# 2019 surveillance of acutely ill adults in hospital: recognising and responding to deterioration (NICE guideline CG50) – consultation document

## Surveillance proposal

We will not update the guideline on acutely ill adults in hospital: recognising and responding to deterioration.

### *Reasons for the proposal*

Topic experts suggested key areas to focus on in this surveillance review, including the use of track and trigger / early warning systems in the recognition of patient deterioration, electronic compared with paper-based systems for recognition of patient deterioration, and response strategies for patients identified as experiencing clinical deterioration. Focused searches for new evidence were undertaken in these areas as part of this surveillance review. Evidence we identified was either consistent with current recommendations or was not considered sufficient to impact on the recommendations in this guideline. Evidence allowing direct comparisons between different track and trigger tools/early warning scores or between different response strategies was limited. Overall, the new evidence that was identified was not considered to impact on the recommendations in this guideline.

It was concluded following the 2019 exceptional surveillance review that this guideline's research recommendations on the evaluation of early warning scores/track and trigger systems should be promoted with the National Institute for Health Research. Due to the considerable period that has elapsed since the publication of this guideline (in July 2007), it would be useful to check in this surveillance review whether stakeholders consider that the

existing research recommendations are still valid. A question has been included in this stakeholder consultation for this purpose.

We identified ongoing research on the use of early warning scales and monitoring of vital signs. The publication status of these studies and any potential impact on guideline recommendations upon publication will be monitored.

For further details and a summary of all evidence identified in surveillance, see the summary of evidence from surveillance.

## Overview of 2019 surveillance methods

NICE's surveillance team checked whether recommendations in acutely ill adults in hospital: recognising and responding to deterioration (NICE guideline CG50) remain up to date.

The surveillance process consisted of:

- Feedback from topic experts via a questionnaire.
- A search for new or updated Cochrane reviews.
- Consideration of evidence from previous surveillance.
- Examining related NICE guidance and quality standards and NIHR signals.
- A search for ongoing research.
- Examining the NICE event tracker for relevant ongoing and published events.
- Literature searches to identify relevant evidence.
- Assessing the new evidence against current recommendations to determine whether or not to update sections of the guideline, or the whole guideline.
- Consulting on the proposal with stakeholders, except if we propose to update and replace the whole guideline (this document).

For further details about the process and the possible update proposals that are available, see ensuring that published guidelines are current and accurate in developing NICE guidelines: the manual.

## *Evidence considered in surveillance*

### Search and selection strategy

We searched for new evidence related to specific parts of the guideline. These areas were suggested by topic experts as the key areas to focus on in this surveillance review. We searched for systematic reviews, experimental primary studies, and observational primary studies published between 22 October 2015 and 30 July 2019. Evidence specific to sepsis was not summarised in this surveillance review as this is covered by the NICE related guideline on sepsis: recognition, diagnosis and early management (NG51).

#### *Track and trigger/early warning systems for recognition of patients whose clinical condition is deteriorating or who are at risk of deterioration*

We searched for evidence on the use of any tool (i.e. track and trigger or early warning score) which triggers a mandated response to predetermined patterns of physiological derangements and includes 'periodic observation' of parameters compared with any other track and trigger system/early warning score or no track and trigger system/early warning score.

#### *Electronic and paper-based warning systems for recognition of patients whose clinical condition is deteriorating or who are at risk of deterioration*

We searched for evidence on the use of electronic alert/monitoring/warning systems compared with any other electronic alert/monitoring/warning system, paper-based alert system, or no alert/monitoring/warning system.

#### *Response strategies for patients identified as having a deteriorating clinical condition*

We searched for evidence on the effects of any response strategy (i.e. formal approach agreed within setting) to deterioration (e.g. critical care outreach team) compared with any other response strategy to deterioration or no specific response strategy to deterioration.

We included a total of 126 studies from these focused searches.

We also included:

- 8 relevant studies from a total of 39 identified by topic experts
- 1 study from an NIHR signal
- 55 studies identified in previous surveillance in 2010, 2016 and 2019

From all sources, we considered 190 studies to be relevant to the guideline.

See the summary of evidence from surveillance for details of all evidence considered, and references.

## *Ongoing research*

We checked for relevant ongoing research; of the ongoing studies identified, 2 studies were assessed as having the potential to change recommendations. Therefore, we plan to regularly check whether these studies have published results and evaluate the impact of the results on current recommendations as quickly as possible. These studies are:

- Use of early warning scales in the prehospital scope as a diagnostic and prognostic tool (ISRCTN17676798)
- Safer and more efficient vital signs monitoring: an observational study (ISRCTN10863045)

## *Intelligence gathered during surveillance*

### Views of topic experts

We considered the views of topic experts who were recruited to the NICE Centre for Guidelines Expert Advisers Panel to represent their specialty. For this surveillance review, topic experts completed a questionnaire about developments in evidence, policy and services related to the guideline.

We sent questionnaires to 11 topic experts and received 6 responses. Responding topic experts included a matron, a medical director, and consultants in the following areas: acute medicine, surgery, emergency medicine, intensive care medicine, and anaesthesia. Five out of 6 responding topic experts considered that recommendations in this guideline need to be updated.

The topic expert feedback was used to inform the selection of the areas for focused searches.

Key points highlighted in topic expert feedback included:

- Need to review evidence on identifying patients whose clinical condition is deteriorating/at risk of deterioration and choice of physiological track and trigger system. Topic experts noted local variations in components of early warning scores, that guidance should include confusion and supplemental oxygen, and the need for standardisation in track and trigger score. Topic expert feedback also highlighted the need for investigation of the use of track and trigger scoring in emergency department patients and recognition of subgroups where track and trigger systems may be less reliable (e.g. pregnant patients or spinal cord injury patients). One topic expert noted issues with outcome metrics for early warning systems, stating that a review of outcome measures of a successful early warning score is needed. A focused search was performed in this surveillance review to identify any new relevant evidence on the use of early warning scores/track and trigger systems.
- Potential issues with monitoring people with delirium/dementia/learning disabilities to reflect clinical risk. No evidence was identified on this topic in this surveillance review.
- Need to integrate track and trigger tools with wider information and correct presentation and use of that information. No evidence was identified on this topic in this surveillance review.
- Publication of the 2019 Healthcare Safety Investigation Branch (HSIB) report on recognising and responding to critically unwell patients, noting patients continue to suffer harm due to failure to recognise and respond in a timely manner. Focused searches for evidence on recognition of and response to patient deterioration were performed in this surveillance review. This HSIB report was also included in the summary of evidence.
- Need to review evidence on electronic alert/warning systems (including comparison of electronic and paper only systems). A focused search was performed to identify evidence on this topic.

- Acute kidney injury recognition should be part of the assessment of acutely ill people in hospital. Two relevant studies were identified in this surveillance review on the use of automated electronic alerts for acute kidney injury and modelling for prediction of acute kidney injury. NICE has produced a quality standard on acute kidney injury (QS76) and a clinical guideline on acute kidney injury: prevention, detection and management (CG169), both of which are included in the NICE Pathway on acutely ill patients in hospital.
- Need to consider evidence on response strategies. A focused search was performed in this surveillance review to identify any new relevant evidence in this area.
- Whether there was an issue with the definition of adult in the guidance and whether this should be ≥ 18 years or ≥ 16 years. The adult age definition is not explicitly defined in the scope or guideline.

### Views of stakeholders

Stakeholders are consulted on all surveillance reviews except if the whole guideline will be updated and replaced. Because this surveillance proposal was to not update the guideline, we are consulting with stakeholders.

### Implementation of the guideline

No relevant information was identified.

### Other sources of information

No relevant information was identified.

## *Equalities*

No equalities issues were identified during the surveillance process.

## *Overall proposal*

After considering all evidence and other intelligence and the impact on current recommendations, we decided that no update is necessary.

# 2019 surveillance of acutely ill adults in hospital: recognising and responding to deterioration (2007) NICE guideline CG50 – summary of evidence

## Overview

Studies identified in searches are summarised from the information presented in their abstracts.

We have noted where abstracts report studies as being undertaken in the United Kingdom. We have assumed that study populations are adults, unless otherwise reported in the abstract.

Evidence specific to sepsis is not summarised in this surveillance review as this is covered by the NICE related guideline on sepsis: recognition, diagnosis and early management (NG51).

Feedback from topic experts was considered alongside the evidence to reach a view on the need to update each section of the guideline.

Evidence from previous surveillance reviews in 2010 and 2016 and the exceptional surveillance review in 2019 for this topic was also considered.

## Identification and evaluation of risk scoring tools: physiological observations in acute hospital settings

### *Surveillance proposal*

The section of the guideline on identification and evaluation of risk scoring tools: physiological observations in acute hospital settings should not be updated.

## *Physiological observations in acute hospital settings*

### Previous surveillance

#### *2010 surveillance summary*

No relevant evidence was identified.

#### *2016 surveillance summary*

Three studies on staff competencies, education and training were suggested by topic experts. This new evidence highlighted the relevance of skills required for recording of physiological observations by staff and was considered consistent with current recommendations to ensure staff are appropriately trained.

One study on minimum physiological observations was highlighted by topic experts. This systematic review described signs and symptoms that trigger nurses to be concerned about a patient's condition. This new evidence was consistent with recommendation 1.8 that the response strategy for patients at risk of deterioration should be triggered by physiological track and trigger score or clinical concern.

#### *2019 surveillance summary*

A before and after study (1) assessed the impact of a short multidisciplinary training intervention for recognition of patient deterioration. Nursing, medical and allied nursing staff took part in a 1-hour long training session with real-life scenarios, simple tools and structured debriefing. Following training, staff were more likely to correctly calculate scores and perform observations at the correct frequency.

### Intelligence gathering

A topic expert queried whether the age cut-off used in this guidance needed to be revised (i.e. 18 years and above or 16 years and above).

### Impact statement

One study identified in the 2019 surveillance review, supported by the evidence from 3 studies on training identified in the 2016 surveillance review,

indicated the value of staff training in recognition of patient deterioration and is consistent with recommendation 1.1. that states that staff recording and acting upon physiological observations should have appropriate training to undertake these procedures and understand the clinical relevance.

A topic expert queried the age cut-off used in this guideline. However, the guideline took a pragmatic approach and did not define 'adult'.

New evidence is unlikely to change guideline recommendations.

# Identification and evaluation of risk scoring tools: identifying patients whose clinical condition is deteriorating or is at risk of deterioration

## *Surveillance proposal*

The section of the guideline on identification and evaluation of risk scoring tools: identifying patients whose clinical condition is deteriorating or is at risk of deterioration should not be updated.

## *Identifying patients whose clinical condition is deteriorating or is at risk of deterioration*

### Previous surveillance

#### *2010 surveillance summary*

No evidence was identified in the 2010 surveillance review.

#### *2016 surveillance summary*

Three studies on the frequency of recording of physiological observations were identified and highlighted the importance of monitoring patients and setting monitoring plans based on their risk level.

#### *2019 surveillance summary*

One randomised controlled trial (RCT) (2) explored the effect of timing of early warning score (EWS) measurements (score and country of setting not

reported) on patient outcomes in acutely admitted surgical and medical patients (n=1,346) at a university hospital. Patients (with an initial EWS of 0 or 1 [assumed low risk score]) were monitored at 8-hour or 12-hour intervals. No significant differences in clinical deterioration at 24 hours post-admission, cardiac arrests, intensive care unit (ICU) admissions, medical emergency team (MET) review, length of hospital stay, or elevated EWS at 48 hours were identified.

### Intelligence gathering

A topic expert commented that, because of changes in policy and their view of possible new evidence, this section of the guideline needed to be reviewed. This topic expert also noted multiple local variations in practice and failure to integrate information. The topic expert stated there are examples of this within the 2019 report on recognising and responding to critically unwell patients by the Healthcare Safety Investigation Branch (HSIB). For example, in the reference patient event in this report, patient information was reported to be dispersed across a range of documentation and clinical staff, with the design and presentation of the information failing to support staff in assessment of the patient. Safety recommendations from this HSIB report advised that the Royal College of Physicians should continue to evaluate the implementation and use of NEWS2 and that NHS England/NHS Improvement expand the remit of the Cross-System Sepsis Programme Board to also include physical patient deterioration. A safety observation in the report noted that NEWS2 is not intended as a stand-alone tool but should be combined with other patient information and clinical observations.

Topic expert feedback also noted that a review should cover the need to integrate track and trigger with wider information and correct presentation and use of that information.

### Impact statement

Recommendation 1.3 states that the frequency of monitoring of physiological observations should increase if abnormal physiology is detected and evidence from the 2016 surveillance review was consistent with this recommendation. However, one RCT was identified in this 2019 surveillance review that

compared the effect of 8-hour or 12-hour EWS measurements on patient outcomes (assumed in low risk patients) and did not find any significant differences in negative clinical outcomes between groups. However, this was a single study and so overall findings support recommendation 1.3 that frequency of monitoring should be at least every 12 hours and with increasing frequency in patients with abnormal physiology. This surveillance review has identified an ongoing UK-based study funded by the National Institute for Health Research, which aims to produce an externally validated vital signs monitoring protocol (including information on how frequently observations should be recorded). The status of this study and any potential impact of publication will be monitored.

A topic expert highlighted the 2019 HSIB report on recognising and responding to critically unwell patients, which includes safety recommendations and observations. However, the key issues were considered to relate primarily to implementation issues for systems for recognition and response to critically unwell patients and so were not considered to affect current guideline recommendations.

# Identification and evaluation of risk scoring tools - choice of physiological track and trigger system

## *Surveillance proposal*

The section of the guideline on identification and evaluation of risk scoring tools: choice of physiological track and trigger system should not be updated.

## *Choice of physiological track and trigger system*

### Previous surveillance

#### *2010 surveillance summary*

Twelve studies were included. It was noted that there was wide variation in the performance of different single and multiple-parameter track and trigger systems, with no evidence directly comparing the accuracy of different systems. A systematic review highlighted there was no evidence for clearly

identified cutoffs or weighting. A study describing the development of ViEWS was included (3). For hospital mortality, the Area Under Receiver Operating Characteristic curve (AUROC) of ViEWS was higher than the other aggregate weighted track and trigger tools tested. Two studies evaluating the use of the Modified Early Warning System (MEWS) were also identified. Overall, the evidence from the 2010 surveillance review reported variation in accuracy of the studied track and trigger systems, with no clearly defined cutoffs or weighting scores.

### *2016 surveillance summary*

A systematic review indicated that EWS had good predictive values, but impact of implementation was uncertain. Six studies on accuracy of track and trigger systems were also identified by topic experts. National Early Warning Score (NEWS) was considered to perform better than other track and trigger systems in some clinical outcomes, but the 2016 surveillance review concluded that further research was required. This evidence was consistent with guideline recommendations that track and trigger systems should be used to monitor all adult patients in acute hospital settings.

Three systematic reviews on the impact of EWS on outcomes were identified. These were consistent with current recommendations on the use of multiple-parameter or aggregate weighted scoring systems.

### *2019 exceptional surveillance summary*

This exceptional review was published in February 2019. Fifteen studies submitted by NHS England and the Royal College of Physicians were considered. The studies evaluated 10 different assessment tools. It was noted in the surveillance review that results were very mixed, and no single tool stood out as the most predictive or accurate. Recommendation 1.4 was revised to state that the EWS NEWS2 has been endorsed by NHS England. The exceptional surveillance review noted that this additional text is factually correct, does not change the intent of recommendations, and helps to provide a consistent message to healthcare professionals.

The exceptional surveillance review concluded that the guideline's research recommendations on the evaluation of early warning scores/track and trigger systems should be promoted with the National Institute for Health Research, with the aim of generating further evidence on EWS (including NEWS2).

**2019 surveillance summary**

Evidence was identified on the National Early Warning Score (NEWS), the Modified Early Warning Score (MEWS), other early warning scores, and mode of delivery.

***National Early Warning Score (NEWS)***

The 25 comparative studies identified on NEWS are presented in Table 1. No systematic reviews or RCTs were identified.

NEWS was compared with other scores or systems (listed alphabetically):

- Acute Physiology and Chronic Health Evaluation II (APACHE II) (4)
- Early Deterioration Indicator (5)
- Goodacre physiological score (6)
- Groake physiological score (6)
- Laboratory Decision Tree risk index (7)
- Logistic EWS (8)
- MET criteria (44 sets) (9)
- Modified Early Warning Score (MEWS) (5), (10), (11), (4)
- NEWS-Lactate (12), (13), (14)
- NEWS-base excess (12)
- NEWS plus fractional inspired oxygen concentration (15)
- NEWS minus systolic blood pressure (BP) (16)
- NEWS minus temperature (16)
- NEWS plus white blood cell count, procalcitonin and midregional-proadrenomedullin or NEWS plus midregional-proadrenomedullin (17)
- NEWS plus age, sex and soluble urokinase plasminogen activator receptor (18)
- NEWS2 (19)

- Patient at Risk Score (20)
- Rapid Acute Physiology Score (RAPS) (6)
- Rapid Emergency Medicine Score (REMS) (6)
- $SpO_2/FiO_2$ (SF) ratio (10)
- VitalPAC EWS (10)
- Worthing physiological score (6)

The only scores that were compared with NEWS in more than one study (where specific scores were named in abstracts) were MEWS and NEWS-Lactate. In all 4 studies comparing NEWS with MEWS, NEWS showed better performance. Of the 3 studies comparing NEWS with NEWS-Lactate, NEWS-Lactate performed better than NEWS in 2 studies.

NEWS was compared with NEWS2 in only one study (19). NEWS was reported to perform better than NEWS2 in prediction of in-hospital mortality. However, this study population was specific to patients at risk of type 2 respiratory failure or with documented type 2 respiratory failure. NEWS2 was also compared with the Hamilton EWS (24) and was reported to have a lower AUROC value than the Hamilton score.

**Table 1. National Early Warning Score (NEWS)**

| First author and year, study type | Population | System(s) evaluated | Outcome | Result |
|---|---|---|---|---|
| Abbott *et al.* (2015) (20)<br>Prospective cohort study | All adult general medical patients admitted to single hospital over 20 days (sample size NR) | NEWS at admission | Composite of critical care admission or death within 2 days of admission | OR 1.54, p<0.001,<br>NEWS ≥ 3 associated with outcome (OR=7.03, p=0.03) |
| | | Patient at Risk Score (PARS) at admission | | OR=1.42, p=0.056 |
| Abbott *et al.* (2016) (12)<br>Single centre prospective cohort study | Adult medical admissions (sample size NR) | NEWS (recorded at admission) | Composite of mortality or critical care escalation within 2 days of hospital admission | OR=1.46, p<0.01 |
| | | NEWS-Lactate | | OR=1.18, p=0.01 |
| | | NEWS-base excess | | OR=1.13, p=0.03 |
| Abbott *et al.* (2018) (21)<br>Prospective cohort study<br>UK | Prehospital score calculated retrospectively for medical ward admissions at 1 UK teaching hospital (n=189) | NEWS (prehospital) | Composite of death or critical care escalation within 48 hours of hospital admission | OR=1.25, p=0.02 |
| | | NEWS (on admission) | | OR=1.52, p<0.01 |

| First author and year, study type | Population | System(s) evaluated | Outcome | Result |
|---|---|---|---|---|
| Bedoya *et al.* (2019) (22)<br>Retrospective before and after cohort study | Hospitalised adults at a tertiary care academic facility and a community hospital (85,322 patients) | Implementation of NEWS in electronic health record and best practice alert | Rate of ICU transfer or death (academic hospital) | Adjusted hazard ratio = 0.94 (95% confidence interval, 95% CI 0.84 to 1.05) |
| | | | Rate of ICU transfer or death (community hospital) | Adjusted hazard ratio = 0.90 (95% CI 0.77 to 1.05) |
| Brabrand *et al.* (2017) (6)<br>Single centre observational study | Adults admitted to an acute medical unit at a teaching hospital (n=5,784) | NEWS<br>RAPS<br>REMS<br>Goodacre physiological score<br>Groake physiological score<br>Worthing physiological score | All-cause 24-hour mortality and overall in-hospital mortality | Discriminatory power for 24-hour mortality > 0.8 for all scores (except Groake score = 0.587) and was highest for the Worthing score (0.847).<br>Discriminatory power for prediction of in-hospital mortality was highest for Goodacre (0.810) and Worthing (0.800) scores and below 0.8 for other scores |
| Chiu *et al.* (2019) (8)<br>Multicentre study<br>UK | Patients discharged from ICU after cardiac surgery in 4 centres (all used VitalPAC for electronic collection of postoperative NEWS data) (13,631 patients) | Logistic EWS 24 h observation period | Composite: in-hospital death, cardiac arrest or unplanned ICU admission | AUROC=0.779 (95% CI 0.771 to 0.786) |
| | | NEWS 24 h observation period | | AUROC= 0.754 (95% CI 0.746 to 0.761), p<0.001 |
| | | Logistic EWS 6 h observation period | | AUROC= 0.841 (95% CI 0.829 to 0.853) |
| | | NEWS 6 h observation period | | AUROC= 0.813 (95% CI 0.800 to 0.825), p<0.001 |
| Dundar *et al.* (2019) (13)<br>Retrospective observational study | Geriatric patients at emergency department (ED) (n=455) | NEWS | In-hospital mortality | AUC= 0.686 (95% CI 0.628 to 0.744) |
| | | NEWS-Lactate | | AUC= 0.714 (95% CI 0.658 to 0.770) |
| Eckart *et al.* (2019) (17)<br>Multinational observational study (TRIAGE) | Adult medical patients needing ED care at 3 tertiary care centres in France, Switzerland and USA. NEWS calculated from admission data (1303 patients) | NEWS | All-cause 30-day mortality | AUROC=0.73 |
| | | NEWS plus white blood cell (WBC) count, procalcitonin (PCT) and midregional-proadrenomedullin (MR-proADM) or NEWS plus MR-proADM | | AUROC=0.82 (p=0.002) |
| | | NEWS | ICU admission | AUROC=0.65 |
| | | NEWS plus WBC count, PCT and MR-proADM | | AUROC=0.70 (p=0.006) |

| First author and year, study type | Population | System(s) evaluated | Outcome | Result | |
|---|---|---|---|---|---|
| Faisal *et al.* (2018) (23)<br>Logistic regression modelling | Emergency admission patients with NEWS data over 24-month period (4.05% with hospital-acquired acute kidney injury) (33,608) | Models using index NEWS | Prediction of hospital-acquired acute kidney injury | Lower AUC (0.59 to 0.68) and lower sensitivity (19.84%) than models using maximum NEWS | |
| | | Models using maximum NEWS | | Higher AUC (0.75 to 0.77) and higher sensitivity (67.6%) than models using index NEWS | |
| Fernando *et al.* (2019) (24)<br>Retrospective analysis of prospectively collected data | Consecutive rapid response team (RRT) patients from 2 hospitals (5,491 patients) | NEWS2 (low risk threshold) | Mortality | Sens 84.5% (95% CI 82.8% to 86.2%)<br>Spec 49.0% (95% CI 47.4% to 50.7%)<br>AUROC=0.72 (95% CI 0.71 to 0.74) | |
| | | Hamilton EWS (HEWS) ≥ 5 (low risk threshold) | | Sens 75.9% (95% CI 73.9 to 77.9)<br>Spec 67.6% (95% CI 66.1 to 69.1%)<br>AUROC=0.76 (95% CI 0.75 to 0.77) | |
| Ghosh *et al.* (2018) (5)<br>Model development and validation study | General ward patients (11,864 admissions for development, 2,418 general ward stays for validation) | NEWS | Deterioration | Validation AUROC=0.6569 | |
| | | MEWS | | Validation AUROC=0.6487 | |
| | | Early Deterioration Indicator (electronic) | | Validation AUROC=0.7655 | |
| Hydes *et al.* (2018) (25)<br>Observational study<br>England | 1 acute care hospital in England (sample size NR), NEWS assessed in patients with primary liver disease, non-primary liver disease, no diagnosis of liver disease, alcohol-related liver disease | NEWS (primary liver disease) | Discrimination for 24-hour mortality, cardiac arrest or unanticipated admission to ICU | AUROC=0.873 (95% CI 0.860 to 0.886) | |
| | | NEWS (non-primary liver disease) | | AUROC=0.898 (95% CI 0.891 to 0.905) | |
| | | NEWS (no diagnosis of liver disease) | | AUROC=0.879 (95% CI 0.877 to 0.881) | |
| | | NEWS (alcohol-related liver disease) | | AUROC=0.927 (95% CI 0.912 to 0.941) | |
| Jo *et al.* (2016) (14)<br>Retrospective cohort study | Adult patients at ED of academic tertiary care university hospital (n=4,624) | NEWS | 2-day mortality | AUROC=0.94 (95% CI 0.91 to 0.96) | |
| | | NEWS-Lactate | | AUROC= 0.96 (95% CI 0.94 to 0.98) (p=0.002) | |
| Kwack *et al.* (2017) (10)<br>Retrospective study | Adult patients admitted to respiratory ward (n=456) | NEWS | Unexpected ICU transfer | 0.667 | |
| | | MEWS | | 0.653 | |
| | | VitalPAC EWS (ViEWS) | | 0.744 | |
| | | $SpO_2/FiO_2$ (SF) ratio | | 0.744 (p>0.05 vs. NEWS, MEWS, p=0.06 vs. ViEWS) | |
| | | NEWS-Lactate | Composite of in-hospital death, ICU admission, and need for ≥ 5 | AUROC=0.76 (95% CI 0.70 to 0.82) | Sens by score: 3 (100%), 5 (98.3%), 5 (96.6%) |

| First author and year, study type | Population | System(s) evaluated | Outcome | Result | |
|---|---|---|---|---|---|
| Kim *et al.* (2018) (26)<br>Retrospective study | Patients with upper gastrointestinal bleeding (n=530) | Pre-endoscopic Rockall score | packs of red blood cell transfusion within 24 hours | AUROC=0.66 (95% CI 0.59 to 0.73), p=0.004 | |
| | | Glasgow-Blatchford score | | AUROC=0.70 (95% CI 0.64 to 0.77), p=0.141 | |
| | | AIMS65 | | AUROC=0.76 (95% CI 0.70 to 0.83), p=0.999 | Sens by score: 0 (91.5%) |
| Lee *et al.* (2018) (27)<br>Retrospective observational study | Number of patients NR | NEWS | In-hospital mortality | AUROC 0.765, 95% CI 0.659 to 0.846 | |
| | | Combination model incorporating other factors, e.g. age, diagnosis | | AUROC 0.861, p<0.005 | |
| Luis *et al.* (2018) (16)<br>Observational study | Patients from 6 Portuguese hospital wards (sample size NR) | NEWS | Detection of patient clinical deterioration in preceding 24 hours | AUROC=0.944 | |
| | | Model minus temperature | | AUROC=0.965 | |
| | | Model minus systolic BP | | AUROC=0.903 | |
| Malycha *et al.* (2019) (15)<br>Multicentre retrospective observational cohort study<br>UK | Adult admissions with ≥ 1 complete set of vital sign observations recorded electronically at 5 hospitals from 2 UK NHS trusts (83,304 patients prescribed oxygen) | NEWS | In-hospital death or unplanned ICU admission within 24 hours of a complete set of vital sign observations | AUROC=0.811 (95% CI 0.809 to 0.814) | |
| | | NEWS plus fractional inspired oxygen concentration | | AUROC=0.823 (95% CI 0.819 to 0.824) | |
| Mitsunaga *et al.* (2019) (11)<br>Retrospective single centre observational study | Prehospital<br>(sample size NR) | Prehospital NEWS | In-hospital mortality | AUROC=0.678 | |
| | | Prehospital MEWS | | AUROC=0.652 (no significant difference between prehospital scores, p=0.081) | |
| | | ED NEWS | | AUROC=0.789 | |
| | | ED MEWS | | AUROC=0.720 (p<0.001 between ED scores) | |
| Pimentel *et al.* (2019) (19)<br>Multicentre retrospective observational study<br>UK | Adult admissions at 5 acute hospitals from 2 UK NHS trusts with type II respiratory failure (48,898 patients at risk of (by diagnostic coding), 1,394 patients with documented type II respiratory failure (T2RF)) | NEWS2 in patients at risk of T2RF | In-hospital mortality within 24 hours | c-statistic=0.860 (95% CI 0.857 to 0.864) | |
| | | NEWS in patients at risk of T2RF | | c-statistic=0.881 (95% CI 0.878 to 0.884) | |
| | | NEWS2 in patients with documented T2RF | | c-statistic=0.841 (95% CI 0.827 to 0.855) | |
| | | NEWS in patients with documented T2RF | | c-statistic=0.862 (95% CI 0.848 to 0.875) | |

| First author and year, study type | Population | System(s) evaluated | Outcome | Result | |
|---|---|---|---|---|---|
| Rasmussen *et al.* (2018) (18)<br>Registry-based cohort study | Admitted acute medical patients (17,312 patients, admission NEWS available for 16,244) | NEWS | Prediction of 30-day mortality | AUC=0.86 (95% CI 0.85 to 0.87) | |
| | | NEWS plus age, sex and soluble urokinase plasminogen activator receptor | | AUC=0.90 (95% CI 0.89 to 0.91), p<0.0001 | |
| Redfern *et al.* (2018) (7)<br>Model development and validation study | Adult emergency medical admissions with vital signs and lab tests measured within their hospitalisation.<br>Validation in 2 hospitals<br>(Development n=97,933 admissions, validation n=21,028 + 16,383) | NEWS | Unanticipated ICU admission or in-hospital mortality within 24 hours | Validation c-statistic=0.877 (95% CI 0.873 to 0.882) to 0.898 (95% CI 0.898 to 0.904) | |
| | | Laboratory Decision Tree EWS: NEWS risk index | | Validation c-statistic=0.901 (95% CI 0.898 to 0.905) to 0.916 (95% CI 0.911 to 0.921) | |
| Smith *et al.* (2016) (9)<br>Retrospective cohort study | Adults hospitalised at a large UK NHS district general hospital (2,245,778 vital signs sets, 103,998 admissions) | NEWS | Combined outcome: death, cardiac arrest, or unanticipated ICU admission | AUROC=0.88 | |
| | | | | NEWS score of 7: Sens 44.5% | NEWS score of 7: Spec 97.4% |
| | | 44 sets of MET criteria (no further details reported in abstract) | | Sens 19.6 to 71.2% | Spec 71.5 to 98.5% |
| | | | | Position of NEWS ROC curve above and left of all MET criteria points (i.e. better discrimination). Positions of all MET criteria points above and to left of NEWS score efficiency curve (i.e. higher workload/trigger rate) | |
| Sutherasan *et al.* (2018) (28)<br>Prospective cohort study | General wards (1,145 patients) | Hospital protocol in response to deterioration stratified using NEWS | In-hospital mortality and ICU transfer | No significant difference between intervention (protocol) and control (pre-protocol) groups | |
| Yuan *et al.* (2018) (4)<br>Observational study | Patients in resuscitation room of a university hospital (621 cases) | NEWS | ICU admission | AUROC=0.760 | |
| | | Modified EWS (MEWS) | | AUROC=0.729 | |
| | | Acute Physiology and Chronic Health Evaluation II (APACHE II) | | AUROC=0.817 | |
| | | NEWS | 28-day mortality | AUROC=0.827 | |
| | | MEWS | | AUROC=0.723 | |
| | | APACHE II | | AUROC=0.883 | |

Four additional, non-comparative studies (not summarised in Table 1) were suggested by topic experts and are summarised below.

The ability of NEWS to predict ICU admission within 48 hours or 30 day mortality in the prehospital setting (via clinical observations from 1,713 patients recorded by emergency ambulance crews) (AUROC NEWS total score = 0.740, 95% CI 0.685 to 0.795) was demonstrated in an observational study (29).

A further observational study (30) of the performance of NEWS in a prehospital setting (n=35,800 patients) reported AUROC values for death within 1 day of 0.840 (95% CI 0.832 to 0.858), with a higher AUROC for this outcome in the trauma subgroup (AUROC 0.901, 95% CI 0.859 to 0.942).

A mixed methods study (31) based at English hospitals participating in the National Cardiac Arrest Audit found that introduction of the NEWS score was associated with an additional 8.4% reduction in in-hospital cardiac arrests.

The application of the NEWS2 oxygen saturation parameters to a previously studied cohort (32) indicated that 44% (n=27/62) of patients who were scored ≥ 7 on the original NEWS and who then died would have been placed in a lower call-out threshold.

### *Modified Early Warning Score (MEWS)*

Eight comparative studies on MEWS were included (and are tabulated below). Additional studies where MEWS was compared with NEWS are presented in Table 1.

Evidence was identified in which MEWS was compared with other scores or systems (listed alphabetically):

- Gastrointestinal EWS (33)
- Hypotension, Low Oxygen Saturation, Low Temperature, Abnormal Electrocardiogram (ECG), Loss of Independence (HOTEL) score (34)
- Linear predictors model (35)
- Logistic regression model with spline predictors (35)

- Novel metabolic score (36)
- Random forest model (35)
- RAPS (37)
- REMS (37)
- Simple Clinical Score (34)
- VitalPAC EWS (38)

All direct comparisons of MEWS with another score (other than the comparisons with NEWS described above) are from single studies.

**Table 2. Modified Early Warning Score (MEWS)**

| First author and year, study type | Population | System(s) evaluated | Outcome | Result |
|---|---|---|---|---|
| Churpek *et al.* (2016) (35)<br>Observational cohort study (model development and validation) | Hospitalised ward patients at 5 hospitals (269,999 patients admitted) | MEWS | Combined: cardiac arrest, ICU transfer, or death | AUC=0.70 |
| | | Random forest model | | AUC=0.80 |
| | | Logistic regression model with spline predictors | | AUC=0.77 |
| | | Linear predictors model | | AUC=0.74 |
| | | | | Machine learning methods more accurate in predicting clinical deterioration than logistic regression |
| Dundar *et al.* (2016) (38)<br>Prospective single-centred observational study | Geriatric (aged ≥ 65 years) ED patients at university hospital. Vital parameters measured on admission (n=671) | MEWS | Hospitalisation | AUC=0.727 (95% CI 0.689 to 0.765) |
| | | VitalPac EWS | | AUC=0.756 (95% CI 0.720 to 0.792) |
| | | MEWS | In-hospital mortality | AUC=0.891 (95% CI 0.844 to 0.937) |
| | | VitalPac EWS | | AUC=0.900 (95% CI 0.860 to 0.941) |
| Jafar *et al.* (2016) (36)<br>Prospective observational study | Patients presenting to resuscitation area of ED in teaching hospital (n=200) | MEWS | 48-hour organ failure | OR=1.19, p>0.05 |
| | | Novel metabolic score (derived from a blood gas) (no further details) | | OR=1.34, p>0.05 |
| | | MEWS | 48-hour death | OR=1.32, p>0.05 |
| | | Novel metabolic score (derived from a blood gas) (no further details) | | OR=1.56, p>0.05 |
| | | MEWS | | Neither score was predictive (no further detailed) |

| First author and year, study type | Population | System(s) evaluated | Outcome | Result |
|---|---|---|---|---|
| | | Novel metabolic score (derived from a blood gas) (no further details) | 48-hour escalation of care | |
| | | Metabolic score still significantly predictive of organ failure or death after controlling for MEWS parameters, p>0.05 | | |
| Kim *et al*. (2017) (33)<br>Observational study | Consecutive events triggering MET calls in adults admitted to gastroenterology wards of medical centre (1,219 patients) | MEWS | ICU transfer | AUC=0.64 |
| | | Gastrointestinal EWS (EWS-GI) | | AUC=0.76, p<0.001 |
| Norman *et al.* (2018) (39)<br>Before and after interventional study | Teaching hospital (sample size NR) | Emergency Room Safer Transfer of Patients (ER-STOP) system to avoid unexpected patient deterioration. Includes use of MEWS as component of a checklist | Critical care response team response within 24 hours of admission from ED to adult medical and surgical wards | Decreased |
| | | | ED wait times | Unchanged |
| | | | Cardiac care unit admissions | Unchanged |
| | | | ICU admissions | Unchanged |
| Weenk *et al.* (2019) (40)<br>RCT | Patients on surgical and internal medicine ward with minimum expected hospitalisation of 3 days (60 patients randomised) | MEWS via Visi Mobile continuous monitoring | Detection of high MEWS periods | 71 (14 patients) high MEWS periods detected between non-nurse-observed periods. Time between high MEWS and next regular nurse measurement ranged 0 to 10 hours |
| | | MEWS via HealthPatch continuous monitoring | | 32 (7 patients) high MEWS periods detected between non-nurse-observed periods. Time between high MEWS and next regular nurse measurement ranged 0 to 9 hours |
| Wei *et al.* (2019) (37)<br>Retrospective observational study | Adult patients presenting to emergency department of university hospital (39,977 patients presented to ED, 4,857 admitted, 213 died) | REMS | Hospital admission | AUROC=0.76 |
| | | RAPS | | AUROC=0.59 |
| | | MEWS | | AUROC=0.55 |
| | | REMS | Hospital mortality | AUROC=0.88 |
| | | RAPS | | AUROC=0.72 |
| | | MEWS | | AUROC=0.73 |
| | | REMS | Length of hospital stay | AUROC=0.76 |
| | | RAPS | | AUROC=0.67 |

| First author and year, study type | Population | System(s) evaluated | Outcome | Result |
|---|---|---|---|---|
| | | MEWS | | AUROC=0.65 |
| Wong *et al.* (2016) (34)<br>Retrospective cohort study | All interfacility transfer cases by ambulance with nurse-led or physician-led escort (n=659) | MEWS at triage | Prediction of en-route complication during interfacility transfer in emergency department | AUROC=0.662 |
| | | MEWS at ambulance departure | | AUROC=0.479 |
| | | Hypotension, Low Oxygen Saturation, Low Temperature, Abnormal ECG, Loss of Independence (HOTEL) score at triage | | AUROC=0.613 |
| | | HOTEL at ambulance departure | | AUROC=0.597 |
| | | Simple Clinical Score (SCS) at triage | | AUROC=0.600 |
| | | SCS at ambulance departure | | AUROC=0.568 |

### *Other early warning scores*

Studies on other EWS are presented in Table 3. No direct comparison between other EWS or systems was made in more than one study.

**Table 3. Other early warning scores (EWS)**

| First author and year, study type | Population | System(s) evaluated | Outcome | Result |
|---|---|---|---|---|
| Bellomo *et al.* (2018) (41)<br>Pilot RCT | Surgical ward of a tertiary hospital (205 patients) | Laboratory alerts to trigger early ICU team review compared with usual care | RRT activation during first alert | Significantly more likely |
| | | | Receipt of allied health referral | Significantly less likely |
| | | | Mortality at 24 hours | No significant difference |
| | | | Overall mortality | No significant difference |
| Churpek *et al.* (2016) (42)<br>Observational cohort study | Patients admitted to 5 hospitals (269,999 patient admissions) | Vital signs models using current and trend values | Combined: cardiac arrest, ICU transfer, and death | Use of trends improved accuracy vs. model using only current vital signs (AUC 0.78 vs. 0.74, p<0.001) |
| Douw *et al.* (2016) (43)<br>Prospective cohort study | Adult surgical patients admitted to 3 surgical wards (trauma, | Dutch-Early-Nurse-Worry-Indicator- | Composite of unplanned ICU/high | AUC=0.85 |

| First author and year, study type | Population | System(s) evaluated | Outcome | Result | |
|---|---|---|---|---|---|
| | vascular, and abdominal/oncological surgery) at a university teaching hospital (n=3,522) | Score (DENWIS) | dependency unit (HDU) admission or unexpected mortality | | |
| | | 'Worry' | | AUC=0.81 | |
| | | EWS | | AUC=0.86 | |
| | | DENWIS plus 'worry' | | AUC=0.87 | |
| | | DENWIS plus EWS | | AUC=0.91 | |
| Dziadzko *et al.* (2018) (44)<br>Model development and validation | Patients admitted to 4 hospitals in 2013 or 5th hospital in 2017 (68,775 admissions in 2013, 2,258 in 2017) | APPROVE model | Risk of death or respiratory failure needing ≥ 48 hours of mechanical ventilation | AUROC=0.87 (95% CI 0.85 to 0.88) in 2013 and 0.90 (95% CI 0.84 to 0.95) in 2017 | |
| | | MEWS | | AUROC NR<br>Compared to APPROVE in 2013, at threshold to achieve comparable positive predictive value (PPV) (19% at MEWS > 4 and 22% at NEWS >6), MEWS had lower sensitivity (16%).<br>In 2017, at comparable sensitivity threshold, (64% APPROVE >0.25, 67% MEWS and MEWS >4), more patients who triggered alert developed event with APPROVE (PPV 16%) than MEWS (PPV 7%). | |
| | | NEWS | | AUROC NR<br>Compared to APPROVE in 2013, at threshold to achieve comparable PPV (19% at MEWS > 4 and 22% at NEWS >6), NEWS had lower sensitivity (16%).<br>In 2017, at comparable sensitivity threshold, (64% APPROVE >0.25, 67% MEWS and NEWS >4), more patients who triggered alert developed event with APPROVE (PPV 16%) than NEWS (PPV 4%). | |
| Kwon *et al.* (2018) (45)<br>Retrospective observational cohort study | Data from Korean National Emergency Department Information System on visits from 151 EDs and 1 general hospital for score development and validation (11,656,559 patients) | Deep-learning-based Triage and Acuity Score | Primary outcome: in-hospital mortality | AUROC=0.935 | Area Under Precision and Recall Curve (AUPRC)=0.264 |
| | | Korean Triage and Acuity Score | | AUROC=0.785 | AUPRC=0.192 |
| | | MEWS | | AUROC=0.810 | AUPRC=0.116 |
| | | Logistic regression | | AUROC=0.903 | AUPRC=0.209 |
| | | Random forest | | AUROC=0.910 | AUPRC=0.179 |
| Linnen *et al.* (2019) (46)<br>Systematic review | Adult patients on general hospital wards (6 studies) | EWSs using statistical modelling | ICU transfer or death | Mean AUC=0.80 | |
| | | EWSs using aggregate-weighting | | Mean AUC=0.73<br>(with approximately 50% relative workload increase compared with statistical modelling EWSs) | |

| First author and year, study type | Population | System(s) evaluated | Outcome | Result | |
|---|---|---|---|---|---|
| | | | | | |
| Merriel *et al.* (2017) (47)<br>Before and after study | Women in hospital (Zimbabwe) (sample size NR) | Modified Obstetric EWS | Preoperative stabilisation | Increased | |
| | | | Action taken | Significantly improved | |
| O'Connell *et al.* (2016) (48)<br>Before and after study | Adult tertiary hospital (sample size NR) | Observation and response chart and altered calling criteria | RRT call rate | Significantly increased | |
| | | | Ward admissions to ICU | Significantly increased | |
| | | | Deaths | No change (no further details) | |
| | | | Cardiac arrest | No change (no further details) | |
| Peek *et al.* (2017) (49)<br>Review of clinical records | Consecutive post-cardiac surgery patients (n=400) | EWS | MET events, inpatient deaths and ICU admissions | 73 events, no inpatient deaths and 12 ICU readmissions in study cohort | |
| | | New Zealand EWS (NZEWS) | | Rescoring with NZEWS resulted in 53 events. 8 of 12 ICU admissions preceded by a NZEWS event | |
| Romero-Brufau *et al.,* 2017 (50)<br>Retrospective cohort study | All patients discharged (January to December 2011) from 2 tertiary care academic medical centre hospitals (sample size NR) | Published EWS (no further details reported) | Included unscheduled transfers to ICU, activation of rapid response system (RRS), and calls for cardiorespiratory resuscitation | All EWS had significantly higher PPV and sensitivity in medical population compared with surgical population.<br>All EWS had PPV < 25% | |
| Ryan *et al.* (2017) (51)<br>Observational study | 46 cases, 138 randomly selected controls. Pregnant or recently delivered women admitted at 2 maternity units (Canada) for > 24 hours | Modified Early Obstetric Warning System (MEOWS) | ICU admission > 24 hours | Sens 96% | Spec 54% |
| | | | | Sens 96% (≥ 1 red trigger) | Spec 73% (≥ 1 red trigger) |
| Street *et al.* (2017) (52)<br>Non-randomised pre-post intervention study | Adults who had elective surgery at 3 hospitals. Tool implemented in Post Anaesthesia Care Unit (PACU). Pre (n=723 patients), post (n=694 patients) phases | Post-Anaesthetic Care Tool (new observation, response and discharge chart) | Medical consultations initiated by PACU nurses | Significantly increased | |
| | | | Patients with MET activation criteria modified by anaesthetist while in PACU | Significantly increased | |

| First author and year, study type | Population | System(s) evaluated | Outcome | Result | |
|---|---|---|---|---|---|
| | | | Analgesia administration | Significantly increased | |
| | | | Nurse assessment of pain and documentation of ongoing analgesia before discharge | Significantly increased | |
| | | | Adverse events recorded in PACU | Significantly increased | |
| | | | Adverse events after discharge from PACU | No change | |
| | | | Cardiac events after PACU discharge | Significantly decreased | |
| | | | Clinical deterioration after PACU discharge | Significantly decreased | |
| Williams *et al.* (2016) (53) Systematic review | Patients transported by ambulance in prehospital setting (8 studies) | EWS vs. standard practice using clinical judgement alone | Identification of critical illness | EWS pooled diagnostic OR=10.9 (95% CI 4.2 to 27.9) | EWS summary AUROC=0.78 (95% CI=0.74 to 0.82) |

A further systematic review (54) identified 17 studies (n=157,878 participants) of the predictive performance of EWS for detection of patient deterioration in prehospital settings. AUROC values were reported to range from 0.50 (95% CI NR) to 0.89 (95% CI 0.82 to 0.96). The review concluded that 5 studies were at low or unclear risk of bias, with the remainder having high risk of bias.

### *Mode of delivery*

A focused search was used to identify evidence comparing the use of electronic early warning systems with paper-based systems in recognition of patient deterioration. Seventeen studies were included (Table 4).

**Table 4. Mode of delivery**

| First author and year, study type | Population | Intervention | Comparator | Outcome | Result |
|---|---|---|---|---|---|
| Bartkowiak *et al.* (2019) (55)<br>Retrospective cohort study | Adults hospitalised on wards after surgical procedure at academic medical centre (32,537 admissions) | eCART | Scores were compared with each other | Composite: ICU transfer, ward cardiac arrest, or ward death | AUROC=0.79 (95% CI 0.78 to 0.81) |
| | | NEWS | | | AUROC= 0.76 (95% CI 0.75 to 0.78) |
| | | Modified EWS | | | AUROC= 0.75 (95% CI 0.73 to 0.76) |
| Fletcher *et al.* (2017) (56)<br>Repeated treatment study | Patients in inpatient acute care wards of academic medical centre (6,736 eligible admissions) | Electronic medical record based alerting dashboard. Displayed all hospital patients in single view ranked by severity score and updated in real time | Dashboard display turned on and off each week for 10 2-week cycles over 20-week period | Overall rapid response team (RRT) activations | No significant difference |
| | | | | First RRT activations | Significant increase |
| | | | | Unexpected ICU transfers | No significant difference |
| | | | | Cardiopulmonary arrests on general wards | No significant difference |
| | | | | Deaths on general wards | No significant difference |
| Gagne *et al.* (2018) (57)<br>Before and after study | NR | EWS embedded electronically into medical records and communication bundle with notification and telephone collaboration between medical/surgical and ICU nurses (sample size NR) | Data 3 months before implementation | RRT calls | Non-significantly increased |
| | | | | RRT calls for patients with EWS >4 | Declined (significance NR) |
| | | | | ICU admissions after RRT calls | Significantly decreased |
| | | | | ICU admissions for patients with EWS> 4 | Significantly decreased |
| | | | | Documented reassessment response time | Significantly decreased |
| Green *et al.* (2018) (58)<br>Multicentre retrospective study | Patients admitted to 5 hospitals | Electronic Cardiac Arrest Risk Triage (eCART) score | Scores were compared with each other | Cardiac arrest, ICU transfer or death | AUC= 0.801 (95% CI 0.799 to 0.802) |
| | | NEWS | | | AUC= 0.718 (95% CI 0.716 to 0.720) |
| | | Modified EWS | | | AUC=0.698 (95% CI 0.696 to 0.700) |

| First author and year, study type | Population | Intervention | Comparator | Outcome | Result |
|---|---|---|---|---|---|
| | | Between the Flags calling criteria | | | AUC= 0.663 (95% CI 0.661 to 0.664) |
| Heller *et al.* (2018) (59)<br>Before and after study | Patients on 2 wards recovering from highly complex surgery (3,827) | Automated multiparameter EWS (MEWS based early warning system with paging functionality) | Before phase | Cardiac arrests | Significantly decreased |
| | | | | Unplanned ICU admissions | Significantly decreased |
| Hogan *et al.* (2019) (31)<br>Mixed methods study<br>England | English hospitals participating in National Cardiac Arrest Audit | Electronic track and trigger systems | Paper-based track and trigger systems | In-hospital cardiac arrests | 7.6% decrease (significance NR) |
| Hu *et al.* (2016) (60)<br>Retrospective cohort study | Hospitalised adult patients with haematological malignancies at academic medical centre (565 admissions) | Routine vital signs and laboratory values from electronic medical record and use of machine learning algorithm | VitalPac EWS (ViEWS) | Clinical deterioration events (ICU transfer and cardiac arrest) | Neural network model higher PPV than ViEWS model (82% vs. 24%, p NR) |
| Imperato *et al.* (2017) (61)<br>Retrospective pre and post intervention study | Patient in ED (sample size) | Clinical triggers programme measuring predetermined vital signs to trigger a rapid assessment by an emergency physician-led multidisciplinary team | Before phase | Primary outcome: median days admitted | No significant difference |
| | | | | Secondary outcome: median days in special care unit | No significant difference |
| | | | | Secondary outcome: in-hospital 30-day mortality | No significant difference |
| | | | | Secondary outcome: upgrade in level of care within 24 hours | No significant difference |
| Kang *et al.* (2016) (62)<br>Validation study | Adult inpatients (3,889) | Electronic Cardiac Arrest Risk Triage score (electronic health record based EWS) | Standard of care RRT activation | Cardiac arrest | eCART AUROC=0.88<br>8 of 10 patients with cardiac arrest had high risk eCART scores (RRT activated on 2 patients, p<0.05) |
| | | | | ICU transfer | eCART AUROC=0.80<br>eCART identified 52% of ICU transfers (vs. 34% by current system), p<0.001<br>Patients reached high risk eCART threshold median 30 hours before cardiac arrest/ICU transfer vs. 1.7 |

| First author and year, study type | Population | Intervention | Comparator | Outcome | Result |
|---|---|---|---|---|---|
| | | | | | hours by standard RRT activation. |
| Keim-Malpass *et al*. (2019) (63)<br>Model development and validation study | Patient admissions to cardiovascular medicine and surgery ward (8,111 patients for model training, 4,059 patients for validation, subsequent comparison of 91 patients with large abrupt spikes in risk with 59 control patients) | Spikes in ICU transfer risk from continuous predictive analytics monitoring (real time physiological data from ECG, vital signs, laboratory results and other clinical assessments) | Control patients matched for baseline risk including NEWS | ICU transfer | Event rate significantly higher in patients with risk spikes (PPV 24% vs. 7%, p=0.006). Risk spikes driven by respiratory changes had highest PPV (30 to 35%) and risk spikes from heart rate had lowest PPV (7%). |
| Kipnis *et al.* (2016) (64)<br>Development and validation study | Adult hospitalisations (374,838 patients, 649,418 hospitalisations,<br>analysis set: 48,723,248 hourly observations) | An automated hourly EWS (named Advanced Alert Monitor) based on electronic medical record data | Scores were compared with each other | Unplanned ICU transfer within next 12 hours | AUC=0.82 |
| | | eCART | | | AUC=0.79 |
| | | NEWS | | | AUC=0.76 |
| Pappas *et al.* (2016) (65)<br>Retrospective study | Patients outside ICU (580 mobile cart activations for critical care support, 577 completed) | Tele-ICU support for RRT for patients outside ICU using mobile platform (eMobile platform). Most common interventions: medication orders and laboratory studies. 33% calls managed without ICU upgrade. | RRT programme before testing of eMobile | Cost | Mean 66% increase in projected cost avoidance from unnecessary ICU transfers. For 2014, return on investment < $1.66 per $1 invested in IT support. |
| Subbe *et al.* (2017) (66)<br>Prospective before and after study<br>UK | All patients admitted to 2 clinical wards in UK district general hospital (2,139 patients (before phase), 2,263 | Electronic automated vital signs monitoring and notification system for patient deterioration. Abnormal vital | Before phase | Number of RRT notifications | Significantly increased |
| | | | | Number of patients with do not resuscitate (DNR) orders | Significantly increased |

| First author and year, study type | Population | Intervention | Comparator | Outcome | Result |
|---|---|---|---|---|---|
| | patients (after intervention)) | signs alerted to RRT | | Mortality | Significantly decreased |
| | | | | Cardiac arrests | Significantly decreased |
| | | | | Severity of illness in patients admitted to ICU | Decreased (significance NR) |
| | | | | Mortality in patients admitted to ICU | Significantly decreased |
| Watkinson *et al.* (2018) (67)<br>Model development and validation study | In-hospital patients (development data: 12,153 admissions, 301,644 vital sign observations, validation data: 53,395 admissions, 1,459,422 vital sign observations) | cCEWS (centile based EWS generated from continuously acquired data from bedside monitors) | Scores were compared with each other | Risk of cardiac arrest, unanticipated ICU admission, or death within 24 hours of a given vital sign observation | AUC=0.808 (95% CI 0.804 to 0.812) |
| | | mCEWS (centile based EWS from manually recorded data) | | | AUC=0.868 (95% CI 0.864 to 0.872) |
| | | NEWS | | | AUC=0.867 (95% CI 0.863 to 0.871) |
| Weller *et al.* (2018) (68)<br>Prospective observational pilot study | Adult hospitalised neurological and neurosurgical patients in 26 bed unit (non-ICU) in academic medical centre (sample size NR) | Wireless, portable, body-worn, continuous, multiparameter vital signs monitor with automated nurse alarm notification via smartphones | NR | RRT call rate | Significantly reduced |
| Wilson *et al.* (2015) (69)<br>RCT | Hospitalised patients at a university hospital with ≥ stage 1 acute kidney injury (1,201 patients in intervention group, 1,192 patients in control group) | Automated electronic alerts for acute kidney injury (text-based alert sent to covering provider and unit pharmacist to flag new acute kidney injury) | Usual care | ICU transfers | Non-significantly reduced |

| First author and year, study type | Population | Intervention | Comparator | Outcome | Result |
|---|---|---|---|---|---|
| Wilson *et al.* (2016) (70)<br>Single centre observational cohort study | ED (472 patient episodes) | Data-fusion patient status index for continuous vital sign monitoring (calculated retrospectively from continuous vital sign data) | Paper track and trigger system,<br>Electronic track and trigger system | Unplanned patient deaths | Non-significantly reduced |

## Intelligence gathering

### *Choice and standardisation of systems*

Topic expert feedback highlighted changes in the use of track and trigger systems, particularly noting the introduction of the NEWS2 system.

A topic expert suggested that the area of the guideline on choice of physiological track and trigger system needed to be reviewed, based on change in policy and their view of possible new evidence. This expert also noted that there are multiple local variations used in practice and failure to integrate information, citing the HSIB report as described previously. Another topic expert noted that this guideline does not recommend use of a specific score and that choice of track and trigger score should be standardised with all trusts using a recommended scoring system.

One topic expert reported that NEWS2 was, in their experience, the most widely adopted track and trigger system. Another topic expert commented that, as NEWS2 is being standardised across the NHS, the guideline should also promote NEWS2 in the interests of consistency. It was unclear whether the revised statement within recommendation 1.4 that NEWS2 is endorsed by NHS England was considered adequate or whether additional specific recommendations were being requested. A further topic expert noted the formal endorsement of NEWS2 from NHS England and NHS Improvement and stated that the guideline should reflect safe use and clear documentation of NEWS2.

### *Components of systems*

One topic expert commented that practice still varies in the components of EWSs and that outcome metrics are poor (no further details provided).

Topic expert feedback stated that a review was needed of the outcome measures of a successful early warning system and that the historical use of evidence supporting cardiac arrest as a suitable outcome measure was poor, citing a study by Hogan *et al.,* 2019 (no further details provided). A publication (71), identified during this surveillance review, described a Delphi consensus study to explore endpoints for validation of EWSs. Endpoints related to death, cardiac arrest and ICU admission were described as current compromises for validation of EWSs, with additional endpoints suggested by the study as potentially feasible in the future with large datasets and multiple measured parameters.

### *Settings and populations*

A topic expert stated that clarity was needed on the use of track and trigger scoring systems in ED patients (citing previous concerns that systems are not validated in this population). It was also commented that recognition of subgroups was required where track and trigger systems may not be as reliable, such as in pregnancy or people with spinal cord injury.

A topic expert reported potential issues with monitoring in people with delirium, dementia, or learning disabilities and a possible need to consider how to score people in these subgroups who cannot have a score recorded for an observation. No information was identified in this surveillance review.

### *Electronic systems*

One topic expert raised the use of electronic alert systems, indicating that a comparison with electronic versus paper only systems would be of value. Three NICE medical technology innovation briefings (VitalPAC for assessing vital signs of patients in hospital MIB79, EarlySense for heart and respiratory monitoring and predicting patient deterioration MIB49, and Visensia for early detection of deteriorating vital signs in adults in hospital MIB36) and an in-development digital health technologies pilot of Lifelight First for monitoring

vital signs were identified in this surveillance review that have relevance to electronic monitoring of patient physiological observations.

**Impact statement**

***Choice and standardisation of systems***

The 2016 surveillance review concluded that NEWS appeared to perform better than other scores but that more research was required. Recommendation 1.4 states that 'track and trigger systems (NEWS2 has been endorsed by NHS England) should use multiple-parameter or aggregate weighted scoring systems, which allow a graded response. These systems should define the parameters to be measured and the frequency of observations, [and] include a clear and explicit statement of the parameters, cut-off points or scores that should trigger a response.' Recommendation 1.4 does not currently recommend any specific track and trigger system but now states that NEWS2 has been endorsed by NHS England.

In this surveillance review, evidence was identified where NEWS was compared with another EWS or system. However, the only named scores that were compared with NEWS in more than one study were MEWS and NEWS-Lactate. There were only 2 studies identified in which NEWS2 was compared with another score. All direct comparisons of MEWS with another score (other than the comparisons with NEWS described above) were from single studies. For other EWSs, no direct comparison between scores or systems was made in more than one study.

As most identified comparisons between track and trigger systems were only available in single studies, the evidence identified in this surveillance review does not allow a definitive conclusion on which track and trigger tool may have superior performance. Therefore, the identified evidence is not sufficient to impact on recommendation 1.4.

***Components of systems***

One topic expert reported that practice varies in EWS components and that outcome metrics are poor, advising that a review of the outcome measures of

a successful EWS was required. One study was identified that proposed the most suitable endpoints for studies of EWSs but, as current recommendations do not refer to the use of endpoints in EWS research, this study does not impact on recommendations.

### *Settings and populations*

A topic expert stated that clarity was needed on the use of track and trigger scoring systems in emergency department (ED) patients (citing previous concerns that systems are not validated in this population). Evidence of the use of track and trigger systems in EDs is now available and was included in this surveillance review. Recommendation 1.1 advises that physiological observations be recorded for adult patients in acute hospital settings, including patients in the ED for whom a clinical decision to admit has been made. The identified evidence on use of track and trigger systems in patients in EDs is consistent with this recommendation.

Topic expert feedback noted that recognition of subgroups was required where track and trigger systems may not be as reliable, such as in pregnancy or people with spinal cord injury. Two studies were included that showed that the modified obstetric EWS may have high sensitivity and positively affect clinical outcomes. However, as the monitoring of physiological observations are already covered in the NICE guidelines on intrapartum care for healthy women and babies (CG190) and intrapartum care for women with existing medical conditions or obstetric complications and their babies (NG121) it is considered that this evidence fits within these guidelines and so these studies are not considered to impact on current recommendations in this guideline (CG50). NICE guideline NG41 provides recommendations for spinal injury: assessment and initial management. A NICE guideline on rehabilitation after traumatic injury is also in development.

### *Electronic systems*

Recommendation 1.4 does not specify the mode of delivery of track and trigger systems or whether electronic systems should be used. The evidence identified in this 2019 surveillance review indicates that the use of electronic monitoring systems show promise in improving patient outcomes. However,

the available evidence does not allow a single electronic system to be identified as most effective and so this evidence is not considered to have potential impact on recommendation 1.4.

# Identification and evaluation of risk scoring tools: physiological parameters to be used by track and trigger systems

## *Surveillance proposal*

The section of the guideline on identification and evaluation of risk scoring tools: physiological parameters to be used by track and trigger systems should not be updated.

## *Physiological parameters to be used by track and trigger systems*

### Previous surveillance

#### *2010 surveillance summary*

A total of 7 studies were identified and serum lactate was noted to be a potential additional parameter. However, the available evidence on predictive accuracy and generalisability was not conclusive and the review concluded that no new evidence contradicted the existing guideline recommendations.

#### *2016 surveillance summary*

No new evidence on physiological parameters to be used by track and trigger systems was identified.

The 2016 surveillance review identified examples of other pieces of NICE guidance that describe the management of diseases or conditions where specific parameters should be measured (e.g. chest pain of recent onset: assessment and diagnosis [CG95], head injury: assessment and early management [CG176]). Further guidance on physiological observations in specific circumstances is available in such related NICE guidelines.

### *2019 surveillance summary*

Two studies were identified in the 2019 surveillance review.

### *Parameters to be measured in specific clinical circumstances*

Continuous ECG monitoring was evaluated in a cohort study of 8,105 acute care patient admissions (72). Models with addition of continuous ECG measures improved prediction of deterioration leading to ICU transfer and unanticipated death within the next 24 hours compared with models using only laboratory results and vital signs.

In a prospective observational study (73) of 148 non-critical care inpatients, networked blood glucose meters with a visual alert for out of range blood glucose levels and a clinical glucose alert escalation pathway significantly increased nursing and medical action in response to episodes of adverse glycaemia. Patient-days with hyperglycaemia and patient-days with mean blood glucose > 15 mmol/l were significantly decreased.

## Intelligence gathering

### *Parameters to be measured by scoring systems*

Two topic experts commented that this guidance needed to be updated to include development of confusion and use of supplemental oxygen. New evidence for the differing EWSs and track and trigger systems (including NEWS2) is summarised in choice of physiological track and trigger system.

### *Recognition of acute kidney injury*

One topic expert suggested that the guideline considered recognition of acute kidney injury. It is noted that guidance on recognition of acute kidney injury is already covered by some related NICE products. NICE has produced a quality standard on acute kidney injury (QS76) and a clinical guideline on acute kidney injury: prevention, detection and management, both of which are included in the NICE Pathway on acutely ill patients in hospital. Statement 3 (monitoring in hospital for people at risk) of the quality standard on acute kidney injury (QS76) uses CG50 recommendation 1.6 as source guidance. Recommendation 1.2.1 from the acute kidney injury guideline CG169 directly

refers to CG50: 1.2.1 Follow the recommendations in [CG50] on the use of track and trigger systems (EWSs) to identify adults who are at risk of acute kidney injury because their clinical condition is deteriorating or is at risk of deteriorating. Recommendation 1.2.2 from the acute kidney injury guideline CG169 also refers to monitoring of urine output, which can be considered in line with CG50 recommendation 1.6 that advises additional monitoring (e.g. hourly urine output) in specific clinical circumstances.

**Impact statement**

***Parameters to be measured in specific clinical circumstances***

Two studies were included in the 2019 surveillance review that showed that monitoring of glucose and ECG monitoring may be of value to patients. This evidence is considered consistent with recommendation 1.6 that additional monitoring should be considered in specific clinical circumstances.

Recommendation 1.6 refers to lactate as a physiological parameter that may be used in additional monitoring in specific clinical circumstances. Three studies were identified that supported the performance of the NEWS-Lactate tool (see choice of physiological track and trigger system). This evidence supports the potential value of lactate as a physiological parameter to be used by track and trigger systems and so is consistent with this recommendation.

***Recognition of acute kidney injury***

One topic expert flagged the need for this guidance to consider recognition of acute kidney injury.

Existing recommendations do not refer to recognition of acute kidney injury. Two relevant studies were identified in this surveillance review on the use of automated electronic alerts for acute kidney injury and modelling for prediction of acute kidney injury. The evidence identified was from single studies and was not considered to impact on current recommendations.

# Response strategies for patients identified as having a deteriorating clinical condition: critical care outreach services for patients whose clinical condition is deteriorating

## *Surveillance proposal*

The section of the guideline on response strategies for patients identified as having a deteriorating clinical condition: critical care outreach services for patients whose clinical condition is deteriorating should not be updated.

## *Critical care outreach services for patients whose clinical condition is deteriorating*

### Previous surveillance

#### *2010 surveillance summary*

A focused search for evidence on whether provision of critical care outreach services improve outcomes in patients at risk of deteriorating and/or deteriorating identified 26 studies, including evidence on the effectiveness of response strategies (e.g. critical care outreach services [CCOS] and METs). The new evidence was inconclusive with no available evidence directly comparing different response strategies. A stakeholder commented at consultation that it would be useful if this guideline included recommendations on standardised methods for communicating patient deterioration. The 2010 surveillance review concluded that there was no impact on the existing guideline recommendations.

#### *2016 surveillance summary*

One systematic review assessed EWS or emergency response teams in hospital survival of adult patients. While the included evidence was described as of poor quality by the review authors, it supported a global approach of including track and trigger systems and teams having critical care competencies. A second systematic review found RRSs in acute care settings

to be associated with reduced cardiorespiratory arrests outside of ICU and reduced mortality. An observational study also reported that RRS results in decreased admissions and mortality.

This guideline does not recommend a specific service configuration and, since the identified evidence did not allow a specific service configuration to be recommended, the evidence identified in the 2016 surveillance review was consistent with existing recommendations.

**2019 surveillance summary**

***Education and training***

One RCT (74) with 67 nurses examined a 3-hour interactive web-based educational intervention for early recognition and response to patient deterioration in a simulated environment; the control group did not receive the educational intervention. There was a significant increase in respiratory rate monitoring by the intervention group compared with control group nurses. The intervention group also had significantly better post-test scores for knowledge, performance in assessment and management of clinical deterioration, and reporting clinical deterioration.

An RCT (75) assessed whether a training intervention could improve escalation of care by junior doctors. Before undertaking simulated escalation of care scenarios, postgraduate surgeons (n=33) were randomised to either receive an educational intervention or act as a control group with no intervention. The intervention group demonstrated significantly improved patient assessment, communication, and non-technical skills and detected significantly more medical errors compared with the control group.

A simulated RRT (76) assessed the impact of a cognitive aid booklet intervention on performance in volunteer residents from a medical school. Resident performance was significantly better in the intervention group compared with an undefined control group.

### *Response triggers*

A pilot retrospective cohort study (77) (n=620) assessed outcomes in patients with modifications to hospital RRT call triggers (n=393) compared with patients without modifications in (i.e. with standardised) RRT call triggers. Repeat RRT calls and in-hospital mortality were increased in patients with modifications. Modifications that were more conservative than standardised calling criteria were associated with mortality.

## Intelligence gathering

No information was identified.

## Impact statement

### *Education and training*

Two RCTs and 1 intervention study were identified in the 2019 surveillance review. These studies assessed the provision of educational/training interventions in 2 RCTs and a cognitive aid booklet intervention in 1 intervention study. These interventions resulted in improved performance by professionals in simulated test settings, improved knowledge and other post-test scores and skills. This evidence is consistent with recommendation 1.7 that staff caring for patients in acute settings should have competencies in monitoring, measurement, interpretation and response appropriate to the level of care they provide, and that education and training should be provided to ensure staff have the required competencies.

### *Response triggers*

One cohort study identified in the 2019 surveillance review found that modifications to RRT call triggers resulted in increased repeat RRT calls and in-hospital mortality compared with standardised RRT call triggers. This study does not contradict recommendations 1.8 and 1.9 that response strategies should be triggered by track and trigger score or clinical concern and that thresholds should be set locally.

# Response strategies for patients identified as having a deteriorating clinical condition: graded response strategy

## *Surveillance proposal*

The section of the guideline on response strategies for patients identified as having a deteriorating clinical condition: graded response strategy should not be updated.

## *Graded response strategy*

### Previous surveillance

#### *2010 surveillance summary*

Evidence identified in the 2010 surveillance review is summarised in the above section on critical care outreach services for patients whose clinical condition is deteriorating.

#### *2016 surveillance summary*

Evidence identified in the 2016 surveillance review is summarised in the above section on critical care outreach services for patients whose clinical condition is deteriorating.

### 2019 surveillance summary

The evidence identified in the 2019 surveillance review is presented in categories reflecting the terminology used in individual studies to describe the response strategy.

#### *Critical care response team / critical care outreach team*

Three included studies described critical care response teams (CCRT) or outreach teams (CCOT).

A stepped wedge cluster RCT (78) of patients on general hospital wards in Iran (n=7,802 patients admitted before implementation, 10,990 patients admitted after implementation) assessed impact of a CCOT delivered by a

team of intensive care nurses. The order of implementation was randomised. The intervention did not reduce mortality and focus groups highlighted lack of management and nurse endorsement of the intervention.

Addition of a critical care medicine-trained physician assistant to the CCOT was evaluated in a retrospective study (79) of 3,099 adults in ED and hospital requiring CCOT consultation. Compared with a control hospital with no staffing change, time to ICU transfer and hospital mortality were both significantly reduced.

A before and after study (80) showed a 5.2% increase in initiation and completion of DNR orders after critical care response team implementation (n=5,406 CCRT activations).

### *Intensive care consult service*

One study (81) in adult patients (sample size not reported) found that an ICU consult service with a dedicated intensivist (a dedicated daytime/weekday service without formal training of ward teams) did not reduce total hospital mortality but significantly decreased both 30-day mortality of patients admitted to ICU and the 14-day ICU readmission rate.

### *Medical emergency teams*

Four studies were identified that assessed the use of METs.

A data mining study (82) of 13,656 MET calls from 7,936 patients modelled the impact of redesign of the MET service to include a pre-emptive management algorithm for direct treatment of patients without waiting for MET team attendance. Decreases of 69% in projected MET calls for hypotension and 20% in projected total MET calls were reported.

MET implementation in a tertiary care hospital led to a significant decrease in crude hospital mortality rate in a retrospective cohort study of 511 MET activations (83).

A prospective study (84) (83 MET activations) found no significant difference in in-hospital mortality after MET implementation but a significant decrease in serious events (no further details).

In inpatients requiring MET activations for respiratory decompensation (n=50) (85), a prospective study showed that lung ultrasonography during MET activations had a higher diagnostic accuracy than MET diagnosis (84% versus 75%, p=0.29).

### *Patient at risk teams*

One single centre before and after study (86) (number of patients not reported) of a patient at risk team (composed predominantly of experienced ward nurses) found significant decreases in ward cardiac arrests and hospital length of stay and decreases in direct ward admissions to ICU and number of MET calls compared with a historical control.

### *Rapid response teams / systems*

Twenty-six studies were included that evaluated the use of rapid response teams (RRT) or systems (RRS). These are summarised below according to the study designs used.

### *Rapid response teams / systems – systematic reviews*

Three systematic reviews were identified. One systematic review and meta-analysis (87) included 29 studies and reported that RRTs resulted in significant reductions in adult hospital mortality and cardiopulmonary arrests. A second systematic review and meta-analysis (88) included 20 studies published in English, Portuguese or Spanish on patients in adult hospital units and reported reductions in mortality and cardiac arrest. However, the review authors noted a low quality of evidence, high heterogeneity and risk of bias in the included studies. A further systematic review and meta-analysis (89) of 30 studies in adults hospitalised in non-ICU care found reductions in hospital mortality and non-ICU cardiac arrests.

### *Rapid response teams / systems – RCTs*

Three RCTs were also included. A cluster RCT (90) of 3,135 emergency team calls for patients at 23 hospitals evaluated outcomes from implementation of RRTs compared with standard practice (with conventional cardiac arrest team responses to emergencies). The 1-year trial found that the proportion of delayed calls was significantly decreased with intervention. In all hospitals, delayed calls were significantly associated with increased risk of unplanned ICU admission and death. An RRS including a standardised observation and communication protocol with a pragmatic medical response strategy was described in a pragmatic stepped wedge cluster RCT of patients on 28 wards of 7 hospitals (intervention n=35,389, control n=34,267) (91). There were no significant differences between groups in unexpected death rates, cardiac arrest rates, or unplanned ICU admissions. However, the study authors noted a lower than expected baseline incidence of unexpected death and cardiac arrests that reduced the study statistical power. In an RCT (92) of 714 patients in emergency wards, a rapid response nursing team including an intensive care nurse and anaesthesia technician was compared with a control group receiving conventional emergency ward treatment. Transfer to special care units and the level of care in the first 24 hours after admission were both significantly decreased.

### *Rapid response teams / systems – non-RCTs*

Of the remaining 20 non-RCT primary studies, details of the composition or delivery of the RRT/RRS were available at abstract level for 10 studies.

A multicomponent intervention was tested in adults hospitalised in medical-surgical wards (sample size not reported) (93). This included an intensivist-led RRT (available 24 hours per day, 7 days per week), with educational modules, publicity, and bedside simulation-based training. A single activation criterion (heart rate < 40/minute or > 140/minute, systolic BP < 80 mmHg, cardiac arrest, respiratory rate <8/min or > 30/min, pulse oximetry < 90% with oxygen, respiratory distress in tracheostomy, respiratory arrest, coma, or sudden change in consciousness, seizure) allowed any caregiver to directly contact the RRT via a dedicated telephone number. Significant decreases in

unexpected mortality, overall mortality, and sequential organ failure assessment score upon ICU admission were observed. ICU admission significantly increased.

A different multicomponent intervention was assessed in patients in a teaching hospital (sample size not reported) (94). This involved an RRS with introduction of a medical emergency team (MET) and redesign of a ward observation chart with colour coding of vital sign variables to indicate variation from normal; mandated minimum frequency of vital sign measurements; 3 formal levels of escalation according to physiological instability measured by MEWS; an education and e-learning package; and practice in escalation and communication. All-cause hospital mortality and the hospital-standardised mortality ratio both decreased (significance not reported).

Changes in RRS were implemented and assessed in adult ward patients (28,914 patients in control period, 39,802 patients in intervention period) (95). Expanded administrative oversight of an existing RRS resulted in restructure of ward nurse education for early recognition of deterioration; system changes to facilitate RRT mobilisation; development of RRT treatment protocols; changes to data collection and analysis for system compliance and performance improvement. RRT activations significantly increased. Cardiac arrests and hospital mortality significantly decreased.

Across 225 hospitals in an Australian region, a Between the Flags system for recognition and management of patient deterioration was evaluated (sample size not reported) (96). This included implementation of a Standard Adult General Observation Chart, staff awareness training, and two-level clinical emergency response systems. Implementation resulted in a significant decrease in cardiac arrest rate and a significant increase in rapid response rate.

A 2 tier RRS (including ICU outreach nurse and RRT) resulted in a decrease in patients (sample size not reported) meeting MET call criteria without current treatment and non-significant decreases in unplanned ICU admissions and cardiac arrests compared with before implementation (97).

An RRS with after-hours Clinical Team Coordinator was assessed in 300 medical patients (98). Compared with before implementation, there was an increase in identification of adverse events and major adverse events (significance not reported).

Pharmacist involvement on an RRT was evaluated (before phase n=234, after phase n=157 rapid response events) (99). Median time to medication administration from central pharmacy was significantly decreased.

An RRT programme was implemented in a before and after study (sample size not reported) to decrease non-ICU cardiopulmonary arrests and overall hospital mortality (100). Charge nurses undertook training as unit specific RRT members. All inpatient staff undertook annual training in RRT including surveillance and recognition of deterioration. Overall hospital mortality was significantly decreased.

In a study (101) of 40,177 admissions and 795 RRT activations, RRT triggers were displayed on each floor and in-house staff were trained on RRT activations. No significant difference in mortality was observed.

EWS-based proactive RRT rounding was assessed in hospitalised adults (n=12,148) and compared with an RRT model based on staff nurse identification of abnormalities in vital signs (102). Unplanned ICU transfer was more likely during the RRT baseline (OR=1.392, 95% CI 1.017 to 1.905) compared with EWS-based proactive rounding.

In the remaining 10 non-RCT primary studies, no details were available at abstract level on the composition and delivery of the RRT/RRS and results were mixed (103), (104), (105), (106), (107), (108), (109), (110), (111), (112). Sample sizes (where reported) ranged from 82 to 166,569 patients.

Statistically significant results from RRT/RRS implementation were identified in some of these non-RCT primary studies for which no details of composition or delivery was available at abstract level. These statistically significant results included:

- increase in frequency of RRS activation (109)
- decrease in time from patient deterioration to intervention (105)
- decrease in cardiopulmonary arrests (110)
- decrease in number of ICU admissions (105)
- decrease in in-hospital mortality (110)
- decrease in cardiopulmonary arrest, unplanned ICU admission or death (110)
- decrease in illness severity scores at ICU admission (109)
- significant decrease in waiting time for ICU beds (103)
- decrease in ICU length of stay (109)
- increase in recognition of patients requiring palliative care (103)
- increase in detection of adverse events (104)
- decrease in rate of incidents occurring as a result of staff leaving normal duties to attend to MET calls (112)

In a multicentre prospective cohort study (113) (Grieve *et al.*,2019) of 49 UK NHS hospitals, 9,192 ward patients experiencing clinical deterioration were assessed for ICU transfer or continuing care on general wards. Effects of ICU transfer were estimated to be increased for patients with higher physiological severity (based on NEWS), particularly for older patients.

### Intelligence gathering

A topic expert (under potential areas requiring update) suggested the specific actions for staff during waiting for responsive personnel and on who to contact out of hours be considered.

A further topic expert commented that any guideline update could also consider effective response (no further details provided).

### Impact statement

Evidence included in the 2019 surveillance review evaluated the effects of a range of response strategies, including RRTs or systems, METs, patient at risk teams, intensive care consult services, and critical care outreach teams. The included evidence showed some promising patient benefits from

response strategies, including reductions in cardiac arrests and mortality. However, the response strategies tested varied between studies and no evidence was available that directly compared one response strategy configuration with another.

The guideline states that 'no specific service configuration can be recommended as a preferred response strategy for individuals identified as having a deteriorating clinical condition.' The evidence identified in the 2019 surveillance review is consistent with this statement.

New evidence is unlikely to change guideline recommendations.

# Transfer of patients from critical care areas: transfer of patients from critical care areas to general wards

## *Surveillance proposal*

The section of the guideline on transfer of patients from critical care areas to general wards should not be updated.

## *Transfer of patients from critical care areas to general wards*

### Previous surveillance

#### *2010 surveillance summary*

No new evidence was identified that contradicted the existing guideline recommendations.

#### *2016 surveillance summary*

No relevant evidence was identified on timing of patient transfer from critical care to general wards.

### 2019 surveillance summary

Topic experts did not suggest this area as being of particular interest for this surveillance review and so focused evidence searches were not performed. Key relevant evidence identified in the course of the surveillance review was summarised.

### *Timing of transfer from critical care areas to general wards*

A systematic review and meta-analysis (114) assessed whether time of discharge from ICU was associated with hospital mortality. Fourteen studies were included that assessed timing of discharge in 953,312 patients. Hospital mortality was significantly increased for patients discharged from ICU during nighttime compared with daytime.

In a further systematic review and meta-analysis (115), 18 cohort studies (n=1,191,178 patients) were included. Patients who were discharged from ICU during 'out of hours' had significantly higher in-hospital mortality and readmission rates compared with patients discharged 'in hours.'

Crude hospital mortality was significantly greater for patients discharged from ICU at nighttime compared with daytime discharges in a multicentre retrospective cohort study (n=19,622 patients) (116). This finding was confirmed by multivariable analysis. No difference in ICU readmission was observed for patients discharged at nighttime compared with daytime.

A single centre retrospective cohort study (117) in a medical-surgical ICU in a Brazilian tertiary care hospital examined the impact of timing of ICU discharge on patient outcomes. Patients (n=4,313) were classed as nighttime or daytime ICU discharge. There were no significant differences in in-hospital mortality, frequency of ICU readmission and length of hospital stay between groups. Length of ICU stay was significantly lower in nighttime compared with daytime ICU discharged patients.

### *Prediction and prevention of poor outcomes at transfer from critical care areas from general wards*

In a retrospective observational study (118) in a cohort of gastrointestinal surgery patients (n=124 patients) following transfer from an ICU/HDU, NEWS at transfer from ICU predicted readmission (OR 1.32, 95% CI 1.01 to 1.72, p=0.04).

The ability of the Rothman Index (generated automatically from vital signs, laboratory data, cardiac rhythms, and nursing assessments) to predict

mortality and readmissions in 1,445 patients transferred from the surgical ICU to the surgical ward was assessed in a single centre retrospective study (119). Seventy-nine patients were readmitted to ICU within 48 hours of transfer. Readmitted patients had significantly lower Rothman Index scores at 72, 48 and 24 hours before transfer and at 24 and 48 hours after transfer.

A retrospective observational study (120) of 194 adults discharged from the ICU found that higher Rothman Index (≥ 50) was associated with significantly lower odds of an adverse event within 72 hours (including readmission to a higher level of care) compared with a Rothman Index < 50.

After implementation of a nationwide quality improvement project with detailed public display via the internet of ICU discharge proportions and outcomes (n=163,371 patients), the prevalence of nighttime discharges from ICU significantly decreased (121).

**Intelligence gathering**

No intelligence was identified.

**Impact statement**

***Timing of transfer from critical care areas to general wards***

Recommendation 1.14 states that, after it has been decided that a patient is to be transferred from critical care to the general ward, that this transfer should be made as early as possible during the day. It is also recommended that transfer between 22.00 and 07.00 should be avoided where possible and documented as an adverse event if it happens.

Two systematic reviews and 2 cohort studies were identified in the 2019 surveillance review that contributed data on the effect of timing of transfer from critical care areas to general wards.

Both systematic reviews and a multicentre cohort study found that poor outcomes (i.e. mortality and readmission rates) were increased in patients discharged from ICU at nighttime or ‘out of hours’ compared with daytime or ‘in hours.’ One retrospective cohort study found no significant differences in

mortality, ICU readmission or length of stay between patients discharged from ICU at nighttime or daytime. However, since this was a single centre, non-UK study, this study was not considered enough to affect recommendation 1.14. The evidence identified on timing of discharge was considered on balance to be supportive of recommendation 1.14 to avoid transfer out of critical care to the general ward during nighttime hours.

#### *Prediction and prevention of poor outcomes at transfer from critical care areas from general wards*

An observational study noted that applying NEWS at transfer from ICU predicted readmission. Two observational studies also found the Rothman Index to be associated with readmission to ICU or a higher level of care. Current recommendations do not describe the use of scores in predicting outcomes at the point of patient transfer from critical care to the general ward. However, since these findings were based from a relatively small number of observational studies, this evidence was not sufficient to affect existing recommendations.

One quality improvement project was reported to reduce nighttime discharges from ICU. Current recommendations do not describe interventions to reduce nighttime ICU discharges, but evidence from this single study was not considered adequate to impact the recommendations.

# Transfer of patients from critical care areas: care on the general ward following transfer

## *Surveillance proposal*

The section of the guideline on care on the general ward following transfer should not be updated.

## *Care on the general ward following transfer*

### Previous surveillance

#### *2010 surveillance summary*

No new evidence was identified that contradicted the existing guideline recommendations.

#### *2016 surveillance summary*

One systematic review studied the use of risk stratification tools for identification of patients at high risk of adverse events following ICU discharge. Identified tools had AUROC values ranging from 0.66 to 0.92. The review authors concluded that more research was required in this field.

A systematic review found some evidence that provision of continuity, coordination and transition for patients with advanced illness improved patient caregiver and satisfaction.

A second systematic review assessed the effectiveness of interventions for improving safety and efficiency of patient discharge from ICU to the general ward. The authors reported that there was no difference in mortality reduction between the interventions and that there was a lack of good quality evidence in the area.

An additional systematic review assessed the impact of critical care transition programmes on patients discharged from an ICU to general wards. This evidence supported the recommendations in this guideline and that critical care transition programmes may have a role in patient transfer from ICU to general wards, but more research is required.

The identified evidence was consistent with guideline recommendation 1.15 that the critical care transferring team and receiving ward team should share responsibility and assure patient care continuity, including support by a care plan with a formal handover.

A systematic review demonstrated that interventions for the provision of information to family members and patients reduced transfer anxiety compared with standard care.

Decision tools were found to support patient knowledge and awareness of treatment choices in a further systematic review.

This evidence was supportive of recommendation 1.1.6 that patients being transferred from critical care to a general ward should be offered information about their condition and encouraged to actively participate in decision relating to their recovery.

**2019 surveillance summary**

Topic experts did not suggest this area as being of particular interest for this surveillance review and so focused evidence searches were not performed. Key relevant evidence identified in the course of the surveillance review was summarised.

***Tools for risk stratification following discharge from critical care areas to general wards***

A prospective cohort study (122) was performed in adults who had been admitted to the ICU in a single tertiary hospital for more than 24 hours. The effectiveness of selected scores in predicting unplanned ICU readmission or unexpected death in the first 48 hours after ICU discharge was compared. Scores were calculated on the day of ICU discharge. The Stability and Workload Index for Transfer score (SWIFT), Sequential Organ Failure Assessment score (SOFA) and simplified Therapeutic Intervention Scoring System (TISS-28) had similar predictive performance (AUC 0.66, 0.65 and 0.67 respectively, p=0.58).

A novel machine learning algorithm was developed to predict post-ICU outcomes in patients (n=2,018 patient episodes) at a single UK hospital (123). The developed model showed better discrimination for unplanned ICU readmission or death compared with the SWIFT score (AUROC=0.7095 vs. 0.6082, p=0.014).

A prospective observational study (124) demonstrated that NEWS recorded immediately before ICU discharge was a significant independent predictor of early clinical deterioration (acute respiratory failure or circulatory shock) within 24 hours of ICU discharge. The AUROC of NEWS was 0.92 (95% CI 0.89 to 0.94), and a score > 7 gave a sensitivity of 93.6% and a specificity of 82.2% for detection of early clinical deterioration.

Patient characteristics and physiological variables were collected from 3,109 surgical patients within 48 hours before surgical ICU discharge (125). Among these patients there were 141 unplanned ICU readmissions within 72 hours. A clinical nomogram was developed and found to have moderate performance (AUC=0.71) for prediction of ICU readmission risk.

### *Interventions and discharge practices for patients transferred from critical care areas to general wards –pharmacist input and medicines reconciliation*

A clinical pharmacist was integrated at the point of transfer of patients from ICU to wards in a multicentre RCT (126). The involvement of a clinical pharmacist resulted in a significant decrease in drug-related problems.

A multicentre retrospective study (127) of 985 patients transferred from 58 ICUs to non-ICU locations was performed. Daily patient care rounds in the ICU and orders discontinued and rewritten at point of transfer from the ICU were associated with decreased odds of medication error.

A medication reconciliation programme by pharmacists at the point of ICU admission and before ICU discharge was reported in a prospective study at 2 ICUs (n=478 patients) to reduce the proportion of patients with 1 or more medication transfer errors after discharge (128).

### *Interventions and discharge practices for patients transferred from critical care areas to general wards – multidisciplinary quality improvement intervention*

A quality improvement intervention involving a multidisciplinary team was used to improve the transfer of patients from the ICU to the surgical ward

(129). The intervention included verbal handovers, time-sensitive patient evaluations, and visual cues and was piloted over 1 year in high risk surgical patients discharged from the ICU. Patients received a baseline bedside examination from the primary team and respiratory therapists within 60 minutes of arrival on the ward. The rate of readmissions was reported to have decreased non-significantly, but the intervention was valued by stakeholders and had become standard of care.

### *Interventions and discharge practices for patients transferred from critical care areas to general wards –transition programmes*

An interrupted time series analysis (130) of adult patients (n=32,234) discharged from medical-surgical ICUs in 8 hospitals assessed the effects of a critical care transition programme on risk of readmission to ICU within 72 hours and 14-day mortality. A multidisciplinary ICU provider team (including a physician, nurse and respiratory therapist) evaluated each patient after ICU discharge in 3 hospitals but not in the other 5 hospitals. Following programme implementation, there were no significant effects on readmission to ICU within 72 hours or mortality.

A MET follow up programme for patients discharged from ICU to general wards (including respiratory care, regular visiting and staff communication) (n=1,229 patients enrolled in an intervention study) (131) reported no significant difference in readmission to ICU within 72 hours but significant improvements in cardiac arrest, SOFA score, and readmission to ICU within 72 hours for patients discharged to a step-down unit only.

A new model for transition of care from the medical ICU (MICU) to medical ward was implemented in a before and after study (n=966 patients) at a single academic centre (132). In this model, MICU staff continued management of all patients transferred to the medical ward from the MICU for at least 24 hours. This model resulted in a significant decrease in hospital length of stay after MICU transfer but no significant differences in adjusted mortality or MICU readmission rates.

### *Interventions and discharge practices for patients transferred from critical care areas to general wards –nurse-led interventions*

The ability of an acute post-ICU nurse-led ward based review tool (PIRT) to identify high risk patients at ICU discharge and improve ward based review and outcomes was tested in a prospective cohort of patients (n=1,028) discharged from 2 adult UK ICUs (133). The cohort received risk scoring at ICU discharge and inpatient review using PIRT. The use of ward based PIRT review did not show significant correlation with reduced poor outcomes overall or overall readmission. However, use of PIRT significantly reduced early readmission within 48 hours from 4.5% to 3.6% (p=0.039) while significantly increasing rate of late readmission (48 hours to 14 days) from 2.7% to 5.8% (p=0.046).

In a prospective intervention study with historical control (134) of a nurse-led multidisciplinary ICU follow up programme in patients with respiratory issues discharged from ICU (n=369), ICU readmission within 72 hours, all ICU readmission and hospital mortality were all significantly reduced, with no significant difference reported for 90-day mortality.

A study used analysis of registry data on 42,040 ICU admissions and a questionnaire to all Dutch ICUs to assess the association between post-ICU outcomes and ICU discharge practices (135). The ICU discharge practices of interest included ICU discharge criteria, bed managers, early discharge planning, step-down facilities, medication reconciliation, verbal and written handover, monitoring of post-ICU patients, and consulting ICU nurses. It was reported that no association between ICU discharges and rates of ICU readmission or post-ICU in-hospital mortality could be demonstrated.

### *Patient and caregiver information*

In a prospective cohort study (136) of 451 adult patients at 10 hospitals transferred from a medical-surgical ICU to a hospital ward, patients more frequently reported satisfaction with their transfer when they received more information, when their questions were addressed, when they met the ward physician before transfer, and were assessed by a nurse within 1 hour of their arrival on the ward.

### Intelligence gathering

No information was identified.

### Impact statement

#### *Tools for risk stratification following discharge from critical care areas to general wards*

The systematic review of risk stratification tools for identification of patients at high risk of adverse events that was identified in the 2016 surveillance review found variable predictive performance between tools and concluded that additional research was required.

In this 2019 surveillance review, a further 4 studies were identified on the use of scores in identification of adverse outcomes following discharge from critical care to the general ward. Current recommendations do not describe the use of scores or tools to identify patients at high risk of adverse outcomes following transfer from critical care to general wards. The evidence identified in the 2016 and 2019 surveillance reviews indicates that some scores and algorithms may show promise in supporting the identification of patients at risk following ICU transfer, but no single tool emerges as the most predictive of negative outcomes following transfer to the general ward from critical care. This evidence is not considered to have impact on current recommendations.

#### *Interventions and discharge practices for patients transferred from critical care areas to general wards*

In the 2016 surveillance review, 3 systematic reviews were identified that were consistent with recommendation 1.15 that the team transferring from critical care and the receiving ward team should share responsibility and ensure continuity of patient care, with support from a care plan with a formal handover.

A further 9 primary studies were identified in this 2019 surveillance review. The guideline does not currently recommend any specific interventions for care on the ward or discharge practices and the evidence identified in this surveillance review does not demonstrate which specific interventions or

practices would be most effective and so this evidence is considered to support existing recommendations.

#### *Patient and caregiver information*

The 2 systematic reviews identified in the 2016 surveillance review were consistent with recommendation 1.16 that patients transferred from critical care to general wards should be offered information about their condition and actively encouraged to participate in shared decision making. The one cohort study found in this 2019 surveillance review is consistent with recommendation 1.16 on provision of information to patients and encouraged involvement in shared decision making.

## Research recommendations

### *Identification and evaluation of risk scoring tools*

- What is the clinical effectiveness and cost effectiveness of automated (electronic) monitoring systems compared with manual recording systems in identifying people at risk of clinical deterioration in general hospital ward settings?
- What are the sensitivities and specificities of track and trigger systems in different clinical settings?
- Can track and trigger systems that have higher sensitivities and specificities than existing scores be developed and validated?

Focused searches were performed to identify evidence on the use of track and trigger and EWSs and electronic monitoring systems for recognition of patient deterioration. New evidence was identified in the 2019 surveillance review. This evidence and potential impact on guideline recommendations is summarised under the following sections: physiological observations in acute hospital settings, identifying patients whose clinical condition is deteriorating or is at risk of deterioration, choice of physiological track and trigger system,

and physiological parameters to be used by track and trigger systems. Since it is considered that existing evidence is unlikely to have potential impact on recommendations, further research would be of value.

### *Response strategies for patients identified as having a deteriorating clinical condition*

- What is the clinical and cost effectiveness of a structured educational programme to improve recognition of and response to acute illness compared with no structured programme in improving outcomes for people who clinically deteriorate in general hospital ward settings?

Two RCTs and 1 intervention study on provision of educational interventions were identified in the 2019 surveillance review. These studies assessed the provision of educational/training interventions in 2 RCTs and a cognitive aid booklet intervention in 1 intervention study. These interventions resulted in improved performance by professionals in simulated test settings, improved knowledge and other post-test scores and skills. Further research on this area would be of value to determine the optimal configuration of the educational intervention.

- What is the clinical and cost effectiveness of CCOS compared with usual care or educational outreach in improving health outcomes for patients who clinically deteriorate in general hospital ward settings? Such research should:
    - use a cluster RCT design conducted on multiple sites, with analysis of the cluster at hospital level rather than ward level
    - investigate a range of health outcomes, including mortality, morbidity, quality of life measures and patient satisfaction
    - include a parallel qualitative process evaluation to help establish which components of outreach (a complex intervention) are likely to be most effective
    - consider 24-hour critical care outreach as well as daytime outreach.

Three cluster RCTs were identified in the 2019 surveillance review and are summarised under graded response strategy. Additional research would benefit this area.

### *Transfer of patients from critical care areas*

- What is the clinical and cost effectiveness of providing structured educational advice (such as an information booklet) compared with usual care to patients who have been transferred from critical care areas back to general hospital ward settings?

Focused evidence searches were not performed in this area, but key relevant evidence identified in the course of the surveillance review was summarised. No evidence relating to this research recommendation was identified.

- What is the clinical and cost effectiveness of a transfer facilitator for patients transferred from critical care to a general ward environment? Such research could include outcome measures on:
    - patient satisfaction
    - time to discharge from acute hospital
    - destination when transferred.

Focused evidence searches were not performed in this area, but key relevant evidence identified in the course of the surveillance review was summarised. No evidence relating to this research recommendation was identified. Additional research on these 2 research recommendations would be useful.

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