and two budget impact analysis conducted on implementation of NEWS. They suggested that the NEWS leads to cost and/or efficiency savings. If this trend is continuous and savings can be realised, it could be hypothesized that NEWS may indeed be cost effective.

Organisational implication

There was fair level of evidence to suggest:

- Length of stay (LOS) was found to be significantly correlated with NEWS, where median LOS was more than doubled for a NEWS score >7 compared with a score of 0–4.
- Level of workload was inversely associated with NEWS scoring or threshold level. A NEWS score of 3 as a trigger would have increased doctors workload by 40% with only a small increase in the number of detected adverse outcomes per day (a 3% improvement in detection) whereas NEWS threshold of 5 would generate lower workload and higher detection rates (medical: workload 12·3%, detection 70·2%; surgical: workload 6·1%, detection 60·6%).
- Reduced sensitivity of the triggering system and the overall effectiveness of the NEWS were likely to be caused by poor recording of vital signs, incorrect calculations and non-adherence to the escalation protocol.
- Chart design affected the speed and accuracy of documentation. The use of graphical display and avoiding visual clutter, and the use of overlapping graphical displays of data helped to improve adherence.
- Interdisciplinary, multimodal and follow-up educational programmes were most effective in improving adherence rate.
- Improved efficiency and accuracy of recording vital sign parameters and compliance with escalation protocols were seen with automation of EWS.

Ethical and legal issues

There was evidence to suggest that in overcoming ethical and legal challenges of performing predictive analytics on healthcare, developing a governance structure at the earliest phase of model development is recommended in order to guide patients and participating stakeholders across the process. Liability issues such as failure to obtain crucial knowledge of patient's medical history due to dependency on predictive model to make clinical decision which lead to harm, overriding an alert or recommendation or following the recommendations of faulty predictive analytic model should be anticipated and preventive measures should be put in place. Ethical issue surrounding doctor-patient relationship whereby the treatment approach could be shifted from catering to individual patient's best interest to the interest of healthcare organization in maximizing population based health should be foreseen.

Social implication

There was evidence to suggest that understanding the organisational culture, systems, practices, barriers and facilitators and the stakeholders' perceptions and interactions with the NEWS pre-implementation is important. The success of NEWS intervention depends on human interaction with the system and understanding the variable organisational practices; this involved understanding how the nursing staff incorporate the EWS system into their daily work routines and how they feel the system works for them. Organisations also need to address power hierarchy between medial teams to reduce delays in response to deteriorating patients. A 'whole system' approach incorporating a EWS, well designed chart, communication tool, decision aides, evidence based care bundles, Rapid Response Team (RRT), bedside evaluation, education, reinforcement and audit is most effective at identifying and responding to deteriorating patients. A poor-quality implementation likely to worsen patient care.

9.0 RECOMMENDATIONS

Based on the findings of this review, NEWS may have a role in the early identification of deteriorating patient and can be used for adult non-obstetric patients within the hospital system to improve safety and efficiency of patient care through standardisation of early warning score application. The following considerations should be taken into account in the development of national approach of early warning score in order to ensure its effective implementation;

- A requirement for systems approach supported by appropriate governance as NEWS is a system-level complex intervention. The emphasis should be given on regular reinforcement and auditing to promote high levels adherence to NEWS to ensure effectiveness.
- For effective escalation of care, the appropriate trigger levels should be set and a mechanism should be in place to ensure that the appropriate individuals with higher NEW scores are reviewed promptly by health care professionals with critical care competencies and diagnostic skills.
- Ensuring regular training and continuous education of all health care providers using NEWS; such training and education should include: interdisciplinary in person simulations/case-reviews; be multimodal, and inclusion of regular reinforcement.
- In healthcare settings where automated healthcare service is available, the potential use of electronic data capture, EWS triggering, notification and tracking of outcomes should be carefully considered. The implementation of electronic NEWS should be initiated as a pilot programme before expansion to other hospitals.
- In settings that still utilize manual system in delivering services to patients, a structured manual approach (paper-based NEWS) would be a more suited choice.

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11.0 APPENDICES

Appendix 1

HIERARCHY OF EVIDENCE FOR EFFECTIVENESS STUDIES
DESIGNATION OF LEVELS OF EVIDENCE

I Evidence obtained from at least one properly designed randomized controlled trial.
II-I Evidence obtained from well-designed controlled trials without randomization.
II-2 Evidence obtained from well-designed cohort or case-control analytic studies, preferably from more than one centre or research group.
II-3 Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled experiments (such as the results of the introduction of penicillin treatment in the 1940s) could also be regarded as this type of evidence.
III Opinions or respected authorities, based on clinical experience; descriptive studies and case reports; or reports of expert committees.

SOURCE: US/CANADIAN PREVENTIVE SERVICES TASK FORCE (Harris 2001)

Appendix 2

PTK-FM-02 Pin.1/2016

HEALTH TECHNOLOGY ASSESSMENT (HTA) PROTOCOL
NATIONAL EARLY WARNING SCORE

1.0 BACKGROUND

Reduction in the incidence of hospital adverse events and the number of preventable deaths in hospital has been the major focus of many quality improvement initiatives worldwide. It is a reflection on the capacity of the healthcare service in delivering high quality care to the patients. In 2016, approximately 24% of all deaths in the UK were considered preventable (141,101 deaths out of 597,206).[1] About one-third of potentially preventable deaths in the UK relate to poor clinical monitoring.[2] The total number of deaths in EU that could have potentially been prevented through effective medical interventions was just over 1.2 million in 2015.[3] According to a newly published analysis led by Harvard Medical School, eight million largely preventable deaths from lack of high quality medical care cost $6 trillion in lost economic welfare in low- and middle-income countries. If current conditions persist, low- and middle-income countries could lose collectively $11 trillion in gross domestic product (GDP) by 2030.[4]

'Catastrophic' medical or sentinel events which include in-hospital cardiopulmonary arrests and deterioration in the patient's clinical condition are often preceded by a steady accumulation of small clinical clues or a period of abnormal physiological status of the patient. In numerous studies, this abnormality was reflected on recorded patient's vital signs (blood pressure, heart rate, respiratory rate and temperature) suggesting that potential serious complications or adverse events in patient outcomes can be avoided if they were anticipated early.[5-10] Research suggests that patients suffering from a cardiac and/or respiratory arrest usually display physiological deviations (changes in vital signs and/or mental status) at least eight hours prior to their need for more intensive care.[10] A study reported that 86% of code blue events or rapid response team (RRT) activation could have been predicted beforehand, with a median advanced warning time of 11.5 hours.[9]

Recording patient's physiological observations is considered part of daily routine management in hospital either in acute hospital setting like in emergency department or in general ward setting. It is currently based mostly on intermittent measurements of basic parameters; blood pressure, heart rate, temperature and oxygen saturation by nursing staffs. Several hours can pass between such measurements and patient deterioration can go unnoticed especially on busy wards or during the night.[11] Analysis of 576 deaths reported to the UK National Patient Safety Agency's (NPSA) National Reporting and Learning System (NRLS) over a one year period identified that 11% were as a result of deterioration not recognised or acted upon.[12] According to the report produced by the UK NPSA, contributing factors for failure to recognise and respond to patient's clinical deterioration were observations not being taken or poorly documented, observations causing concern not being reported, early signs of deterioration not being recognised or misinterpreted and not responding appropriately.[12] These were often due to demanding workloads, poor staffing level, time limitation and communication failure between teams.[13, 14] Studies revealed that this failure had led to delays in diagnosis, treatment or referral, resulting in increased patient morbidity, mortality and admission to intensive care units or cardiac arrests, which were preventable.[15-19]

In order to address these challenges, hospitals require robust escalation of care processes to ensure that worsening conditions in patients are recognised and treated. A high quality response is essential to stop the potential transition from an initial serious complication to a progressive cascade of adverse occurrences that can lead to preventable patient harm and death, or 'failure to rescue'. Current nursing practise (routine vital signs observation) in hospitals is not sensitive enough to detect a deteriorating or critically ill patient at an early stage. Providing clinical staffs with the tools they need, to be aware of those patients who are deteriorating fast will be a significant step forward. Early warning scores (EWS) are clinical bedside decision support tools used by care teams to potentially predict a patient's risk of deterioration and facilitate changes in management. Currently, it has been implemented across a variety of specialties and international settings.

1.1 Local Background and Context

In Malaysia, Ministry of Health is the major provider of healthcare services in public sector and consists of 144 hospitals (including special medical institutions namely Rehabilitation Hospital, Women & Children Hospital, National Leprosy Control Centre, Institute of Respiratory Medicine, National Cancer Institute and Pyschiatric Institutions) with a total inpatient bed capacity of 42 302.20 A total of 57 831 doctors and 106 289 nurses are currently working in public and private healthcare facilities, delivering services for patients, with a doctor and nurse to population ratio of 1:554 and 1:302, respectively.[20] There are challenges in sustaining the quality and patient safety in Malaysia. As the population increases, demand for healthcare increases as well.[21]

The highly subsidised government healthcare services with inequitable distribution of resources, changing in pattern of diseases and rising costs have resulted in heavy workload and long waiting time for patients to receive treatment.[21] Nowdays, patients are better informed and have an expectation that the care they receive is evidence based, effective, safe and of high quality. Advances in medical technology are constantly pushing the healthcare providers for better services but at great cost. According to Malaysia Health Systems Research Key Findings 2016, 219 deaths for every 100 000 population in Malaysia can be prevented with better healthcare.[22]

In order to elevate patient care and outcomes, a number of Ministry of Health hospitals as well as private hospitals have introduced EWS into their routine nursing practice for monitoring patient's clinical parameters as one of the strategic steps to strengthen its ability to better serve patients while easing the tasks of the hospital's personnel and management team. Early warning score is used mostly in general adult medical and surgical wards. In recent years, some of these hospitals mainly private hospitals started transitioning their EWS from paper observation charts to electronic platforms. University Malaya Medical Centre (UMMC) has become the first public hospital in the country to implement a warning score system that is fully integrated into its electronic patient management system.[23] Penang Adventist Hospital and Bagan Specialist Centre in Penang are two examples of private hospitals that have adopted fully automated early warning scoring system.[24, 25]

At present, there has not been a formal adoption of single standardised EWS at national level that can be used across Malaysian healthcare system. While the few have adopted EWS either in its original version or adapted versions, tailored to their personalised hospital needs, majority of local hospitals are still using a conventional observation chart with routine four basic vital signs monitoring. The staff use their clinical judgement regarding the frequency of observations and adjust where necessary. Consistent use of a single nationally agreed EWS system as a tool for detection and response to clinical deterioration in adult patients will ensure that all patients are objectively assessed in the same way, regardless of the clinical expertise of the clinician or where the patient is assessed. This will ensure that the severity of illness and the rate of deterioration can be explicitly stated and understood throughout the entire Malaysian healthcare system. Hence, this Health Technology Assessment (HTA) was requested by Head of Department and Senior Consultant of General Surgery from Kuala Krai Hospital, Kelantan, to assess the effectiveness, safety, economic and organisational impacts of National Early Warning Score (NEWS) as standardised approach for the detection of and response to clinical deterioration in patients with acute illness.

2.0 TECHNICAL FEATURES

2.1 Early Warning Scores/Systems (EWS) [26-28]

Early Warning Scores/Systems, also referred to as 'Track and Trigger Systems', are simple scoring systems for bedside monitoring, to serve as clinical support tools using routinely collected vital sign data. The scoring tools have been established in acute clinical care settings to facilitate early detection of deterioration by categorising a patient's severity of illness and prompting nursing staff to request a medical review at specific trigger points utilising a structured communication tool while following a definitive escalation plan. They were developed initially as paper based approach then later moved to electronic platform.

In its simplest form, Early Warning/Track and Trigger Systems require an efficient data collection mechanism to '**track'** physiological signs or changes followed by a data analysis algorithm to generate an early '**trigger'** to intervene and escalate care. Overall, these systems focus on combating the problem of "failure to rescue"; they are then broken down into issues of "failure to identify" (afferent limb) and "failure to escalate" (efferent limb). The afferent limb of the system is meant to identify patient deterioration and trigger a response indicating the need for a higher level of care. The efferent limb is the response to the trigger—delivered through higher levels of monitoring and care or a rapid response/medical emergency team. (Figure 1) Numerous EW/TTS are used internationally to detect patients at risk of deteriorating. They are broadly divided into single parameter, multiple parameter and aggregate weighted systems, which are shown in the Table 1.

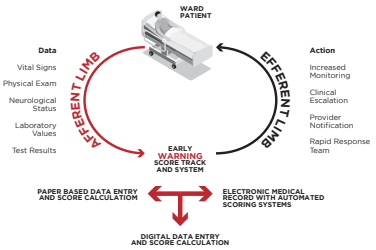

Figure 1: A schematic representation of early warning/track-and-trigger systems demonstrating the afferent and efferent limbs of the system.[28]

Table 1: Types of Early Warning System

System	Characteristics
Single parameter system	Periodic observation of selected vital signs or laboratory values that are compared with a simple set of criteria with predefined thresholds, with a response algorithm being activated when any single criterion is met. ❖ Thresholds for classifying the values as abnormal are not uniform among hospitals and scoring systems are chosen somewhat arbitrarily based on local preferences and expertise. ❖ Examples: qSOFA, SIRS
Multiple parameter system	Response algorithm requires more than one criterion to be met or differs according to the number of criteria met. ❖ Example: shock index (SI)—heart rate divided by systolic blood pressure
Aggregate scoring system	**Weighted scores are assigned to physiological values and compared with predefined trigger thresholds.** ❖ **Examples: NEWS, MEWS, ViEWS**

2.2 Electronic early warning systems[29]

While commercial electronic early warning systems may comprise a wide range of features, there are four core elements that are common to all systems.

a) Electronic reporting (information capture) of vital sign parameters at the bedside using a mobile, user-friendly platform
b) Computer learning systems that calculate the early warning score
c) Escalation of care when appropriate
d) Communication of the actions to be taken/or have been taken to address deteriorating vital sign and patient parameters.

When an electronic early warning system is introduced into a setting, the threshold parameters are usually set in line with national or local guidelines for early warning scores and escalation protocols.

2.3 National Early Warning Score (NEWS)[26]

National Early Warning Score was developed in 2012, through collaborative work of Royal College of Physicians (RCP) and National Health Service (NHS) Trusts in UK on the basis of there should be a national system for recognising very sick patients whose condition is deteriorating and who need more intensive medical or nursing care. It is a pragmatic approach, with a key emphasis on system-wide standardisation and the use of physiological parameters that are already routinely measured in hospitals and in prehospital care, recorded on a standardised clinical chart. The NEWS is an **adjunct** to decision making, used in combination with clinical judgement and communicated across the care pathway. NEWS **does not replace** disease-specific validated scoring systems but highly recommended to be used alongside these validated scoring systems as dictated by patient need. It offers the following features;

- a standardised method to characterise acute illness severity
- a standardised method to detect patient deterioration
- a common language of illness severity
- system-wide unitary documentation - instantly recognisable
- a standardised system for education, training and accreditation for all staff in the local healthcare system

Based on EWS concept, it is used to quickly determine the degree of illness of a patient and simplify trend tracking, enabling a more timely response using a common language across hospitals nationally. The principles of the NEWS highlight a key triad consists of early detection, speed of response and competencies of the responder(s) that determine the clinical outcomes (hospital mortality, cardiac arrest, admission to critical care).

In 2017, NEWS was updated to NEWS2 to include additional features (Chart 1);

- Observation chart re-odered to reflect the resuscitation council ABCDE format
- Chart colours changed from red/amber/green as they were not ideal for staff with red/green colour blindness. (Chart 1)
- New section for scoring oxygen saturations for patients with hypercapnic respiratory failure (SpO2 Scale 2). (Figure 2)
- "New confusion / delirium" added and scores 3. (Figure 3)
- Strong emphasis use of NEWS to raise suspicion of potential sepsis as a cause for a NEWS score of 5 or more. (Chart 3)

PHYSIOLOGICAL PARAMETERS	3	2	1	0	1	2	3
Respiration Rate	≤8		9 - 11	12 - 20		21 - 24	≥25
Oxygen Saturations	≤91	92 - 93	94 - 95	≥96			
Any Supplemental Oxygen		Yes		No			
Temperature	≤35.0		35.1 - 36.0	36.1 - 38.0	38.1 - 39.0	≥39.1	
Systolic BP	≤90	91 - 100	101 - 110	111 - 219			≥220
Heart Rate	≤40		41 - 50	51 - 90	91 - 110	111 - 130	≥131
Level of Consciousness				A			V, P, or U

Physiological parameter	Score 3	2	1	0	1	2	3
Respiration rate (per minute)	≤8		9–11	12–20		21–24	≥25
SpO_2 Scale 1 (%)	≤91	92–93	94–95	≥96			
SpO_2 Scale 2 (%)	≤83	84–85	86–87	88–92 ≥93 on air	93–94 on oxygen	95–96 on oxygen	≥97 on oxygen
Air or oxygen?		Oxygen		Air			
Systolic blood pressure (mmHg)	≤90	91–100	101–110	111–219			≥220
Pulse (per minute)	≤40		41–50	51–90	91–110	111–130	≥131
Consciousness				Alert			CVPU
Temperature (°C)	≤35.0		35.1–36.0	36.1–38.0	38.1–39.0	≥39.1	

NEWS (2012) - - - -> NEWS2 (2017)

Chart 1: Physiological Parameter Score Chart

Six simple physiological parameters form the basis of the NEWS scoring system.

1. Respiratory rate
2. Oxygen saturation
3. Systolic blood pressure
4. Pulse rate
5. Level of consciousness or new confusion
6. Temperature

A score is allocated to physiological measurements already undertaken when patients present to, or are being monitored in hospital, with the magnitude of the score reflecting how extremely the parameter varies from the norm. The score is then aggregated. The score is uplifted by 2 points for people requiring supplemental oxygen to maintain their recommended oxygen saturation. The clinical parameters [6 vital signs as well as the AVPU scale ("alert, voice, pain, unresponsive")] produces an aggregate score between 0 and 20. (Chart 1)

NEW score	Clinical risk	Response
Aggregate score 0–4	Low	Ward-based response
Red score Score of 3 in any individual parameter	Low–medium	Urgent ward-based response*
Aggregate score 5–6	Medium	Key threshold for urgent response*
Aggregate score 7 or more	High	Urgent or emergency response**

Chart 2: NEWS Thresholds and Triggers

NEWS recommends four trigger levels for a clinical alert requiring clinician assessment based on the NEWS (Chart 2) :

- **LOW score:** an aggregate NEW score of 1–4
- **A single red score:** an extreme variation in an individual physiological parameter (a score of 3 in any one parameter, which is colour-coded **red** on the NEWS chart)
- **MEDIUM score:** an aggregate NEW score of 5 or 6. **A NEW score of 5 or more is a key threshold** and is indicative of potential serious acute clinical deterioration and the need for an urgent clinical response
- **HIGH score:** an aggregate NEW score of 7 or more.

NEWS recommends that these triggers should determine the urgency of the clinical response and the clinical competency of the responder(s). (Chart 3)

	NEW score	Frequency of monitoring	Clinical response
	0	Minimum 12 hourly	• Continue routine NEWS monitoring
NEWS < 5 Ward-based Care	Total 1–4	Minimum 4–6 hourly	• Inform registered nurse, who must assess the patient • Registered nurse decides whether increased frequency of monitoring and/or escalation of care is required
High scoring single parameter Odd - Why?	3 in single parameter	Minimum 1 hourly	• Registered nurse to inform medical team caring for the patient, who will review and decide whether escalation of care is necessary
NEWS 5 or more Concern "Think Sepsis"	Total 5 or more Urgent response threshold	Minimum 1 hourly	• Registered nurse to immediately inform the medical team caring for the patient • Registered nurse to request urgent assessment by a clinician or team with core competencies in the care of acutely ill patients • Provide clinical care in an environment with monitoring facilities
NEWS 7 or more Major Concern Immediate Response Blue light from the community	Total 7 or more Emergency response threshold	Continuous monitoring of vital signs	• Registered nurse to immediately inform the medical team caring for the patient – this should be at least at specialist registrar level • Emergency assessment by a team with critical care competencies, including practitioner(s) with advanced airway management skills • Consider transfer of care to a level 2 or 3 clinical care facility, ie higher-dependency unit or ICU • Clinical care in an environment with monitoring facilities

Chart 3: Clinical response to the NEWS trigger threshold

NEWS recommends the use of the standardised NEWS observation chart for the routine recording of clinical observations, across the hospitals. The NEWS chart is colour-coded to provide both visual and numeric prompts to aid identification of abnormal clinical parameters. It is recognised that the rest of the chart area will be customised to reflect other key parameters not incorporated in the NEWS, eg urine output and pain scores, according to the clinical environment. (Chart 4)

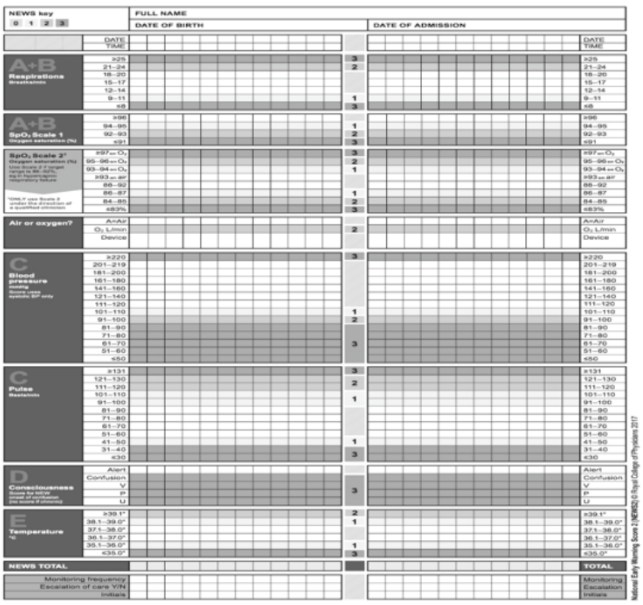

Chart 4: NEWS Observation Chart

3.0 POLICY QUESTION

Should National Early Warning Score (NEWS) be implemented in Ministry of Health (MOH) hospitals to improve safety, efficiency and standardisation of patient care?

4.0 OBJECTIVE

4.1 To assess the effectiveness and safety of NEWS in timely detection of patient's clinical deterioration by evaluating its predictive ability and impact on patient's clinical outcomes
4.2 To determine the economic implications of a nationally implemented Early Warning Score system
4.3 To evaluate the organisational, ethical, legal and social implications of NEWS implementation

Research Questions

i. How effective and safe is NEWS as clinical decision support tools, in predicting patient's clinical deterioration?
ii. What is the economic impacts of NEWS implementation in minimizing occurrence of adverse events and preventable hospital mortality?
iii. What are the organisational, ethical, legal and social issues related to NEWS implementation?

5.0 METHODS

5.1. Search Strategy

Electronic database will be searched for published literatures pertaining to NEWS.

5.1.1. Databases as follows; MEDLINE, EMBASE, PubMed, CINAHL, EBM Reviews-Cochrane Database of Systematic Review, EBM-Reviews-Cochrane Central Register of Controlled Trials, EBM Reviews-Health Technology Assessment, EBM Reviews-Cochrane Methodology Register, EBM Reviews-NHS Economic Evaluation Database, Database of Abstracts of Reviews of Effects (DARE), Horizon Scanning, INAHTA Database, HTA database and FDA database will be searched.

5.1.2. Additional literatures will be identified from the references of the retrieved articles.

5.1.3 General search engine will be used to get additional web-based information if there is no retrievable evidence from the scientific databases.

5.1.4 There will be no limitation applied in the search such as year and language.

5.1.5 The search strategy will be included in the appendix.

5.2 Inclusion and Exclusion Criteria

5.2.1 Inclusion Criteria

a) Population	i. All adult patients (aged 16 years old and above) in pre-hospital and hospital settings ii. Heathcare staffs who are involved in delivering the intervention
b) Intervention	National Early Warning Score (NEWS) [paper based or digitised approach ie VitalPAC Early Warning Score (ViEWS)]
c) Comparators	i. Other established scoring system designed to identify deteriorating patients [ie Patient at Risk (PAR) score, Physiological Scoring Systems (PSS), Vital Sign Score (VSS), BioSign] ii. Standard/Usual care (Standard Observation Charts) iii. No comparator

d) Outcomes	i. Effectiveness ❖ Predictive ability to detect clinical deterioration - model discrimination for outcomes of mortality, cardiopulmonary arrest, serious adverse events and ICU admission within 48 hours of measurement. ❖ Patient's clinical outcomes - in-hospital mortality - cardiovascular (CV) events (cardiac arrest, acute coronary syndrome, cardiogenic shock) ii. Safety ❖ Adverse events [Adoption issues ie. inconsistency in NEWS application among staffs and across medical specialties, the inaccuracies and miscalculations related to manual data collection leading to inappropriate clinical response or misalerts.] iii. Economic impacts ❖ Cost effectiveness analysis ❖ Cost utility analysis ❖ Cost benefit analysis ❖ Cost analysis ❖ Any other measure of economic outcomes iv. Organisational issues ❖ Resource utilisation - length of hospital stay - admissions to ICU - use of Rapid Response or Code Team - nursing staffs – staffing demand, level of workload, compliance rate ❖ Training requirement ❖ Efficiency in work process ❖ NEWS application adaptability - in resource limited settings - cross specialty application ❖ Opportunity for automation (electronic charting and scoring system for NEWS) v. Ethical and legal issues ❖ Ethical challenge of predictive analytics - impact on the role of the physician - clinical decision making ❖ Liability or litigation risk as a predictive modelling user for either overriding alerts or for following the recommendation of a predictive analytics model that contains an error (especially for electronic version) against using professional judgement and knowledge ❖ Liability of healthcare system for defective equipment (electronic system) vi. Social implications (Nursing staffs and doctors) Acceptance Attitude Work satisfaction Experience
e) Study Designs	HTA reports, systematic review with meta- analysis, systematic review, randomised controlled trial (RCT), cohort, case-control, cross-sectional, qualitative studies and economic evaluation studies.
f) English full text articles	

5.2.2. Exclusion Criteria

a) Studies that involved subgroup populations: obstetric and paediatric patients
b) Study design : Animal study, laboratory study, narrative review
c) Non English full text articles

Based on the above inclusion and exclusion criteria, study selection will be carried out independently by two reviewers. Disagreement will be resolved by discussion.

5.3 Critical Appraisal of Literature

The risk of bias of all retrieved literatures will be assessed using the relevant checklist of Critical Appraisal Skill Programme (CASP) and The Cochrane Collaboration's tool for RCT.

5.4 Analysis and Synthesis of Evidence

5.4.1. Data extraction strategy

The following data will be extracted:

i. Details of methods and study population characteristics
ii. Detail of intervention and comparators
iii. Details of individual outcomes specified

Data will be extracted from selected studies by a reviewer using a pre- designed data extraction form and checked by another reviewer. Disagreements will be resolved by discussion.

5.4.2 Methods of data synthesis

Data on the outcome measures will be presented in tabulated format with narrative summaries. Meta-analysis may be conducted for this Health Technology Assessment.

6.0 REPORT WRITING

7.0 REFERENCES

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Appendix 3

SEARCH STRATEGY

OVID MEDLINE searched 3.04.2019, 13.08.2019 and 9.09.2019

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non- Indexed Citations and Daily <2015 to September 5, 2019>

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1 ACUTE DISEASE/ (55200)
2 (acute adj1 disease$1).tw. (2029)
3 CRITICAL ILLNESS/ (10520)
4 (critical* adj1 illnesse$1).tw. (225)
5 adult patient.tw. (2753)
6 1 or 2 or 3 or 4 or 5 (70079)
7 SEVERITY OF ILLNESS INDEX/ (72216)
8 severity of illness index.tw. (32)
9 MONITORING, PHYSIOLOGIC/ (16167)
10 ((physiologic* or patient) adj1 monitoring).tw. (1901)
11 RISK ASSESSMENT/ (79591)
12 (health risk adj1 assessment$1).tw. (1967)
13 (risk assessment$1 adj health).tw. (10)
14 (risk adj1 assessment$1).tw. (28181)
15 (benefits adj2 risks).tw. (8424)
16 ((risk benefit or benefit risk) adj1 assessment$1).tw. (559)
17 EARLY DIAGNOSIS/ (8224)
18 (early adj1 diagnosis).tw. (31097)
19 (early detection adj2 disease).tw. (367)
20 detection of deterioration.tw. (28)
21 identification of deterioration.tw. (4)
22 track.mp. and trigger system.tw. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (13)
23 (warning system$ or early warning).tw. (3317)
24 physiological scoring system.tw. (12)
25 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 (224381)
26 HOSPITAL MORTALITY/ (14921)
27 (hospital adj2 mortalit*).tw. (17451)
28 (in house adj2 mortalit*).tw. (29)
29 HEART ARREST/ (9521)
30. ((heart or cardiac or cardiopulmonary) adj1 arrest).tw. (15894)
31 SENSITIVITY.mp. and SPECIFICITY/ [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (95452)
32 sensitivity.tw. (348178)
33 specificity.tw. (193988)
34 (sensitivity adj2 specificity).tw. (58266)
35 PREDICTIVE VALUE OF TESTS/ (66388)
36 predictive value of tests.tw. (23)
37 INTENSIVE CARE UNITS/ (18275)
38 (intensive adj2 care).tw. (59279)
39 HOSPITALIZATION/ (36900)
40 hospitali#ation$1.tw. (67408)
41 TREATMENT OUTCOME/ (311839)
42 ((clinical or treatment) adj1 eff*).tw. (87577)
43 ((patient relevant or rehabilitation or treatment) adj1 outcome$1).tw. (23920)
44 ((patient relevant or rehabilitation or treatment) adj1 outcome$1).tw. (23920)
45 HEALTH KNOWLEDGE, ATTITUDES, PRACTICE/ (33125)
46 health knowledge, attitudes, practice.tw. (1)
47 knowledge, attitudes, practice.tw. (16)
48 HEALTH CARE COSTS/ (11570)
49 ((health care or medical care) adj1 cost$1).tw. (6014)
50 ((health or treatment) adj1 cost$1).tw. (4581)
51 COST OF ILLNESS/ (8194)
52 ((disease or sickness or illness) adj2 cost$1).tw. (1611)

53 (economic burden adj2 disease).tw. (97)
54 (illness adj2 burden$1).tw. (884)
55 COSTS.mp. and COST ANALYSIS/ [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (11533)
56 (cost adj1 analys#s).tw. (3146)
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58 (cost adj1 comparison$1).tw. (491)
59 (cost analys#s adj2 cost$1).tw. (3003)
60 (cost adj1 measure$1).tw. (296)
61 COST BENEFIT ANALYSIS/ (23292)
62 ((cost benefit or cost utility or marginal or cost effectiveness) adj1 analys#s).tw. (7894)
63 (cost benefit adj1 data).tw. (6)
64 (cost adj1 effectiveness).tw. (26068)
65 (economic adj1 evaluation$1).tw. (5100)
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67 6 and 25 and 66 (2876)

PUBMED searched 3.04.2019, 13.08.2019 and 9.09.2019

((track and trigger [Title/Abstract])) OR (((((((“Hospital Information Systems”[Mesh]) OR Risk Assessment/ methods [Mesh]) OR Point-of-Care Systems [Mesh]) OR Monitoring, Physiologic/ methods[Mesh])) OR ((clinical deterioration[Title/Abstract]) OR risk assessment report[Title/Abstract])) OR (((early warning[Title/ Abstract]) OR warning system*[Title/Abstract]) OR warning scoring[Title/ Abstract])) AND ((((((physiological scoring system[Title/Abstract])) OR ((vital sign[Title/Abstract]) AND score[Title/Abstract])) OR (vitalpac[Title/ Abstract])) OR (sbar[Title/Abstract])) OR (situation background assessment recommendation[Title/Abstract])) AND ((((((((((C statistic*[Title/Abstract])) OR (Likelihood ratio[Title/Abstract])) OR (expected to observed[Title/ Abstract])) OR (calibration[Title/ Abstract])) OR (Calibration[Mesh])) OR (area under curve[Title/ Abstract])) OR (Area Under Curve[Mesh])) OR ((((PPV[Title/Abstract]) OR positive predictive value[Title/Abstract]) OR NPV[Title/ Abstract]) OR negative predictive value[Title/Abstract])) OR (Predictive Value of Tests[Mesh])) OR (((Receiver Operating[Title/ Abstract]) OR Receiver Operator[Title/Abstract]) OR ROC[Title/Abstract])) OR (ROC Curve[Mesh])) OR (discriminative function[Title/Abstract]) AND ((mortality[Title/Abstract])) OR (Hospital Mortality[Mesh]) AND ((length of stay[Title/Abstract])) OR (Length of Stay[Mesh]) AND (((((cardiac arrest[Title/Abstract]) OR cardiogenic shock[Title/Abstract]) OR ACS[Title/Abstract]) OR acute coronary syndrome[Title/Abstract])) OR ((Shock, Cardiogenic[Mesh]) OR Acute Coronary Syndrome[Mesh]) AND ((Respiratory Insufficiency[Mesh])) OR (respiratory failure[Title/Abstract]) AND (((Sepsis[Mesh]) OR Shock, Septic[Mesh])) OR ((sepsis[Title/Abstract]) OR septic[Title/Abstract]) AND (((((ICU[Title/Abstract]) OR intensive care unit[Title/ Abstract])) AND ((admission[Title/Abstract]) OR admissions[Title/Abstract]))) OR ((Patient Transfer[Mesh]) OR Intensive Care Units/ utilization[Mesh])

CINAHL searched 21.05.2019 and 9.09.2019

(MH “Hospital Information Systems”) OR (MH “Risk Assessment/MT”) OR “point of care systems” OR (MH “Monitoring, Physiologic/MT”) OR “track and trigger” OR “clinical deterioration” OR “risk assessment report” OR “early warning” OR “warning system*” OR “warning scoring” AND (TI vital sign AND TI score) OR TI physiological scoring system OR TI worthing OR TI vialpac OR TI sbar OR TI situation background assessment recommendation AND (M H “Calibration”) OR (MH “ROC Curve”) OR (MH “Predictive Value of Tests”) OR TI C statistic* OR TI likelihood ratio OR TI expected to observed OR TI calibration OR TI area under curve OR TI ppv OR TI positive predictive value OR TI NPV OR TI negative predictive value OR TI receiver operating OR TI receiver operator OR TI ROC OR TI discriminative function AND (MH “Hospital Mortality”) OR TI mortality AND (MH “Length of Stay”) OR “length of stay” AND (MH “Shock, Cardiogenic”) OR “cardiogenic shock” OR “acute coronary syndrome” OR (MH “Acute Coronary Syndrome”) OR “cardiac arrest” OR TI ACS AND (MH “Length of Stay”) OR “length of stay” AND (M H “Shock, Cardiogenic”) OR “cardiogenic shock” OR “acute coronary syndrome” OR (MH “Acute Coronary Syndrome”) OR “cardiac arrest” OR TI ACS AND (M H “Respiratory Failure”) OR “respiratory failure AND (M H “Respiratory Failure”) OR “respiratory failure AND ((TI ICU OR TI Intensive care unit) AND (TI Admission OR TI Admission)) OR “patient transfer” OR (MH “Intensive Care Units/UT”)

Appendix 4

Evidence table can be downloaded from:

MOH website : http://www.moh.gov.my/index.php/pages/view/1749
MaHTAS apps: HTA: National Early Warning Score (NEWS)

KEMENTERIAN KESIHATAN MALAYSIA

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9 789672 173984