Data and Methods

Describe how obs are clustered within admissionss within pts

diagram

Description of data

Pt and obs characteristics Number dying/going to ICU Key variables Age, sex Time of day Obs per pt Missing data

Data

Source of data

All data used in this thesis was collected and collated from adult (aged at least 16 years) acute admissions to the Oxford University Hospitals (OUH) trust as part of the Hospital Alerting Via Electronic Noticeboard (HAVEN) dataset18. Clinical staff recorded patients' vital signs at the bedside using the System for Electronic Notification and Documentation (SEND, Drayson Health, www.draysonhealth.com)19. The following data were recorded: date and time of observation (automatically by SEND); heart rate, systolic blood pressure, respiratory rate, body temperature, neurological status using the Alert-Voice-Pain-Unresponsive (AVPU) scale, SpO2; and the patient's inspired gas (air or supplemental oxygen) at the time of SpO2 measurement. All outcomes were obtained retrospectively from different clinical information systems, including the hospitals' patient administration systems, the ICU clinical information systems, and the hospitals' National Cardiac Arrest Audit (https://ncaa.icnarc.org) databases. The HAVEN database also contains administrative and patient demographic information. Prescription data from the electronic patient record is also available within the database for OUH admissions.

Study sites and times

The study took place at four hospitals in the OUH group [The John Radcliffe Hospital (large university hospital), The Horton General Hospital (small district general hospital), The Churchill hospital (large university cancer centre) and The Nuffield Orthopaedic Hospital]. All completed adult admissions to the four hospitals between xxx and xxx were considered.

Early warning scores

Vital sign sets were recorded using SEND. Where the patient's conscious level had been assessed only using the Glasgow Coma Scale (GCS), we converted GCS to an AVPU equivalent21. Vital signs were then assigned weights for NEWS. The sum of the weights (aggregate score) results in the NEWS value for each observation set. SEND uses a modified EWS, CEWS23. Clinical staff entering vital signs data were therefore unaware of NEWS or NEWS2 scores.

Statistical methods

Each observation set where at least one vital sign was recorded were included in the analysis. All hospital admissions with at least one observation set were included. Multiple observation sets were included per subject, according to the results of the previous chapter.

The outcome measures were death, unanticipated ICU admission, and a composite of the two. These were all assessed using a time horizon of 48 hours from the observation set. Death may be considered as a competing risk for unanticipated ICU admission, i.e. a patient cannot be admitted to ICU if they have already died. Therefore two analyses were carried out for the uICU outcome, one accounting for the competing risk and one not doing so.

Imputing missing data

Multiple imputation was used to impute missing vital signs values within an observation set. The imputation model included all of the vital signs, as well as the patients' age, sex, Charlson Comorbidity Index, and outcomes (i.e death, ICU admission, and the composite). Further, the time series nature of the data was incorporated into the imputation process. This meant that previous or future recordings of the missing vital sign could contribute to the estimation of the missing value, and therefore enhance the accuracy. Although the outcomes were included in the imputation model, missing outcomes were themselves not imputed, and instead these cases were omitted from the analysis. According to recommendations 20 imputed datasets were created. Performance metrics and summary statistics were calculated for each dataset, and pooled using Rubin's Rule. The C-Index was pooled on a logit scale in order to maintain the zero to one bounds.

Performance assessment

C-Index (time series) R2 Brier Calibration (plot, int, slope)

The C-Index was used to assess the discrimination of NEWS overall, and within each subgroup of interest. These results were graphically presented using forest plots. In order to examine whether any variables may explain potential heterogeneity between groups meta-regression methods were used. For each group the average of the variable of interest was calculated, and these values were entered into a random-effects model, where each group was weighted according to the number of events, and the logit C-Index was the outcome. Additionally, for each group, the distribution of the NEWS was plotted separately according to whether or not the event of interest occurred within 48 hours. For this purpose a single imputed dataset was used, instead of multiple imputation. Again within groups, the risk of each event was plotted against the NEWS. This is similar to a calibration plot, except that NEWS does not give a predicted risk, but instead an integer between 0 and 21. Finally, to check its consistency, the C-Index was plotted for each subgroup over the entire 48 hour time frame.

Data description

In total, there were 218521 admissions to the hospital trust between March 2014 and March 2018, which included at least one observation on the SEND e-Obs system. These admissions included 4089038 sets of vital sign observations. All of these admissions and vital signs were included in the the analysis.

In total 1065 admissions included an unanticipated ICU admission, 3392 ended in death, and either death or unanticipated ICU admission occurred in 4332. The characteristics of the population are shown in table @ref(tab:baseline).

Patient Characteristics	
Total number of hospital admissions	218521
Total number of observation sets	4088274
Sex	
Female	112633 (52%)
Male	105888 (48%)
Age	
<20	4914 (2%)
20-29	19956 (9%)
30-39	20690 (9%)
40-49	23661 (11%)
50-59	31821 (15%)
60-69	35193 (16%)
70-79	40117 (18%)
80-89	32285 (15%)
>89	9884 (5%)
Median Age (IQR)	62 (44 - 76)
Admission Characteristics	
Main Specialty	
Medical	133611 (16%)
Surgical	84906 (39%)
Admission Method	
Emergency	138678 (63%)
Elective	79843 (37%)
Mean no. of observations per admission in analysis	18.7
Number of admissions with ICU admission	1065 (0%)
Number of admissions ending in death	3392 (2%)
Number of admissions with composite outcome	4332 (2%)