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Implementing an electronic observation and early warning score chart in the emergency department: a feasibility study.
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Abstract:	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 calculation in the high acuity area of an emergency department. Methods This study enrolled approximately 3,000 subjects before and 3,000 after implementation of an automated system, using bedside vital signs entry on networked mobile devices. The primary outcome measure was the percentage of subjects for whom an early warning score was accurately recorded in each stage. Results 52.7% of subjects before and 92.9% after implementation of the electronic system had an accurate EWS recorded on charts available to the study team. Subject groups were well balanced for baseline characteristics and acuity. Conclusions In this study the feasibility and limitations of implementing an electronic observation chart in ED were demonstrated. Accurate EWS documentation was more frequent after implementation of the electronic observation chart. Retrospective analysis suggests

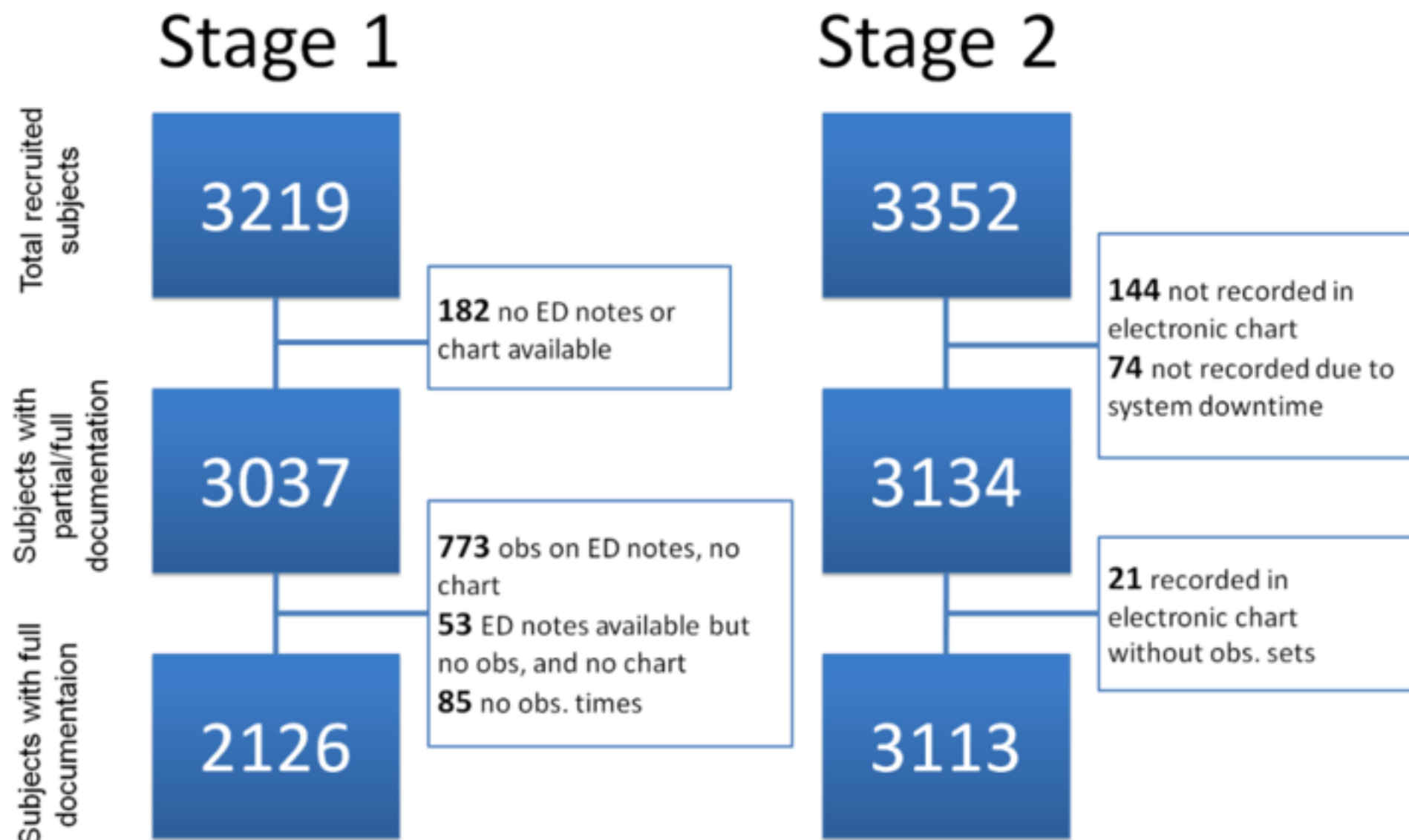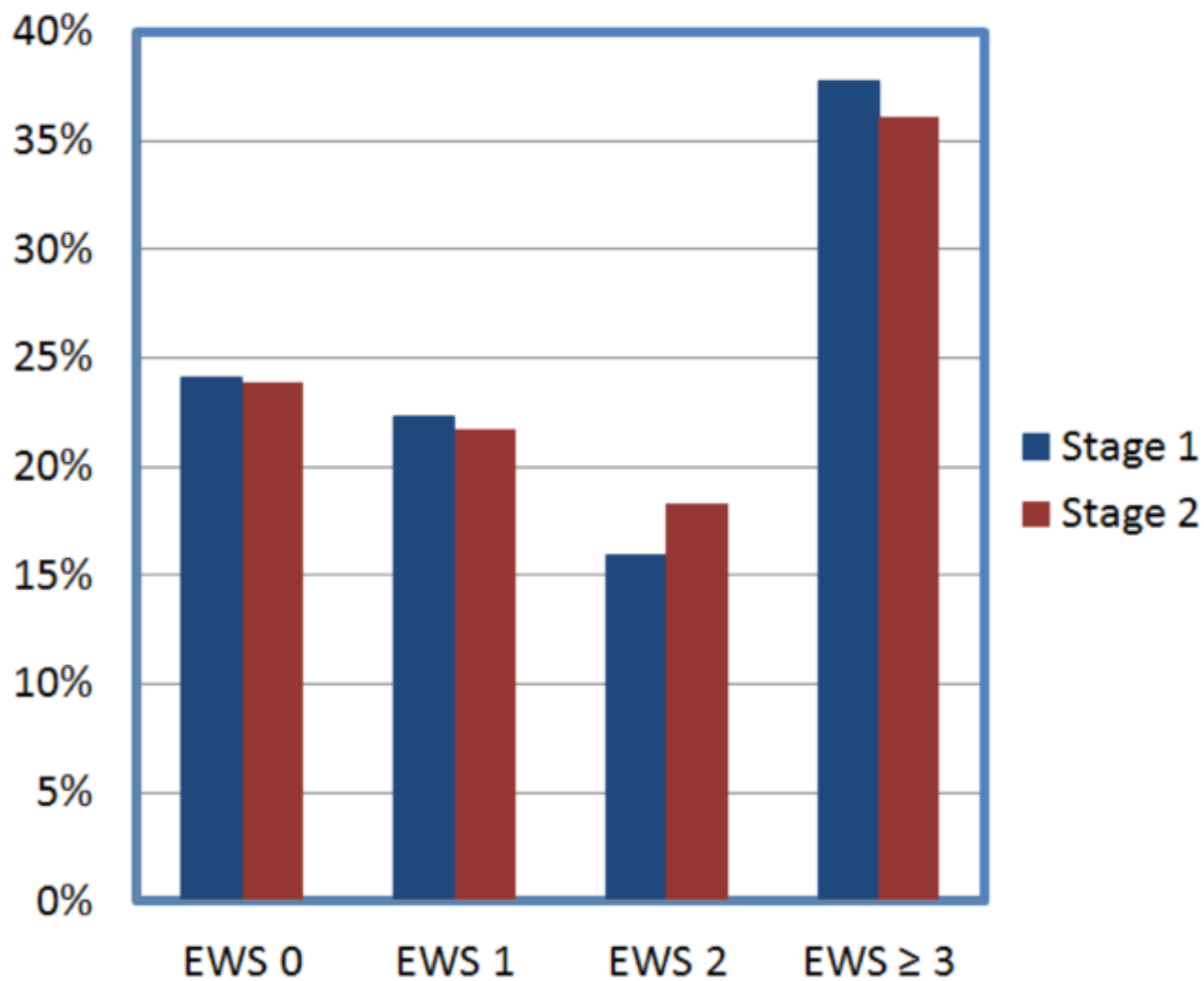| | that the use of an electronic observation system may lead to a greater percentage of observations being taken from those patients with a higher EWS. |

Figure 1

Figure 1

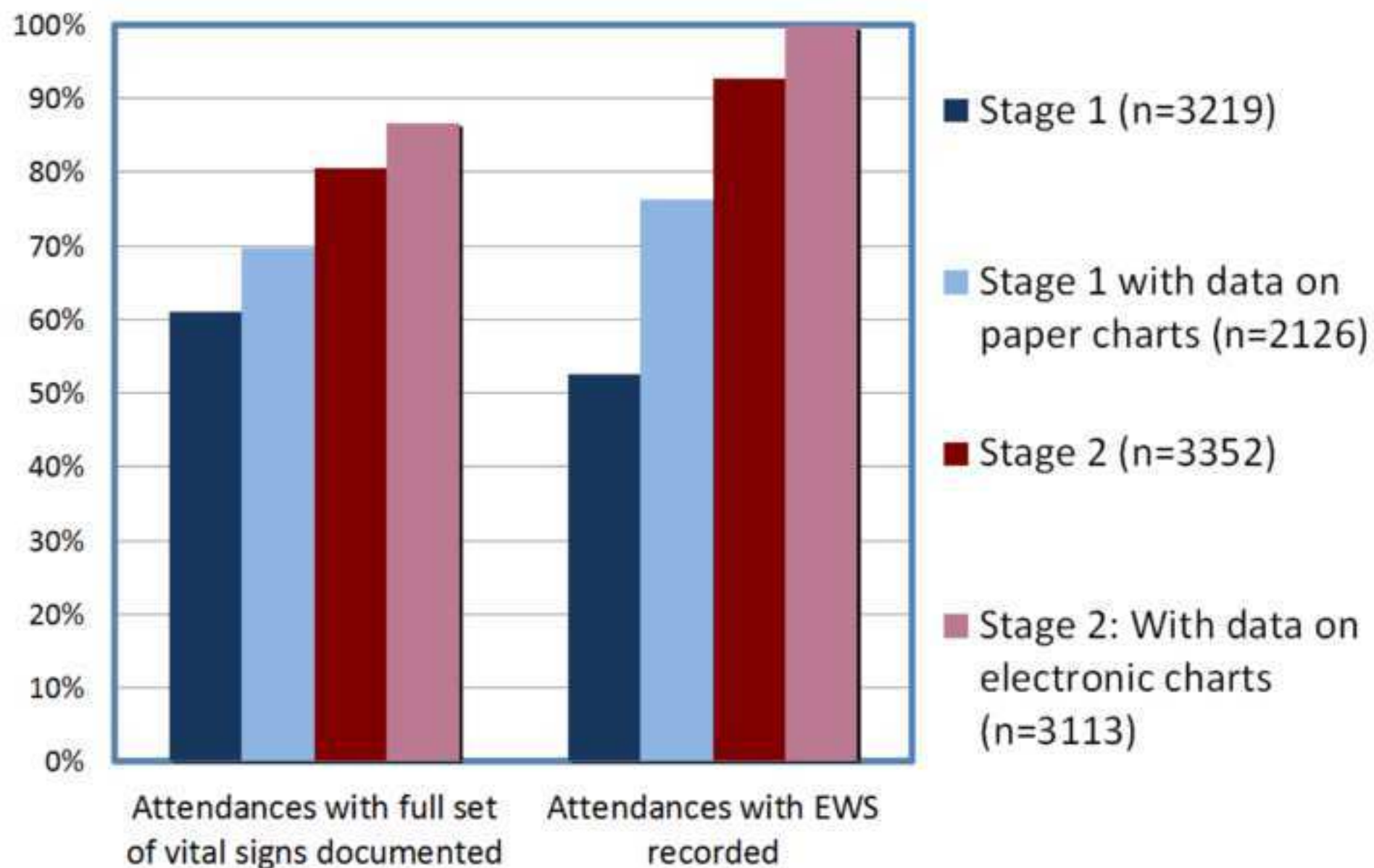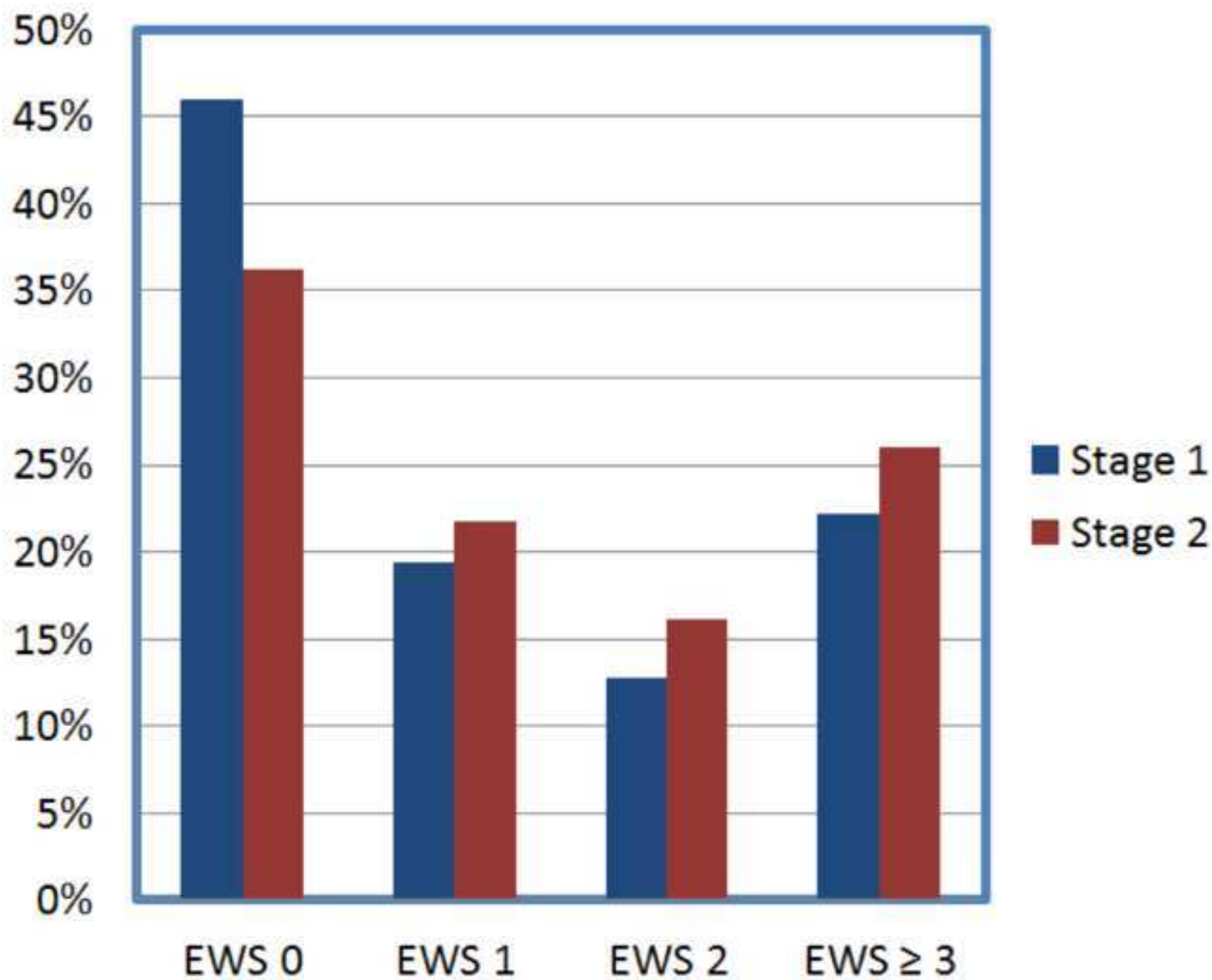Figure 2

Figure 3

Figure 4

Figure 4

Original article

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

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Abstract

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 calculation in the high acuity area of an emergency department.

Methods
This study enrolled approximately 3,000 subjects before and 3,000 after implementation of an automated system, using bedside vital signs entry on networked mobile devices. The primary outcome measure was the percentage of subjects for whom an early warning score was accurately recorded in each stage.

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

Conclusions
In this study the feasibility and limitations of implementing an electronic observation chart in 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.

Introduction

Published reports show that identification of patient deterioration and quality of care prior to intensive therapy unit (ITU) admission are suboptimal (1, 2). Paper-based charting

systems incorporating early warning scores (EWS) have been implemented in the UK and elsewhere to formalise arrangements for identification and escalation of patients who are deteriorating. In these systems EWS are calculated "manually" by adding weighted scores based on 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 EWS to assess the severity of patients' illness (3), whereby a score exceeding certain thresholds then triggers additional actions. 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 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 approximately 80,000 presentations annually across majors, resuscitation, minors and childrens' areas.

Ethical considerations and conflict of interests
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 prior to patient enrolment.

Selection of study participants
All patients over the age of 16 were recruited sequentially from the "majors" area of ED during each study stage. A decision was taken to enrol approximately 3,000 subjects in each stage of this feasibility study, balancing the need for sufficient subjects against operational and staffing constraints.

Data collection
Normal clinical care continued throughout each of two study stages. In Stage 1, vital signs (pulse rate (PR), respiratory rate (RR), temperature, blood pressure (BP), oxygen saturation (SpO_2), Glasgow Coma Scale score) were recorded by the clinical nursing team using a standard paper "observation" chart. Early warning scores were manually calculated and recorded on the chart, together with any actions taken. In Stage 2, vital signs were recorded using handheld electronic devices (iPod Touch 8Gbyte, Apple Inc.). The recorded data were used to populate the electronic observation charts (VitalPAC, The Learning Clinic, UK), with automatic calculation of EWS (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 (HR, RR, BP and SpO_2) were acquired at least every 30 seconds from each Phillips Intellivue 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 members of the clinical research team. Mortality, hospital length-of-stay and ITU admissions were identified using the hospital electronic patient record (EPR). Patient movement into the resuscitation room and episodes of cardiopulmonary resuscitation were identified using the ED resuscitation room register and the resuscitation audit database. Anonymised data from observation charts were assessed for completeness (defined by having one or more full sets 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) were 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 subjects.

Change management

Procedures for recording observations and EWS in stage 1 were identical to those prior to study commencement. Between stages 1 and 2 a one month period of training for all ED staff 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 Wi-Fi network, and integration with the local EPR were supported at 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 early warning score had been accurately recorded.

Secondary outcome measures were 24- and 48-hour, 15- 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 (CPR) 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 minutes in a 5 minute window. Metrics were compared between patients with and 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 χ^2 test were used to compare medians and proportions where appropriate. During IT system downtime, staff reverted to paper-based recording of vital signs and EWS. Analysis of data includes these patients, to reflect the real effects on a department of 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

Subject recruitment and data availability
The number of subjects recruited and availability of observation data are summarised in figure 1.

Figure 1: subject recruitment and data availability

Characteristics of study subjects
Age, gender, 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 prior to stage 2. Presenting complaint percentages remained comparable between stages. Manchester Triage System is an internationally recognised triage tool commonly used in UK emergency departments to identify clinical priority for each patient on arrival. Patients are colour coded into red/orange/yellow/green and blue, indicating the urgency with which they need to be seen by a doctor (0/10/60/120/240 minutes 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.

Table 1: age, gender, triage category and presenting complaint[#]

	Stage 1	Stage 2
Age (median, IQR)	54 (33-76)	55 (35-77)
Gender: % male (CI)	49.2 (47.5-51)	47.1 (45.5-49)
NA*: %	5.8	6.8
Manchester Triage NA*: %	22.7	14
Blue: %	0.2	0.2
Green: %	21.6	14.7
Yellow: %	45.3	54.7
Orange: %	9.9	16.3
Red: %	0.3	0.1
Presenting Complaint NA*: %	22.9	13.5
Unwell Adult: %	13.1	12.9
Chest Pain: %	12.2	12.7
Abdominal Pain in Adults: %	11.7	14.1
Collapsed Adult: %	7.3	9.1
Shortness of Breath in Adult: %	4.5	4.7
Overdose and Poisoning: %	3.9	3.9
Falls: %	3.6	5.4
Other: %	20.8	23.7
Total subjects	3219	3352

[#]From Manchester Triage "presenting complaint" field
*NA: not available
Wilcoxon rank-sum test and the χ^2 test were used to determine the significance between medians and proportions, respectively.

To compare criticality of subjects between study stages, distributions of maximum EWS for each subject are shown in figure 2.

Figure 2: patient criticality by worst EWS

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

Main results

For the primary outcome measure, 52.7% of 3219 subjects enrolled in stage 1 (paper charts) and 92.9% of 3352 subjects in stage 2 (electronic charts) had EWS accurately recorded in documentation available to the study team. Considering only subjects for whom full documentation was available for analysis, 76.7% of 2126 subjects enrolled in stage 1 and 100% of 3113 subjects in stage 2 had EWS accurately recorded.

Data availability for analysis was sub-optimal, particularly in stage 1. For 320 (9.9% of 3219) subjects in stage 1 no valid observations and no EWS were available for review. Of these 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 subjects (24.0% of 3219) had observations recorded in their ED notes but no EWS chart was available. Therefore full documentation was available for only 2126 subjects (66.0% of 3219) in stage 1.

In contrast, 239 (7.1% of 3352) of stage 2 subjects had no EWS available due to a combination of IT system downtime (74, 2.2% of 3352), no registration on electronic observation chart system (144, 4.3% of 3352), and 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) of subjects.

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

Figure 3: percentage of attendances with complete vital signs recording and correct EWS recording in stage 1 (paper charts) and stage 2 (electronic charts)

Subject outcomes
Mortality, length of hospital admission, transfers to resuscitation room, transfers to ITU and CPR 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 resuscitation room or ITU, and duration of admission. Subjects recruited during stage 2 were slightly more likely to be admitted than subjects from stage 1 (66.4% and 61.6% respectively). Whilst 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 ED, is very likely to have increased admissions from majors.

Table 2: patient outcomes

	Stage 1	Stage 2
Mortality, total 30 days: %	2.36	2.36
In-hospital, 24 h: %	0.25	0.24
In-hospital, 48h: %	0.28	0.3
Total 15 days: %	1.8	1.46
Admitted: %	61.6	66.4
Admission duration: mean ± sd days	4.16 ± 9.49	3.86 ± 8.22
Transfers to resuscitation room: %	2.3	2.57
Transfers to intensive therapy units*: %	0.78	0.72
Cardiopulmonary resuscitation events: %	0.16	0.24
Total Attendances	3219	3352

[a] Wilcoxon rank-sum test and
[b] χ^2 test was used to determine the significance between medians and proportions respectively.
* "intensive therapy units" includes all Oxford adult intensive therapy areas

Accuracy of vital signs transcription to research database in stage 1
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 subjects (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 per minute, respiratory rate 1 breath per minute, systolic and diastolic blood pressure 10mmHg, and oxygen saturation 1%. Errors occurred in 1.34% (35 of 2,621) of observation values.

Downtime of electronic systems
In stage 2 the electronic observation chart was non-functional for a single episode of 14 hours 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.

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

Duration of physiological abnormality
Bedside monitoring data were available for a median of 52.1% (stage 1) and 65.2% (stage 2) of patients' total duration in ED. Those who had cardiac arrest, death, ITU admission or resuscitation room events spent a significantly greater proportion of time in 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 percentage of monitored time spent above local EWS thresholds had a median value of 22.9% (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 minimise 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 for hospital notes.

Data availability in stage 2 (93%) was limited by the downtime of IT systems and by failure to register subjects on the electronic observation chart system. In stage 2, successful documentation of vital signs (and therefore EWS) requires a working mobile device, wireless network, chart software and server, EPR, and a data-feed from the EPR to chart server, all of which are subject to planned and unplanned downtime. If analysis is restricted to subjects 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 than in stage 1 (figure 4). This difference may relate to changes in clinical behaviour over time, or to automated prompts from the electronic observation charting system to take further observations in more unwell subjects. The higher frequency of observations with high EWS scores in the group with electronic observation charts suggests more attention was paid to high acuity patients, a desirable response in a safe emergency department.

Figure 4: percentage of observations taken at each EWS value (p<0.001)

Utility and acceptability of paper and electronic vital signs and early warning score charts will be reported separately.

Study limitations

A before-and-after design was considered appropriate for this feasibility study. Although the percentage of subjects 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 regarding 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 randomisation 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 emergency department. The insights gained from this study may inform future, randomised studies of systems which 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 which 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.

Conclusions

This study has demonstrated the feasibility of implementing an electronic observation charting system with automated EWS calculation in an ED setting. Accurate EWS 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 optimising the use of electronic and paper based systems, and to compare directly the two system types in emergency departments and other hospital settings.

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What is already known on this subject?

- Identification of patient deterioration in hospitals is suboptimal.
- Accuracy and completeness of paper-based charting systems incorporating manual early warning score (EWS) calculation are variable.
- Automated electronic EWS calculators can reduce transcription and calculation errors but such systems have not been evaluated the emergency department.

What this study adds

- This study has shown that implementation of an electronic observation chart with bedside data entry and automated EWS calculation is feasible in the high acuity area of an emergency department (ED).
- Potential benefits and drawbacks of such a system in the ED setting have been highlighted.
- Our findings will inform ED clinicians considering implementation of similar systems and guide future research into optimising detection and escalation of patient deterioration in the ED