Comparison of different alerting algorithms across five NHS hospital Trusts: Descriptive analysis of patient characteristics and frequency of process and clinical outcomes

A mainly descriptive project, with some modelling and statistical analysis, comparing groups of patients.
Main cohort: patients (18+) who alerted and patients who were discharged with a SoS code (ICD-10).
Time period: introduction of EHRs to March 2021.
General data description: patient information, admission & discharge information, antibiotic prescribing, microbiology tests ordered and results, ICU admission, alert details (including location of alert)
Introduction

1. Background/rationale

National guidelines for screening for sepsis have been implemented in NHS Trusts. As hospitals in England introduce electronic health records, different screening algorithms have been adopted (summarised in Table 1).

Table 1 Alert algorithms in different Trusts included in the study.

		NEWS	Red Flag	SJSA	Combination*
Trust		UCLH	CW & RB	ICHT	OUHT
Question re infection as part of EHR alert		Yes	Yes	No	Yes
Lungs	Respiratory rate	Yes	Yes	Yes	Yes
	O_2	Yes	Yes	No	Yes
CV	Heart Rate	Yes – low & high	Yes – high only	Yes – high only	Yes – low & high
	Blood Pressure	Yes – low & high (SBP)	Yes – low only (SBP)	Yes – low only (SBP)	Yes – low & high (SBP)
Temperature		Yes – low & high	Amber alert – low	Yes – low & high	Yes
Level of consciousness		Yes (VPU)	Yes (VPU)	No	Yes (VPU)
Fluid balance		No	Yes	No	No
Lactate		No	Yes	No	Yes
Bilirubin		No	No	Yes	No
Creatinine		No	No	Yes	Yes
White blood cell count		No	No	Yes	Yes
AKI		No	No	No	Yes

*OUHT use red flag sepsis and NEWS2

In this study we will compare the characteristics of patients who alert, the frequency of alerts across time (staff shifts, weeks and months) and patient outcomes. In addition, we will describe the completion of process measures associated with treatment of patients with sepsis. Process measures we have included are: blood cultures, lactate measure and IV-antibiotics. It is important to note that not all patients who alert will actually have clinically defined sepsis. Therefore, not all process measures will have been completed, particularly IV antibiotics. We will capture this variation in cohort and process measures across NHS Trusts.

In order to determine if differences between Trusts are algorithm dependent or intake/case mix dependent we will compare patient characteristics in those who 1) alert and 2) in those who had a discharge summary diagnosis of 'at risk of developing sepsis'. We will define those at risk of infection as those discharged with an ICD-10 code from the Suspicion of Sepsis list compiled by Inada-Kim et al.[1]

Costelloe & Honeyford 2021 DRAFT

1.1 Objectives (these are the objectives in the NIHR Application)

a) Describe the total sample of patients who are affected by the alert and baseline outcome data
b) Describe the frequency of the alert across different Trusts, departments within Trusts and specific patient groups
c) Describe any seasonal and temporal variations in alerts across different Trusts.
d) Describe the impact of the Covid-19 pandemic on alerting in terms of total sample, frequency, patient demographics and seasonal/temporal variations.

2. Methods

2.1 Study design & Setting

This is a cross sectional study across five NHS Trusts in England. The period of study is 1st February 2019 to 31st January 2021, divided into two years starting 01/02/19 and 01/02/20 to consider the impact of Covid-19. The time period was selected based on the latest introduction of electronic health records across the five NHS Trusts and to separately consider patients with Covid-19 affecting the pattern of sepsis alerts.

2.2 Participants

All adult (18+) inpatients admitted between 01/02/19 and 31/01/21 are initially eligible for inclusion in the study. We will liaise with data managers at each NHS Trust and identify all patients who triggered a sepsis alert in each Trust. The sample of patients included in the study are adult inpatients who triggered a sepsis alert at any point in their inpatient stay or time in A&E in the 24 months of the study.

The NHS Trusts included in the study are of differing sizes and may differ in case mix. In order to compare hospitals we will use patients with a serios infection, and therefore at risk of sepsis to adjust outcomes for patients with an alert. In order to identify patients with a serious infection will use the ICD-10 codes suggested by Inada-Kim et al and classed as 'Suspicion-of-Sepsis' (SoS). Patients are identified if a patient has an SoS ICD-10 code at discharge or at death.

2.3 Variables

The main aim of this study is to describe and quantify differences in patients who alert in different NHS Trusts. The 'key exposure' is the algorithm used to define the sepsis alert in the five NHS Trusts. Variables of interest are identified in Table 2.

Table 2 Empty table to illustrate proposed data collection for Study 1. Superscript numbers refer to specific questions shown at the end of the document.

NHS Trust	**A**		**B**		**C**		**D**		**E**	
Sepsis alert algorithm	**Red Flag**	**SoS**	**NEWS2**	**SoS**	**Red Flag**	**SoS**	**Oxford's alert**	**SoS**	**SJSA**	**SoS**
Frequency										
Total Number of alerts in 12 months										
Seasonal variation in alerts										
Shift (time) of alert[1]										
Patient characteristics[2]										
%Male										
Age – median and IQR										
Ethnicity										
Comorbidities[3]/Conditions on discharge >Diabetes > Immuno-compromised										
Deprivation										

Costelloe & Honeyford 2021 DRAFT

Location of alerts[4]										
%ED										
%other key wards										
Process measures[5]										
Received IV antibiotics										
Received IV antibiotics within 3 hrs of alert		NA		NA		NA		NA		NA
Blood test ordered										
Blood test ordered within 3 hrs of alert.		NA		NA		NA		NA		NA
Lactate measurement										
Lactate measurement within 3 hrs of alert		NA		NA		NA		NA		NA
Outcomes										
Length of stay for those who alert in the ED										
Admission to ICU after alert										
Mortality – 7 days										
Mortality – 30 days										
Impact on coding/formal diagnosis										
Proportion with a sepsis code at discharge/death										
Proportion with a SoS code at discharge/death		NA		NA		NA		NA		NA
Alert specific response		NA		NA		NA		NA		NA

2.4 Data sources/ measurement

All data are extracted from electronic health records and are part of routinely collected data stored within patient records. As part of the NIHR-Health Informatics Collaborative data managers at each trust shared data through a secure data-sharing platform All data was quality checked and processed by the data warehouse team at ICHT.

2.5 Bias

In order to compare the impact of different algorithms on the characteristics and patterns of alerting, the case-mix being admitted to the hospital is the key source of bias. All hospitals are in a similar region of England, but the intake of the five hospitals is different in terms of ethnicity, age and deprivation. In order to determine if the algorithm is the key factor determining differences in the profiles of the patients who alert we compared the profile with patients discharged with an ICD-10 SoS code.

2.6 Study size

Five NHS Trusts are included in this study. The number of patients included in the study is determined by the number of patients who alerted. The power to detect differences will be determined post-hoc.

2.7 Quantitative variables -

Ethnicity – ethnicity coding is based on recorded ethnicity using NHS ethnicity codes. Due to small numbers some groups will be combined into standard combinations for statistical comparisons.

Age – We will categorise age into 10-year age groups. For statistical comparisons we will combine smaller groups.

Ward of alert – The primary factor for analysis is whether alerts fired in the ED or inpatient wards. This is consistently documented across the NHS Trusts. For some Trusts we were able to determine whether alerts fired in acute wards,

IV antibiotics – Within EHRs medications are categorised as antibiotics and route of administration.

Costelloe & Honeyford 2021 DRAFT

Blood tests – EHRs contain orders for microbiology tests, including the date and time.
Lactate - EHRs include lactate results. Lactate is a point of care test in all Trusts included in the study.
Length of stay - Length of stay, measured in hours, was determined from the date and time of admission and discharge recorded in the patient record. For this descriptive study we will quantify length of stay for patients who are discharged alive.
Mortality – mortality was based on discharge destination recorded in the EHR. For the purposes of this study only in-hospital mortality was available for all NHS trusts.

2.8 Missing data

Patient admissions will not be excluded if patient data is missing, an additional category of missing will be included for age, gender, ethnicity and deprivation. As part of quality checks, we will confirm whether there are any patterns in missing data, for example periods of time where no lactate were reported. Our experience of EHRs indicate that there can be periods of missing data relating to EHR downtime.

3. Statistical methods

***(*a) Describe all statistical methods, including those used to control for confounding**

3.1 Differences in alerting over time and between patient subgroups.

We will describe the number of first alerts in each Trust in total and over different time periods.
In order to compare between Trusts we will consider the number of available overnight beds as an indication of hospital size.[2]
In addition, we will compare the alerts in the ED compared to the number of consultants in the ED.
We will use a Poisson model to determine if there are significant differences in alerts during different 'shifts' days of the week and seasons. The SoS admissions in the same period will be the offset in the Poisson model.
Differences in alert frequency in patient sub-groups will be assessed within and between NHS Trusts. We will use all patients discharged with an SoS diagnosis to adjust between hospitals as a case-mix adjustment.
We will describe differences in percentages of all patients and sub-groups of patients alerting between Trusts and assess the significances in differences using chi-squared tests. As there are many patient sub-groups and therefore multiple significance tests, we will use a p-value of 0.01 to assess significance.

3.2 Association between alerting and process measures

Process measures for inclusion are IV antibiotics, blood samples taken for microbiology and lactate measurement. We will describe process measure completion in alerting patients across Trusts, and subgroups of patients including alert location, age-groups and other sub-groups. We will consider completion of individual process measures and completion of all three within three-hours.
We will model process measure completion using a logistic regression adjusted for confounding factors, primarily patient characteristics which have been identified by clinicians as clinically associated with non-completion of process measures.
We will determine the association between the alert and completion of individual process measures, completion of the three measures, and whether the associations are different for different patient sub-groups.
We will model each Trust separately and also model all patients in a multi-level model with clustering at Trust level.
We will determine the sensitivity of results to the modelling approach.

Association between alerting and patient outcomes

We will assess the association between alerting and patient outcomes using a competing risks survival analysis with discharge and death as competing risks. This will allow us to fully adjust for patient factors and consider both patients who survive to discharge and those who do not. We will include process measure completion as time varying covariates.
In addition, we will separately model ICU admission after alerting using both a survival analysis and logistic model.

Association between alerting and coding

We will describe the coding of alerting patients between Trusts. The Trust which does not have a sepsis specific alert will be excluded. We determine if the differences are significant using chi-squared test.

Costelloe & Honeyford 2021 DRAFT

We will use descriptive approaches to compare sepsis coding between Trusts in patients with a SoS code. We will also consider whether the patterns are the same across the main patient subgroups. Statistical significance will be assessed using chi-squared tests.

(*b*) Methods used to examine subgroups and interactions

Within each model we will separately consider subgroups when we perform our analysis. We will consider a priori interactions.

(*c*) Missing data

Missing data will be included as a category on its own for factors such as ethnicity and deprivation. We will inspect data to identify periods of missing data which may be a result of EHR downtime, if necessary we will consider imputation.

We will ensure from clinicians that all process outcomes are likely to be recorded in the EHR and policy for carrying out the processes are the same across all Trusts.

Bibliography

[1] Inada-Kim M, Page B, Maqsood I, et al Defining and measuring suspicion of sepsis: an analysis of routine data BMJ Open 2017;7:e014885. doi: 10.1136/bmjopen-2016-014885

[2] NHS Bed Availability and Occupancy Data – Overnight. Available from: https://www.england.nhs.uk/statistics/statistical-work-areas/bed-availability-and-occupancy/bed-data-overnight/

[3] Austin SR, Wong YN, Uzzo RG, Beck JR, Egleston BL. Why Summary Comorbidity Measures Such As the Charlson Comorbidity Index and Elixhauser Score Work. *Med Care*. 2015;53(9):e65-e72. doi:10.1097/MLR.0b013e318297429c

Costelloe & Honeyford 2021 DRAFT