Implementing an electronic observation and early warning score chart in the emergency department: a feasibility study

Richard Pullinger, Sarah Wilson, Rob Way, Mauro Santos, David Wong, David Clifton, Jacqueline Birks and Lionel Tarassenko

Background Use of automated systems to aid identification of patient deterioration in routine hospital practice is limited and their impact on patient outcomes remains unclear. This study was designed to evaluate the feasibility of implementing an electronic observation chart with automated early warning score (EWS) calculation in the high-acuity area of an emergency department.

Methods This study enrolled 3219 participants before and 3352 after implementation of an automated system, using bedside vital-sign entry on networked mobile devices. The primary outcome measure was the percentage of participants for whom an EWS was accurately recorded at each stage.

Results Of the participants, 52.7% before and 92.9% after implementation of the electronic system had an accurate EWS recorded on charts available to the study team. Participant groups were well balanced for baseline characteristics and acuity.

Conclusion In this study, the feasibility and limitations of implementing an electronic observation chart in the ED were demonstrated. Accurate EWS documentation was more frequent after implementation of the electronic observation chart. Retrospective analysis suggests that the use of an electronic observation system may lead to a greater percentage of observations being taken from those patients with a higher EWS. European Journal of Emergency Medicine 00:000–000 Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.

Keywords: early warning score, electronic observation chart, emergency department, observation chart, patient deterioration, track and trigger

Introduction Published reports have shown that identification of patient deterioration and quality of care before intensive therapy unit (ITU) admission are suboptimal [1,2]. Paper-based charting systems incorporating early warning scores (EWSs) have been implemented in the UK and elsewhere to formalize arrangements for identification and escalation of patients who are deteriorating. In these systems, EWSs are calculated ‘manually’ by adding weighted scores on the basis of physiological observations taken at intervals by nursing staff, including pulse rate, blood pressure, respiratory rate, and blood oxygen saturation. In the UK, ‘track and trigger’ systems use EWSs to assess the severity of the patients’ illness [3], whereby a score exceeding a certain threshold then triggers additional actions. The accuracy and completeness of paper-based charting systems for generating such scores are variable [4,5]. Automated electronic EWS calculators can reduce transcription and calculation errors [6], and studies of the impact of these systems on patient outcome have shown mixed results [7,8].

This study was designed to determine whether implementation of an electronic observation chart with automated EWS calculation is feasible in the high-acuity area of an emergency department (ED).

Methods Study design and setting This before-and-after study was conducted in the ED of a tertiary referral and major trauma centre in Oxford, UK, during 2012 and 2013. The ED has ~80,000 presentations annually across majors, resuscitation, minors and children’s areas.

Ethical considerations Permission for the study was granted by UK National Research Ethics Service, South Central (12/SC0074). With the agreement of the National Information Governance Board, consent was not required before patient enrolment.

Selection of the study participants All patients over the age of 16 years were recruited sequentially from the ‘majors’ area of the ED during each study stage. A decision was taken to enrol ~3000 participants at each stage of this feasibility study, balancing...
the need for sufficient participants against operational and staffing constraints.

Data collection
Normal clinical care continued throughout each of the two study stages. In stage 1, vital signs [pulse rate, respiratory rate, temperature, blood pressure, oxygen saturation (SpO₂), Glasgow Coma Scale score] were recorded by the clinical nursing team using a standard paper ‘observation’ chart. EWSs were manually calculated and recorded on the chart, together with any action taken. In stage 2, vital signs were recorded using handheld electronic devices (iPod Touch 8 Gb; Apple Inc., Cupertino, California, USA). The recorded data were used to populate electronic observation charts (VitalPAC; The Learning Clinic, Devon, UK), with automatic calculation of EWSs [9] and prompting of further observations according to local protocol. Electronic observation charts were displayed on the handheld device, on bedside electronic tablets and on central stations. In both stages, vital-sign data (heart rate, respiratory rate, blood pressure and SpO₂) were acquired at least every 30 s from each Phillips Intellivue (Royal Philips, Breitner Centre, Amsterdam, The Netherlands) bedside monitor, to which patients in majors are connected in our ED.

ED trial nurses recorded study data on a secure data-entry system using unique trial-specific patient identification numbers. Patient identity was known only to the members of the clinical research team. Mortality, hospital length-of-stay and ITU admissions were identified using the hospital electronic patient record (EPR). Patient transfer into the resuscitation room and episodes of cardiopulmonary resuscitation were identified using the ED resuscitation room register and the resuscitation audit database. Anonymized data from observation charts were assessed for completeness (defined as having one or more full set of observations recorded) and for the presence of an accurately calculated EWS. Data loss resulting from missing paper observation charts (stage 1) and downtimes of the EPR, the electronic observation chart and bedside monitor systems (stage 2) was recorded. The quality of stage 1 data transcription to the research database was assessed using duplicate data entry for an initial sequential sample of 200 participants.

Change management
Procedures for recording observations and EWSs in stage 1 were identical to those before study commencement. Between stages 1 and 2, a 1 month period of ED-staff training and phased system implementation was necessary to ensure adequate staff familiarity and smooth running of the system and ED processes. Training was delivered by study nurses and staff from the supplier of the electronic observation chart. The supplier modified the electronic observation chart from its standard ward-based implementation to enable its use in the ED. Deployment of mobile devices, implementation of the electronic observation chart, linkage with the hospital WiFi network and integration with the local EPR were supported at an executive level by the host institution’s Information and Communication Technology team.

Outcome measures
The primary outcome measure was the percentage of patients for whom an EWS had been accurately recorded.

Secondary outcome measures were 24-h and 48-h and 15-day and 30-day mortality, frequency and duration of periods of physiological abnormality (elevated EWS), median length of hospital stay, transfers to the ED resuscitation room, unplanned admissions to the ITU and in-hospital cardiopulmonary resuscitation events.

The duration of physiological abnormality was calculated by first applying the local EWS criteria to the bedside monitor data and then summing the periods above the alerting threshold for each patient. Locally, the EWS system dictates an alert at a score of 3 (individual parameter or aggregated). The frequency of physiological abnormality was estimated by identifying all the periods above the alerting threshold per patient. Transient alerts were filtered out by requiring alerts to be activated for at least 4 min in a 5-min window. Metrics were compared between patients with and those without the adverse events listed as secondary outcomes.

Analysis of primary data
Summary statistics are presented from each stage of this feasibility study. Wilcoxon’s rank-sum test and the χ²-test were used to compare medians and proportions where appropriate. During information technology (IT) system downtime, the staff reverted to paper-based recording of vital signs and EWSs. Analysis of data includes these patients, to reflect the real effects in a department using such a system. Where analysis is restricted and does not include all patients for either stage, this is clearly stated in the text.

Results
Participant recruitment and data availability
The number of participants recruited and the availability of observation data are summarized in Fig. 1.

Characteristics of study participants
Age, sex, triage category and presenting complaint are shown in Table 1. The difference in Manchester triage category percentages between stages may reflect a departmental process change implemented before stage 2. Presenting complaint percentages remained comparable between stages. The Manchester Triage System is an internationally recognized triage tool commonly used in UK EDs to identify clinical priority for each patient on arrival. Patients are colour coded into red, orange, yellow, green and blue categories, indicating the urgency with which the patient needs to be seen by a doctor (0, 10, 60,
(120, 240 min, respectively). For operational reasons, clinical process was adjusted between stage 1 and stage 2 to ensure more appropriate allocation of patients to major and minor areas according to acuity.

To compare the criticality of participants between study stages, distributions of maximum EWSs for each participant are shown in Fig. 2.

Overall, the study stages were balanced with respect to criticality, as assessed by the worst EWS ($P=0.13$).

### Table 1 Age, sex, triage category and presenting complaint

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [median (IQR)] (years)</td>
<td>54 (33–76)</td>
<td>55 (35–77)</td>
</tr>
<tr>
<td>Sex [% male (CI)]</td>
<td>49.2 (47.5–51)</td>
<td>47.1 (45.5–49)</td>
</tr>
<tr>
<td>NA (%)</td>
<td>5.8</td>
<td>6.6</td>
</tr>
<tr>
<td>Manchester triage NA (%)</td>
<td>22.7</td>
<td>14.0</td>
</tr>
<tr>
<td>Blue</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Green</td>
<td>21.6</td>
<td>14.7</td>
</tr>
<tr>
<td>Yellow</td>
<td>45.3</td>
<td>54.7</td>
</tr>
<tr>
<td>Orange</td>
<td>9.9</td>
<td>16.3</td>
</tr>
<tr>
<td>Red</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Presenting complaint NA (%)</td>
<td>22.9</td>
<td>13.5</td>
</tr>
<tr>
<td>Unwell adult</td>
<td>13.1</td>
<td>12.9</td>
</tr>
<tr>
<td>Chest pain</td>
<td>12.2</td>
<td>12.7</td>
</tr>
<tr>
<td>Abdominal pain in adults</td>
<td>11.7</td>
<td>14.1</td>
</tr>
<tr>
<td>Collapsed adult (%)</td>
<td>7.3</td>
<td>9.1</td>
</tr>
<tr>
<td>Shortness of breath in adults</td>
<td>4.5</td>
<td>4.7</td>
</tr>
<tr>
<td>Overdose and poisoning</td>
<td>3.9</td>
<td>3.9</td>
</tr>
<tr>
<td>Falls</td>
<td>3.6</td>
<td>5.4</td>
</tr>
<tr>
<td>Other</td>
<td>20.8</td>
<td>23.7</td>
</tr>
<tr>
<td>Total participants</td>
<td>3219</td>
<td>3352</td>
</tr>
</tbody>
</table>

The Wilcoxon rank-sum test and the $\chi^2$-test were used to determine the significance of medians and proportions, respectively.

NA, not available.

*From the Manchester Triage ‘presenting complaint’ field.

### Main results

For the primary outcome measure, 52.7% of 3219 participants enrolled in stage 1 (paper charts) and 92.9% of 3352 participants enrolled in stage 2 (electronic charts) had EWSs accurately recorded in documentation available to the study team. Considering only participants for whom full documentation was available for analysis, 76.7% of 2126 participants enrolled in stage 1 and 100% of 3113 participants enrolled in stage 2 had EWSs accurately recorded.
Data availability for analysis was suboptimal, particularly in stage 1. For 320 (9.9% of 3219) participants in stage 1, no valid observations and no EWSs were available for review. Of these participants, 182 (5.7% of 3219) had no available ED notes or EWS chart, 53 (1.6% of 3219) had ED notes but no observations recorded in them and 85 (2.6% of 3219) had observations with no associated time recorded. An additional 773 participants (24.0% of 3219) had observations recorded in their ED notes but no EWS chart available. Therefore, full documentation was available only for 2126 participants (66.0% of 3219) in stage 1.

In contrast, 239 (7.1% of 3352) stage 2 participants had no EWS available because of a combination of IT system downtime (74, 2.2% of 3352), no registration on an electronic observation chart system (144, 4.3% of 3352), and a lack of recorded observations on the electronic observation chart (21, 0.6% of 3352). Full documentation was therefore available in stage 2 for 3113 (93% of 3352) participants.

The percentage of attendances with complete vital signs recording during each block, and the percentages of attendances with an EWS correctly recorded are summarized in Fig. 3.

**Participant outcomes**

Mortality, length of hospital admission, transfers to the resuscitation room, transfers to the ITU and cardiopulmonary resuscitation events for patients in each study stage are shown in Table 2. These data indicate that there are no statistically significant differences between mortality, resuscitation events, transfers to the resuscitation room or ITU and duration of admission. Participants recruited during stage 2 were slightly more likely to be admitted than participants from stage 1 (66.4 and 61.6%, respectively). Although the completeness and accuracy of EWS recording may have influenced admission rates, a clinical process change implemented between stage 1 and stage 2, which involved more accurate acuity-based allocation of patients between the major and minor areas of the ED, is very likely to have increased admissions from majors.

**Accuracy of vital-sign transcription to research database in stage 1**

The accuracy of transcription of vital-sign values from the observation chart to the research database during stage 1 was assessed using duplicate data entry for an initial sequential sample of 200 participants (6.2% of 3219). An error was defined if the differences between data entry exceeded the following values: temperature 0.1°C, pulse rate 10 beats/min, respiratory rate 1 breath/min, systolic and diastolic blood pressure 10 mmHg and oxygen saturation 1%. Errors occurred in 1.34% (35 of 2621) of observation values.

**Downtime of electronic systems**

In stage 2 the electronic observation chart was nonfunctional for a single episode of 14 h, which affected all ED cubicles (1.14% of the total duration of stage 2). This was caused by failure of the hospital’s EPR server. During this time, patient vital signs were recorded on paper EWS charts.

Downtime of bedside monitor systems was observed for 3.6 and 5.3% of the total operational time in stages 1 and 2, respectively. Causes included bedside monitor malfunction and failure of hospital servers to save bedside monitor data.

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Table 2 Patient outcomes

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total 30-day mortality (%,)</td>
<td>2.36</td>
<td>2.36</td>
</tr>
<tr>
<td>In-hospital, 24 h</td>
<td>0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>In-hospital, 48 h</td>
<td>0.26</td>
<td>0.3</td>
</tr>
<tr>
<td>Total 15 days</td>
<td>1.8</td>
<td>1.46</td>
</tr>
<tr>
<td>Admitted (%)</td>
<td>61.6</td>
<td>66.4</td>
</tr>
<tr>
<td>Admission duration (mean ± SD) (days)</td>
<td>4.16 ± 9.49</td>
<td>3.86 ± 8.22</td>
</tr>
<tr>
<td>Transfers to resuscitation room (%)</td>
<td>2.3</td>
<td>2.57</td>
</tr>
<tr>
<td>Transfers to intensive therapy units (%)*</td>
<td>0.78</td>
<td>0.72</td>
</tr>
<tr>
<td>Cardiopulmonary resuscitation events (%)</td>
<td>0.16</td>
<td>0.24</td>
</tr>
<tr>
<td>Total attendances</td>
<td>3219</td>
<td>3352</td>
</tr>
</tbody>
</table>

The Wilcoxon rank-sum test and the χ²-test were used to determine the significance between medians and proportions, respectively.

*Intensive therapy units include all Oxford adult intensive therapy areas.
**Duration of physiological abnormality**

Bedside monitoring data were available for a median of 52.1% (stage 1) and 65.2% (stage 2) of the patients’ total duration in the ED. Those who had cardiac arrest, ITU admission or resuscitation room events, as well as those who died, spent a significantly greater proportion of time in the ED, above local EWS thresholds, than those who had none of these events ($P<0.001$). For those who experienced these events (total $n=68$ in stage 1 and $n=71$ in stage 2), the median percentage of monitored time spent above local EWS thresholds was 22.9% [interquartile range (IQR) = 3.6, 55.8] in stage 1 and 17.0% (IQR = 5.7, 47.8) in stage 2 ($P=0.65$). For those who did not experience these events (total $n=2682$ in stage 1 and $n=2983$ in stage 2), the median percentages of time spent above local EWS threshold were 2.68% (IQR = 0.2, 14.9) and 2.85% (IQR = 0.3, 16.6; $P=0.4$), respectively.

**Discussion**

Analysis of results was hampered by suboptimal data availability, particularly in stage 1 (66%), which was dependent on paper-based filing systems. To minimize data loss, staff undertook a comprehensive search for each set of missing notes and charts on two or more occasions, from archives both in the ED and elsewhere in the hospital.

Data availability in stage 2 (93%) was limited by the downtime of IT systems and by failure to register participants on the electronic observation chart system. In stage 2, successful documentation of vital signs (and therefore EWS) requires a working mobile device, a wireless network, chart software and server, EPR and a data feed from the EPR to the chart server, all of which are subject to planned and unplanned downtime. If analysis was restricted to participants for whom full documentation was available, those recruited in stage 2 were much more likely to have an accurately recorded EWS than those in stage 1 (100.0 vs. 76.7%).

Retrospective analysis of observations taken at each EWS value shows that, in stage 2, a greater percentage of observations were taken at higher EWS values compared with stage 1 (Fig. 4). This difference may be related to changes in clinical behaviour over time, or to automated prompts from the electronic observation charting system to take further observations in more unwell participants. The higher frequency of observations with high EWS scores in the group with electronic observation charts suggests that more attention was paid to high-acuity patients, a desirable response in a safe ED.

Utility and acceptability of paper and electronic vital signs and EWS charts will be reported separately.

**Study limitations**

A before-and-after design was considered appropriate for this feasibility study. Although the percentage of participants with EWS documentation in stage 2 is clearly higher than in stage 1, the before-and-after design of this study does not allow conclusions to be drawn with regard to the degree to which the electronic charting procedure contributed to this improvement. Improvements in staff training, workflow and quality assurance may also have contributed to such an improvement. Study designs, including randomization and crossover, would be required to evaluate the causes of such differences.

This preliminary study focuses on the feasibility of implementing an automated tool aiding detection of deterioration in a busy ED. The insights gained from this study may inform future, randomized studies of systems that detect and communicate deterioration, focusing on outcomes. To be effective, processes designed to reduce clinical impacts of patient deterioration need to detect and communicate deterioration in a way that results in timely corrective action. Meaningful evaluation of such systems against current standards requires much larger studies comparing effectiveness of the call to action from each deterioration and more importantly a comparison of clinical outcomes.

**Conclusion**

This study has demonstrated the feasibility of implementing an electronic observation charting system with automated EWS calculation in an ED setting. Accurate EWSs were documented more frequently using an electronic observation chart with automated EWS calculation than with a standard paper-based observation chart. Although use of the electronic observation chart is limited
by system downtime, more significant drawbacks associated with paper-based charting systems were highlighted by this study. Retrospective analysis suggests that the use of an electronic observation system may lead to a greater percentage of observations being taken from those patients with a higher EWS. Further work is needed to investigate options for limiting downtime of electronic observation charts, for optimizing the use of electronic-based and paper-based systems and to compare directly the two system types in EDs and other hospital settings.

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R.P., S.W., R.W. and L.T. were involved in the conception and design of the study. R.P. drafted this article. M.S., D.W., D.C. and L.T. were involved in data analysis. J.B. provided statistical advice. R.P., S.W., R.W., L.T., M.S., D.W., D.C. and L.T. were involved in critical revision of the manuscript and approved the final version submitted for publication.

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Conflicts of interest

There are no conflicts of interest.

References