

A comparison of the quick Sequential [Sepsis-related] Organ Failure Assessment score and the National Early Warning Score in non-ICU patients with/without infection

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ABSTRACT

Objective: The Sepsis-3 task force recommended the quick Sequential [Sepsis-Related] Organ Failure Assessment score (qSOFA) for identifying patients with suspected infection who are at greater risk of poor outcomes, but many hospitals already use the National Early Warning Score (NEWS) to identify high-risk patients, irrespective of diagnosis. We sought to compare the performance of qSOFA and NEWS in hospitalized, non-ICU patients with and without an infection.

Design: Retrospective cohort study.

Setting: Large UK General Hospital.

Patients: Adults hospitalised between 1st January 2010 and 1st February 2016.

Interventions: None

Measurements and Main Results: We applied the qSOFA score and NEWS to 5,435,344 vital signs sets (241,996 hospital admissions). Patients were categorised as having no infection, primary infection or secondary infection using ICD-10 codes. NEWS was significantly better at discriminating in-hospital mortality, irrespective of infection status (no infection, NEWS 0.831 (0.825-0.838) vs. qSOFA 0.688 (0.680-0.695); primary infection, NEWS 0.805 (0.799-0.812) vs. qSOFA 0.677 (0.670-0.685)). Similarly, NEWS performed significantly better in all patient groups (all admissions, emergency medicine admissions and emergency surgery admissions) for all outcomes studied. Overall, qSOFA performed no better, and often worse, in admissions with infection than without.

Conclusions: The National Early Warning Score outperforms the quick Sequential [Sepsis-Related] Organ Failure Assessment score, irrespective of infection status. These findings suggest that qSOFA should be re-evaluated as the system of choice for identifying non-ICU patients with suspected infection who are at greater risk of poor outcome.

INTRODUCTION

The Sepsis-3 task force recommends the quick Sequential [Sepsis-Related] Organ Failure Assessment (qSOFA) score for identifying patients with suspected infection who are at greater risk of poor outcomes (1). qSOFA assigns one point for each of the following: systolic BP \leq 100 mmHg; respiratory rate \geq 22 breaths per min; altered mentation (Table 1) (1). Analysis of a large US database showed an area under the receiver operating characteristic (AUROC) curve for in-hospital mortality of 0.81 (95% CI, 0.80-0.82) for patients outside the intensive care unit (ICU) (2).

qSOFA is similar to the early warning scores (EWS) used on general wards to warn that a patient is at high risk of a serious adverse outcome, irrespective of underlying diagnosis (3-5). The UK's National Early Warning Score (NEWS) (6) allocates 0-3 points to each of seven clinical parameters (Table 1). NEWS performs well in a range of clinical settings in different countries (7-17) and is increasingly used as a frontline risk tool.

Introducing qSOFA to settings already using NEWS presents difficulties, as they include similar physiological variables but different weighting thresholds. Operating both is likely to introduce unnecessary duplication of staff effort, needless protocol complexity, confusion with respect to clinical practice and increased educational needs.

Recent publications demonstrate that, in patients with suspected infection, NEWS discriminates in-hospital mortality, ICU admission, and their combined outcome as well as or better than qSOFA (10,18,19). However, there is no published comparison in unselected hospital admissions to inform of a benefit to introducing qSOFA when NEWS is already used. Therefore, we compared the diagnostic performance of qSOFA and NEWS in non-ICU patients with and without a diagnosis of infection (hereafter termed "infection status") during their hospital stay, using a large database of routinely collected vital signs. We used a primary outcome of in-hospital death and four clinically relevant, secondary outcomes. To investigate the impact of reducing NEWS to the same three parameters in qSOFA, we also evaluated the performance of a simplified novel modification of NEWS - quick NEWS (qNEWS) (Table 1).

METHODS

This retrospective study falls within local research ethics committee approval (08/02/1394) from the Isle of Wight, Portsmouth and South East Hampshire Research Ethics Committee.

Vital Signs database and its development

A database was created of vital signs collected from consecutive patients aged ≥ 16 years admitted to a large UK hospital (<http://www.porthosp.nhs.uk/about-us>) on or after 1st January 2010 and discharged before 1st February 2016. Patients transferred directly on admission to critical care areas were excluded. Similarly, we excluded patients who (a) were discharged alive on the day of admission, or (b) had no observation set recorded in the 24 hours before discharge.

Vital signs were documented at the bedside in real-time using handheld devices running Vitalpac™ software (The Learning Clinic, London) (20). Vitalpac™ was used throughout the general wards, but not in the ICU. Each vital signs observation set contained the necessary data items to calculate NEWS and qNEWS values. However, because qSOFA evaluates mental status using the Glasgow Coma Scale (GCS) (1) and the study hospital uses the AVPU scale ((alert (A); responds to voice (V); responds to pain (P); or unresponsive (U))), we categorised patients scoring V, P or U as having 'altered mental status' when calculating qSOFA scores. Vital signs sets for which any measurements were absent were excluded because a full set is required to calculate a NEWS value.

qSOFA, NEWS, qNEWS

qSOFA and NEWS values were calculated for each vital signs set using the weightings described previously (1,6) (Table 1). We also calculated a 'quick NEWS' (qNEWS) value using only the systolic blood pressure, respiratory rate and AVPU components of NEWS, and the same weightings for each cut-off as in NEWS (Table 1).

Categorisation of admissions:

The categorisation of admissions into surgical and medical groups followed a previous method (9) and is described in Supplementary Table 1. Admissions were further categorized as “elective” or “non-elective”, as recorded in the hospital's patient administration system (PAS). We analysed three datasets: (a) all admissions, (b) non-elective admissions to surgery, and (c) non-elective admissions to medicine.

Patient comorbidity

Patient comorbidity on admission was measured using Dr. Foster Intelligence's modification of the Charlson Comorbidity index, as used by the National Health Service (NHS) (21).

Categorisation of presence of infection:

Patients' infection status was assigned according to the presence/absence of Suspicion of Sepsis (SOS) ICD-10 codes relating to bacterial infection (22). During hospital admission, if a patient is transferred from one specialty to another, or from one consultant to another, a new 'finished consultant episode' (FCE) is generated. An admission has at least one FCE, but may have many. In our database, each FCE can contain up to eighteen diagnoses. Diagnosis one is the primary diagnosis. After inspection of the data and noting that diagnosis two appeared to have been used for subsidiary primary diagnoses, we decided to interpret it thus. Diagnoses three and higher (if present) are secondary diagnoses. Patients were considered to have had a primary infection if either diagnosis one or two of any FCEs contained an SOS ICD-10 code. Patients were considered to have a secondary infection if there was no primary infection but any of the secondary diagnoses of any FCEs contained an SOS ICD-10 code. Admissions with no associated SOS code were categorised to the “No Infection” group.

Outcomes

We studied a primary outcome of in-hospital death and four secondary outcomes: in-hospital death within 24 hours of a vital signs set; in-hospital death or ICU stay ≥ 3 days; in-hospital death or ICU admission from a ward; and 'in-hospital death or ICU admission from a ward' within 24 hours of a vital signs set. Outcome data were identified from the hospital PAS and ICU database. Where relevant, the maximum length of ICU stay (to account for multiple admissions in a single hospital stay) was calculated.

Observation selection methods

Following a previous method (23), we constructed 10,000 random samples containing one vital signs observation set per admission. The observations were chosen by first randomly selecting a time during every admission, and then choosing the observation set closest to it. Vitalpac™ time-stamps observations automatically as they are entered at the bedside. We used the first and last observation dates and times to determine the time period from which to choose observations. To avoid biasing against selection of the first and last observation sets, we added to the beginning and end of the selection period a length of time equal to half of the mean time between observation sets for that patient episode. We truncated the analysis at the first ICU stay to avoid the inclusion of vital signs taken after ICU admission.

Statistical analysis

All statistical analyses were undertaken using R v3.4 (R Core Team) (24). The ability of NEWS, qSOFA and qNEWS to discriminate outcomes were assessed using AUROC analyses. For each scoring system, the AUROC was calculated using the mean AUROC of the 10,000 samples; 95% confidence intervals were calculated from the distribution.

RESULTS

Characteristics of admissions

There were 751,804 patient admissions in the study period. After exclusions, (Figure 1) 241,966 admissions and 5,435,344 complete vital signs sets were studied. Only 59,300 of 6,298,191 (0.94%) sets were excluded because they were incomplete (Figure 1). Of the 241,996 admissions, 114,822 were non-elective medical and 47,592 non-elective surgical admissions. Patient demographics are shown in Table 2.

Of the all admissions group, 6798 (2.81%) were followed by in-hospital death, 2054 (0.85%) by ICU admission from the wards and 971 (0.40%) by ICU stays \geq 3d. There were more in-hospital deaths, ICU admissions and ICU stays \geq 3d for admissions with infection than for those without (odds ratios ranged from 1.75 to 15.55) Table 2. The 25 most common SOS diagnoses and 25 most common non-SOS diagnoses in the dataset, are shown in Supplementary Tables 2 and 3, respectively.

During admission, a total of 44647 (18.5%) of all patient admissions had a primary and 21536 (8.9%) a secondary infection (Table 2). Similar proportions were seen for non-elective medical (24.3% and 11.9%) and non-elective surgical admission subgroups (22.8% and 8.0%).

The distribution of patients by age and infection status is shown in Supplementary Figure 1. Generally, the risk of having an infection – either primary or secondary – increased with patient age.

Relationship between infection and scores

The distributions of qSOFA, NEWS and qNEWS values, and observed risk of in-hospital death by infection status are shown in Supplementary Figures 2a-c, respectively. For each of qSOFA, NEWS and qNEWS, in-hospital mortality increased with rising score value, irrespective of infection status. However, in-hospital mortality was significantly lower for admissions without infection for scores ≤ 3 (qSOFA), ≤ 7 (NEWS) and ≤ 4 (qNEWS). The relationships of qSOFA, NEWS and qNEWS values against the outcome of in-hospital death within 24 hours of a vital signs set are shown in Supplementary Figures 3a-c.

Plots of qSOFA, NEWS and qNEWS values against the percentage of patient admissions with

each infection status are shown in Supplementary Figures 4a-c. In general, for all three scores, an increasing score value was associated with a greater likelihood of a primary infection. A similar trend was seen for secondary infections. Observation sets with a qSOFA value between 1 and 2, NEWS value = 5, and qNEWS value = 4 were each associated with an approximately 50% risk of having an infection.

Performance of NEWS, qNEWS and qSOFA

The AUROC values for NEWS, qNEWS and qSOFA for all 241,966 admissions are shown in Table 3, and for non-elective admissions to surgery and medicine in Table 4. Pictorial displays of the AUROC values for all scores and all outcomes are shown in Supplementary Figures 5a-c for three groups - all admissions (Figure 5a), non-elective admissions to medicine (Figure 5b) and non-elective admissions to surgery (5c). NEWS performed significantly better than qSOFA for all three patient groups and for all outcomes, irrespective of infection status. Considering the all admissions group and the primary outcome of in-hospital mortality, the AUROC (CI) value for NEWS was significantly higher (0.825 (0.821-0.829)) than for qSOFA (0.681 (0.676-0.686)).

For the all admissions group and primary outcome, qSOFA performed similarly in the no infection and primary infection groups (no infection, 0.688 (0.680-0.695); primary infection, 0.677 (0.670-0.685)), whereas NEWS performed better in the no infection group (no infection, 0.831 (0.825-0.838); primary infection, 0.805 (0.799-0.812)) (Table 3). Overall, qSOFA performed no better, and often worse, in admissions with infection than without.

Considering the all admissions group and the primary outcome, sensitivity (CI) was significantly higher for NEWS values of 5, 6 and 7 (46.6% (45.8-47.4%), 36.2% (35.4-37.0%) and 27.1% (26.4-27.9%)), respectively) than for qSOFA values of >2 (12.5% (12.0-13.1%)), but specificity (CI) was lower (NEWS 5 (95.9% (95.9-96.0%)), 6 (98.0 (98.0-98.1%)), 7 (99.1 (99.1-99.1%)); qSOFA >2 (99.7 (99.7-99.7%))). This relationship was unaltered by infection status.

NEWS consistently showed superior discrimination than qNEWS. However, overall, the performance of qNEWS was significantly better or the same as qSOFA across all groups and outcomes.

Considering the all admissions group and the primary outcome, the AUROC value for qNEWS was higher than for qSOFA (0.701 (0.696-0.706) vs. 0.681 (0.676-0.686)).

To demonstrate the relationship between sensitivity against trigger rate (i.e., percentage of observations at, or above, a given score value) we plotted an EWS efficiency curve (25) for qSOFA and NEWS. We chose to compare qSOFA and NEWS for admissions with a SOS diagnosis using perhaps the most clinically useful of the outcomes we studied – in-hospital death within 24 hours of a vital signs set. The closer the efficiency curve is to the lower right corner, the higher the efficiency of the EWS (i.e., more outcomes are detected for a lower trigger rate). Supplementary Figure 6 shows that NEWS values of 5 and 7 are more efficient than a qSOFA score =2.

DISCUSSION

This study compared the ability of qSOFA and NEWS to discriminate in-hospital mortality and four other outcomes in admissions to non-ICU areas of a hospital. Irrespective of infection status, NEWS discriminated all outcomes significantly better than qSOFA. Sensitivity for NEWS values of 5-7 was significantly higher than for qSOFA values of ≥ 2 . Overall, qSOFA performed no better, and often worse, in admissions with infection than without. Even when NEWS was reduced to a version containing the same physiological variables as qSOFA – qNEWS – it performed significantly better or at least as well as qSOFA across all groups and outcomes.

The Sepsis-3 task force reported an AUROC value of 0.81 for qSOFA for mortality in non-ICU patients with suspected infection (2). Others have since described varying qSOFA performance in patients with suspected infection, with poor sensitivity for a range of outcomes being frequently observed (10,18,19,26-36). Two other studies demonstrate that qSOFA performs similarly in patients in whom infection has not been diagnosed or is not suspected, implying that qSOFA is not infection-specific and should simply be regarded as a general EWS (36,37).

In a few studies, qSOFA's performance has been compared with that of other EWS systems, e.g. the modified early warning score (MEWS) and NEWS, but only in patients with suspected or confirmed infection (10,18,38). Innocenti et al. found that MEWS and qSOFA discriminated 28-day mortality at ED admission similarly (38). However, Churpek et al. (10) reported that both NEWS and MEWS were *"...more accurate than qSOFA for predicting in-hospital mortality and ICU transfer..."*, with NEWS also performing significantly better than MEWS for in-hospital mortality (10). These relationships appear to be constant, irrespective of the criteria used to define 'suspicion of infection' (18).

That qSOFA performs similarly in patients with and without a primary infection is not surprising, as the abnormalities that cause raised qSOFA scores (and NEWS values) in infection also occur in ischemia, inflammation and trauma (39). That NEWS performs better than qSOFA, irrespective of the presence/absence of infection, should also be expected as NEWS contains additional parameters known to be valuable in identifying high-risk patients.

NEWS and qSOFA do not diagnose infection; they merely identify patients with a high risk of adverse outcomes. In this respect, NEWS has already shown superior discrimination to other EWS systems (7, 8, 10) and the physiological components of Medical Emergency Team calling criteria (40). The current study now confirms NEWS's superiority over qSOFA. Consequently, there seems to be no benefit for hospitals already using NEWS to change to or introduce qSOFA. NEWS is already the recommended EWS for the UK (6), with the NHS (41), the Joint Royal Colleges Ambulance Liaison Committee and the UK Association of Ambulance Chief Executives (42) highlighting its use in the suspicion and management of sepsis. The current study results suggest that the Sepsis-3 task force should re-evaluate their recommendation to use qSOFA and reflect upon whether NEWS is a more appropriate score to use, even when infection is suspected.

This study has several strengths. It is a large multi-year study, with 241,966 completed admissions to a large general hospital. It studies over 5.4 million complete vital signs sets, each recorded in a standard manner as part of routine care using identical electronic devices (20). It is the first to compare the performance of qSOFA and NEWS in general ward patients with/without an infection diagnosis. It uses common, standardized, systems for measuring patient comorbidity (21) and categorising infection (22).

The study also has limitations. Whilst each vital signs set contained the data necessary to calculate a NEWS value, GCS score values were not available to calculate a qSOFA score and AVPU was used. This may have disadvantaged qSOFA compared to NEWS, as GCS is likely to be more sensitive than AVPU for mild altered mental status. We obtained the date/time of death/discharge from the hospital's PAS and these data are likely to be systematically late, such that the number of observations followed by death within 24 hours may have been underestimated.

We were unable to study data from the ED as these were unavailable; the operating characteristics of NEWS and qSOFA in the ED could vary from that obtained in other areas of the hospital. However, we undertook a post-hoc analysis comparing the performance of qSOFA and NEWS for two admission groups: (a) those admitted from the ED to non-ICU ward areas of the hospital (n = 121,952), and (b) those admitted directly to non-ICU ward areas of the hospital, without attending the ED

(n = 120,044) (Supplementary Table 4). The results are similar for the two groups suggesting that the route of admission is immaterial to the operating characteristics of NEWS and qSOFA.

Patients on an end-of-life (EoL) pathway could not be explicitly excluded, although we partially mitigated this by excluding those with no complete vital signs sets in the final 24 hours of their stay (it is hospital policy to cease the collection of complete sets of vital signs once a patient enters the EoL pathway). As it would not necessarily be anticipated that a patient would be subsequently managed on an EoL pathway at the time an EWS is applied, we repeated the analyses without excluding admissions where vital signs were not measured in the 24 hours prior to discharge (Supplementary Table 5). We included patients with Do Not Attempt Cardiopulmonary Resuscitation decisions, as such patients continue to receive normal care, including the measurement of vital signs. Finally, the study was conducted in a single site where the precursor of NEWS – ViEWS (25) - was developed and requires validation in independent data sets in various settings.

Conclusions

In this single centre study, NEWS was a significantly better discriminator than qSOFA for identifying non-ICU patients at greater risk of poor outcomes, irrespective of infection status. Overall, qSOFA performed no better and often worse in admissions with infection than without, suggesting that qSOFA should be regarded as no more than another non-specific, but poorly performing, EWS. For hospitals already using NEWS, there seem to be no benefit to changing to or adding qSOFA, even when infection is suspected. The Sepsis-3 task force recommendation to use qSOFA as the system of choice for identifying patients with suspected infection at greater risk of poor outcomes requires re-evaluation. Hospitals seeking a high-performing EWS for identifying patients at high risk of adverse outcomes from any underlying condition, including infection, should consider introducing NEWS.

LEGENDS FOR FIGURES

Figure 1

Data flow diagram for the study.

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Figure 1

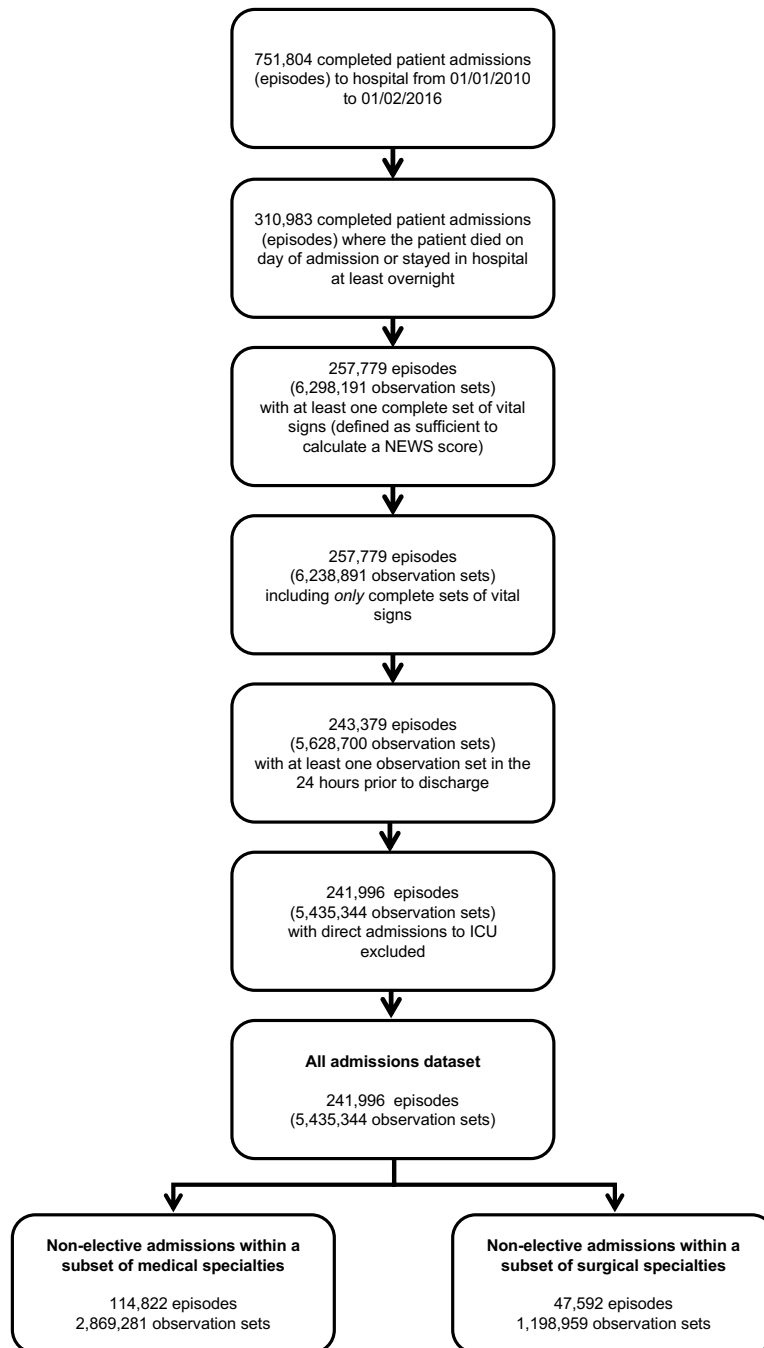


Table 1: Scoring systems evaluated in the study and their weightings

Physiological parameters	3	2	1	0	1	2	3
quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score							
Respiration Rate (breaths per minute)			>22				
Systolic BP (mmHg)			<100				
Altered mentation			GCS < 15				
NEWS							
Respiration Rate (breaths per minute)	≤8		9 - 11	12 - 20		21 - 24	≥25
SpO ₂ %	≤91	92 - 93	94 - 95	≥96			
Any supplemental oxygen?		Yes		No			
Temperature (°C)	≤35.0		35.1 - 36.0	36.1 - 38.0	38.1 - 39.0	≥39.1	
Systolic BP (mmHg)	≤90	91 - 100	101 - 110	111 - 219			≥220
Heart/pulse rate (beats per minute)	≤40		41 - 50	51 - 90	91 - 110	111 - 130	≥131
Level of consciousness (AVPU)				A			V, P or U
quick National Early Warning Score (qNEWS)							
Respiration Rate (breaths per minute)	≤8		9 - 11	12 - 20		21 - 24	≥25
Systolic BP (mmHg)	≤90	91 - 100	101 - 110	111 - 219			≥220
Level of consciousness (AVPU)				A			V, P or U

Level of consciousness: A = Alert; V = Responds to voice; P = Responds to pain; U = Unresponsive
 GCS: Glasgow Coma Scale score

Table 2: Patient demographic and observation data regarding admissions

Admission group		All Admissions	Non-Elective Admissions to Medical Specialties	Non-Elective Admissions to Surgical Specialties	No infection code	Primary infection code	Secondary infection code
All	Number of admissions; (% Male)	241996; (47.0)			175813; (47.2)	44647; (47.5)	21536; (44.5)
	Age, (mean/median/SD)	63/67/20			62/65/20	65/70/22	72/77/18
	Death in-hospital, n (%)	6798 (2.81)			2362 (1.34)	3035 (6.8) ^a	1401 (6.51) ^b
	ICU admission, n (%)	2054 (0.849)			665 (0.378)	740 (1.66) ^c	649 (3.01) ^d
	ICU stay \geq 3d, n (%)	971 (0.401)			192 (0.109)	419 (0.938) ^e	360 (1.67) ^f
	Comorbidity index (IQR)	0 (9)			0 (7)	4 (13)	5 (14)
Surgical	Number of admissions; (% Male)			47592; (47.0)	32902; (47.3)	10874; (47.0)	3816; (45.0)
	Age, (mean/median/SD)			57/59/22	58/60/22	50/48/21	71/76/19
	Death in-hospital, n (%)			863 (1.81)	413 (1.26)	237 (2.18) ^g	213 (5.58) ^h
	ICU admission, n (%)			764 (1.61)	271 (0.824)	238 (2.19) ^j	255 (6.68) ^k
	ICU stay \geq 3d, n (%)			319 (0.67)	76 (0.231)	122 (1.12) ^m	121 (3.17) ⁿ
	Comorbidity index (IQR)			0 (4)	0 (4)	0 (4)	4 (14)
	<i>General Surgery</i> , n			11029	7236	3082	711
	<i>Urology</i> , n			6129	4016	1643	470
	<i>Renal Surgery & Transplantation</i> , n			644	509	58	77
	<i>Colorectal</i> , n			11618	7580	3379	659
	<i>Upper Gastrointestinal</i> , n			5110	3338	1502	270
	<i>Vascular</i> , n			520	320	68	132
	<i>Trauma & Orthopaedics</i>			12542	9903	1142	1497
	Medical	Number of admissions; (% Male)		114822; (49.2)		73198; (50.2)	27932; (48.9)
Age, (mean/median/SD)			69/73/19		66/69/19	73/77/17	74/78/17
Death in-hospital, n (%)			5404 (4.71)		1703 (2.33)	2660 (9.52) ^p	1041 (7.6) ^q
ICU admission, n (%)			896 (0.78)		243 (0.332)	412 (1.48) ^r	241 (1.76) ^s
ICU stay \geq 3d, n (%)			467 (0.407)		75 (0.102)	246 (0.881) ^t	146 (1.07) ^u
Comorbidity index (IQR)			4 (13)		4 (11)	8 (15)	8 (16)

	<i>General Medicine, n</i>		89108		55590	23367	10151
	<i>Gastroenterology, n</i>		929		749	90	90
	<i>Endocrinology, n</i>		302		223	35	44
	<i>Clinical Haematology, n</i>		1495		812	380	303
	<i>Rehabilitation, n</i>		24		16	0	8
	<i>Cardiology, n</i>		7520		6711	231	578
	<i>Respiratory (Thoracic) Medicine, n</i>		2960		1396	1172	392
	<i>Nephrology, n</i>		6280		3449	1588	1243
	<i>Medical Oncology, n</i>		2830		1854	594	382
	<i>Neurology, n</i>		6		4	0	2
	<i>Rheumatology, n</i>		177		127	32	18
	<i>Geriatric Medicine, n</i>		3191		2267	443	481

^a Odds ratio for primary infection vs. no infection = 5.36 (5.07-5.66)

^b Odds ratio for secondary infection vs. no infection = 5.11 (4.77-5.47)

^c Odds ratio for primary infection vs. no infection = 4.44 (3.99-4.94)

^d Odds ratio for secondary infection vs. no infection = 8.18 (7.33-9.14)

^e Odds ratio for primary infection vs. no infection = 8.67 (7.29-10.34)

^f Odds ratio for secondary infection vs. no infection = 15.55 (13.01-18.64)

^g Odds ratio for primary infection vs. no infection = 1.75 (1.49-2.06)

^h Odds ratio for secondary infection vs. no infection = 4.65 (3.91-5.52)

^j Odds ratio for primary infection vs. no infection = 2.69 (2.25-3.22)

^k Odds ratio for secondary infection vs. no infection = 8.62 (7.21-10.31)

^m Odds ratio for primary infection vs. no infection = 4.9 (3.65-6.62)

ⁿ Odds ratio for secondary infection vs. no infection = 14.14 (10.5-19.14)

^p Odds ratio for primary infection vs. no infection = 4.42 (4.15-4.71)

^q Odds ratio for secondary infection vs. no infection = 3.45 (3.19-3.74)

^r Odds ratio for primary infection vs. no infection = 4.49 (3.82-5.29)

^s Odds ratio for secondary infection vs. no infection = 5.38 (4.48-6.46)

^t Odds ratio for primary infection vs. no infection = 8.66 (6.66-11.38)

^u Odds ratio for secondary infection vs. no infection = 10.51 (7.9-14.08)

Table 3: Area under the receiver operator characteristics curve for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score, the National Early Warning Score (NEWS) and the quick National Early Warning Score (qNEWS) for a range of outcomes for the all admissions group.

All admissions		qSOFA	NEWS	qNEWS
	Outcome			
	All admissions	0.681 (0.676-0.686)	0.825 (0.821-0.829)	0.701 (0.696-0.706)
	1 st infection code	0.677 (0.670-0.685)	0.805 (0.799-0.812)	0.694 (0.686-0.702)
	2 nd infection code	0.643 (0.632-0.653)	0.759 (0.748-0.769)	0.663 (0.651-0.675)
	1 st or 2 nd infection code	0.666 (0.660-0.672)	0.790 (0.785-0.796)	0.684 (0.677-0.691)
	No infection code	0.688 (0.680-0.695)	0.831 (0.825-0.838)	0.711 (0.703-0.719)
	All admissions	0.678 (0.674-0.683)	0.824 (0.820-0.828)	0.698 (0.693-0.703)
	1 st infection code	0.680 (0.674-0.687)	0.810 (0.804-0.816)	0.698 (0.690-0.705)
	2 nd infection code	0.637 (0.628-0.647)	0.758 (0.749-0.767)	0.657 (0.646-0.667)
	1 st or 2 nd infection code	0.666 (0.660-0.671)	0.792 (0.787-0.797)	0.683 (0.677-0.690)
	No infection code	0.683 (0.676-0.690)	0.826 (0.820-0.833)	0.706 (0.698-0.714)
	All admissions	0.798 (0.790-0.805)	0.918 (0.913-0.923)	0.823 (0.815-0.831)
	1 st infection code	0.811 (0.798-0.823)	0.919 (0.911-0.926)	0.834 (0.821-0.847)
	2 nd infection code	0.789 (0.768-0.811)	0.906 (0.891-0.920)	0.815 (0.794-0.837)
	1 st or 2 nd infection code	0.805 (0.795-0.816)	0.916 (0.909-0.922)	0.829 (0.819-0.841)
	No infection code	0.778 (0.767-0.789)	0.904 (0.896-0.912)	0.805 (0.794-0.816)
	All admissions	0.671 (0.666-0.675)	0.813 (0.810-0.817)	0.689 (0.685-0.694)
	1 st infection code	0.680 (0.673-0.686)	0.808 (0.803-0.814)	0.697 (0.690-0.704)
	2 nd infection code	0.629 (0.621-0.638)	0.749 (0.741-0.758)	0.647 (0.637-0.657)
	1 st or 2 nd infection code	0.662 (0.657-0.667)	0.787 (0.782-0.791)	0.679 (0.673-0.685)
	No infection code	0.669 (0.663-0.676)	0.806 (0.800-0.812)	0.689 (0.682-0.696)

Table 4: Area under the receiver operator characteristics curve for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score, the National Early Warning Score (NEWS) and the quick National Early Warning Score (qNEWS) for a range of outcomes.

Non-elective admissions to medicine					
	Outcome	qSOFA	NEWS	qNEWS	
	All admissions	0.685 (0.680-0.690)	0.820 (0.815-0.824)	0.710 (0.704-0.716)	
	1 st infection code	0.679 (0.671-0.687)	0.781 (0.775-0.788)	0.701 (0.693-0.710)	
	2 nd infection code	0.651 (0.639-0.663)	0.766 (0.755-0.777)	0.675 (0.661-0.688)	
	1 st or 2 nd infection code	0.671 (0.665-0.678)	0.778 (0.772-0.784)	0.694 (0.687-0.701)	
	No infection code	0.697 (0.688-0.705)	0.839 (0.832-0.847)	0.726 (0.717-0.735)	
	All admissions	0.686 (0.681-0.691)	0.821 (0.817-0.825)	0.711 (0.706-0.717)	
	1 st infection code	0.683 (0.676-0.691)	0.788 (0.781-0.794)	0.706 (0.698-0.714)	
	2 nd infection code	0.653 (0.641-0.664)	0.768 (0.757-0.778)	0.675 (0.662-0.688)	
	1 st or 2 nd infection code	0.674 (0.668-0.681)	0.782 (0.777-0.788)	0.697 (0.690-0.704)	
	No infection code	0.695 (0.686-0.704)	0.837 (0.829-0.844)	0.724 (0.715-0.733)	
	All admissions	0.798 (0.790-0.807)	0.911 (0.905-0.916)	0.826 (0.817-0.834)	
	1 st infection code	0.806 (0.793-0.819)	0.899 (0.890-0.908)	0.829 (0.816-0.843)	
	2 nd infection code	0.785 (0.762-0.809)	0.897 (0.881-0.912)	0.813 (0.789-0.837)	
	1 st or 2 nd infection code	0.801 (0.790-0.812)	0.900 (0.892-0.907)	0.826 (0.814-0.837)	
	No infection code	0.784 (0.772-0.797)	0.908 (0.900-0.917)	0.816 (0.803-0.829)	
	All admissions	0.685 (0.680-0.690)	0.818 (0.814-0.823)	0.710 (0.704-0.715)	
	1 st infection code	0.684 (0.677-0.691)	0.789 (0.783-0.795)	0.707 (0.699-0.716)	
	2 nd infection code	0.649 (0.638-0.660)	0.765 (0.754-0.775)	0.672 (0.659-0.684)	
	1 st or 2 nd infection code	0.674 (0.668-0.680)	0.782 (0.777-0.787)	0.697 (0.690-0.704)	
	No infection code	0.691 (0.683-0.700)	0.829 (0.822-0.836)	0.719 (0.711-0.728)	
	All admissions	0.787 (0.779-0.794)	0.901 (0.895-0.906)	0.814 (0.806-0.822)	
	1 st infection code	0.796 (0.785-0.807)	0.894 (0.886-0.902)	0.823 (0.811-0.835)	
	2 nd infection code	0.771 (0.750-0.790)	0.884 (0.869-0.898)	0.794 (0.774-0.815)	
	1 st or 2 nd infection code	0.790 (0.780-0.800)	0.892 (0.885-0.899)	0.816 (0.805-0.826)	
	No infection code	0.770 (0.758-0.781)	0.890 (0.881-0.899)	0.800 (0.788-0.812)	
Non-elective admissions to surgery					
	OUTCOME	qSOFA	NEWS	qNEWS	
	In-hospital Mortality	All admissions	0.647 (0.635-0.660)	0.796 (0.783-0.808)	0.656 (0.641-0.670)

	1 st infection code	0.668 (0.643-0.693)	0.820 (0.796-0.843)	0.678 (0.650-0.707)
	2 nd infection code	0.593 (0.566-0.620)	0.717 (0.688-0.746)	0.600 (0.569-0.631)
	1 st or 2 nd infection code	0.630 (0.611-0.648)	0.776 (0.757-0.795)	0.633 (0.612-0.654)
	No infection code	0.658 (0.642-0.675)	0.803 (0.785-0.821)	0.669 (0.650-0.689)
In-hospital Mortality or ICU \geq 3 days	All admissions	0.644 (0.634-0.655)	0.800 (0.789-0.810)	0.654 (0.642-0.667)
	1 st infection code	0.670 (0.649-0.690)	0.830 (0.812-0.849)	0.681 (0.658-0.704)
	2 nd infection code	0.596 (0.574-0.618)	0.724 (0.701-0.747)	0.608 (0.583-0.633)
	1 st or 2 nd infection code	0.632 (0.617-0.646)	0.784 (0.769-0.799)	0.638 (0.621-0.655)
	No infection code	0.652 (0.637-0.668)	0.802 (0.786-0.819)	0.663 (0.646-0.681)
Mortality within 24 hours	All admissions	0.770 (0.749-0.792)	0.898 (0.881-0.914)	0.793 (0.769-0.816)
	1 st infection code	0.827 (0.782-0.871)	0.946 (0.916-0.972)	0.865 (0.819-0.910)
	2 nd infection code	0.753 (0.680-0.828)	0.910 (0.855-0.955)	0.776 (0.694-0.857)
	1 st or 2 nd infection code	0.802 (0.763-0.840)	0.936 (0.909-0.960)	0.833 (0.790-0.874)
	No infection code	0.752 (0.726-0.778)	0.878 (0.856-0.900)	0.770 (0.742-0.798)
In-hospital Mortality or unanticipated ICU admission	All admissions	0.629 (0.620-0.638)	0.780 (0.771-0.790)	0.635 (0.624-0.645)
	1 st infection code	0.663 (0.645-0.681)	0.823 (0.806-0.839)	0.673 (0.652-0.693)
	2 nd infection code	0.590 (0.572-0.608)	0.719 (0.699-0.739)	0.596 (0.576-0.617)
	1 st or 2 nd infection code	0.623 (0.611-0.636)	0.775 (0.762-0.788)	0.626 (0.611-0.640)
	No infection code	0.628 (0.615-0.641)	0.771 (0.757-0.784)	0.634 (0.620-0.649)
Mortality within 24 hours or unanticipated ICU admission within 24 hours	All admissions	0.695 (0.682-0.708)	0.843 (0.832-0.855)	0.711 (0.696-0.725)
	1 st infection code	0.742 (0.717-0.768)	0.895 (0.877-0.913)	0.768 (0.741-0.796)
	2 nd infection code	0.653 (0.623-0.683)	0.793 (0.764-0.822)	0.669 (0.635-0.702)
	1 st or 2 nd infection code	0.702 (0.682-0.721)	0.855 (0.838-0.871)	0.719 (0.698-0.741)
	No infection code	0.681 (0.663-0.700)	0.822 (0.804-0.839)	0.694 (0.674-0.714)

Supplemental Digital Content (in order of its citation in the manuscript)

Supplementary Table 1: Categorisation of admissions

Supplementary Table 2: Twenty-five most common infection diagnoses in database

Supplementary Table 3: Twenty-five most common non-infection diagnoses in database

Supplementary Figure 1: The distribution of patient age, categorised by no infection code, or primary and secondary infection codes at any point during an admission.

Supplementary Figure 2. The distribution of quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) (Figure 2a), National Early Warning Score (NEWS) (Figure 2b) and quick National Early Warning Score (qNEWS) (Figure 2c) values and observed risk of observed risk of in-hospital death categorised by no, primary and secondary infection codes at any point during an admission.

Supplementary Figure 3. The distribution of quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) (Figure 3a), National Early Warning Score (NEWS) (Figure 3b) and quick National Early Warning Score (qNEWS) (Figure 3c) values and observed risk of death within 24h of an observation set categorised by no, primary and secondary infection codes at any point during an admission.

Supplementary Figure 4. Plot of qSOFA (Figure 4a), NEWS (Figure 4b) and qNEWS (Figure 4c) values and percentage of admissions with primary infection, secondary infection and no infection.

Supplementary Figure 5. Pictorial display of the area under the receiver operator characteristics curve (AUROC) values for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score, the National Early Warning Score (NEWS) and the quick National Early Warning Score (qNEWS) for all admissions (Figure 5a), non-elective admission to medicine (Figure 5b) and non-elective admission to surgery (Figure 5c) for a range of outcomes.

Supplementary Figure 6. Efficiency curves for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score and National Early Warning Score (NEWS) for the primary outcome of in-hospital death in a) all admissions b) admissions with infection c) admissions without infection. These plot workload (trigger rate) against the sensitivity (both as percentages) of qSOFA and NEWS. Each point on the efficiency curve for each score represents a score value from 0 to 3 (for qSOFA) and 0 to 20 (for NEWS), starting with a value of 0 at the top right. Trigger rate = $\frac{[\text{true positive} + \text{false positive}]}{[\text{true positive} + \text{false positive} + \text{true negative} + \text{false negative}]}$. The closer the efficiency curve is to the lower right corner, the higher the efficiency of the test (i.e., more outcomes are detected for a lower trigger rate).

Supplementary Table 4: Area under the receiver operator characteristics curve for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score, the National Early Warning Score (NEWS) and the quick National Early Warning Score (qNEWS) for a range of outcomes. A comparison of performance between direct admissions and those via the emergency department (ED).

Supplementary Table 5: Area under the receiver operator characteristics curve for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score, the National Early Warning Score (NEWS) and the quick National Early Warning Score (qNEWS) for a range of outcomes for all admissions, including those where there were no vital signs observations taken in the 24 hours prior to discharge.

Supplementary Table 6: Sensitivity, false positive rates and positive predictive values at each threshold of NEWS/qSOFA for the primary outcome of in-hospital mortality.

Supplementary Table 1: Categorisation of admissions

Surgical Specialties
<i>General Surgery</i>
<i>Urology</i>
<i>Renal Surgery & Transplantation</i>
<i>Colorectal</i>
<i>Upper Gastrointestinal</i>
<i>Vascular</i>
<i>Trauma & Orthopaedics</i>
Medical Specialties
<i>General Medicine</i>
<i>Gastroenterology</i>
<i>Endocrinology</i>
<i>Clinical Haematology</i>
<i>Rehabilitation</i>
<i>Cardiology</i>
<i>Respiratory (Thoracic) Medicine</i>
<i>Nephrology</i>
<i>Medical Oncology</i>
<i>Neurology</i>
<i>Rheumatology</i>
<i>Geriatric Medicine</i>

Supplementary Table 2: Twenty-five most common infection diagnoses in database

ICD-10 Code	Admissions (n)	ICD-10 name	Clinical Classifications Software (CCS) name	Mortality (%)
N39.0	7228	Urinary tract infection, site not specified	Urinary tract infections	3.40
J18.1	6160	Lobar pneumonia, unspecified	Pneumonia (except that caused by tuberculosis or sexually transmitted disease)	14.35
J18.9	4453	Pneumonia, unspecified	Pneumonia (except that caused by tuberculosis or sexually transmitted disease)	17.45
J44.0	3200	Chronic obstructive pulmonary disease with acute lower respiratory infection	Chronic obstructive pulmonary disease and bronchiectasis	4.25
J22.X	2941	Unspecified acute lower respiratory infection	Acute bronchitis	4.28
L03.1	2265	Cellulitis of other parts of limb	Skin and subcutaneous tissue infections	2.43
A41.9	1949	Sepsis, unspecified	Septicemia (except in labor)	15.24
K80.1	1214	Calculus of gallbladder with other cholecystitis	Biliary tract disease	0.41
T81.4	1092	Infection following a procedure, not elsewhere classified	Complications of surgical procedures or medical care	0.55
J03.9	1043	Acute tonsillitis, unspecified	Acute and chronic tonsillitis	0
K80.0	869	Calculus of gallbladder with acute cholecystitis	Biliary tract disease	0.69
N12.X	724	Tubulo-interstitial nephritis, not specified as acute or chronic	Nephritis; nephrosis; renal sclerosis	0.28
J69.0	675	Pneumonitis due to food and vomit	Aspiration pneumonitis; food/vomitus	29.04
J36.X	659	Peritonsillar abscess	Acute and chronic tonsillitis	0
K35.8	636	Acute appendicitis, other and unspecified	Appendicitis and other appendiceal conditions	0
L02.4	519	Cutaneous abscess, furuncle and carbuncle of limb	Skin and subcutaneous tissue infections	0.19
K61.0	515	Anal abscess	Anal and rectal conditions	0
K37.X	466	Unspecified appendicitis	Appendicitis and other appendiceal conditions	0.21
L02.2	432	Cutaneous abscess, furuncle and carbuncle of trunk	Skin and subcutaneous tissue infections	1.16
L05.0	385	Pilonidal cyst with abscess	Skin and subcutaneous tissue infections	0
J18.0	363	Bronchopneumonia, unspecified	Pneumonia (except that caused by tuberculosis or sexually transmitted disease)	64.74
K35.3	355	Acute appendicitis with localized peritonitis	Appendicitis and other appendiceal conditions	0.28
A04.7	345	Enterocolitis due to Clostridium difficile	Intestinal infection	5.80
K81.0	337	Acute cholecystitis	Biliary tract disease	2.67
K35.9	319	Acute appendicitis, unspecified	Appendicitis and other appendiceal conditions	0

ICD-10 codes were subsequently mapped to Clinical Coding Software (CCS) groups using tables^a available from NHS Digital^b

^aClinical Coding Software (CCS) groups (http://hcup-us.ahrq.gov/toolssoftware/icd_10/ccs_icd_10.jsp).

^bSummary Hospital-Level Indicator, NHS Digital (<http://content.digital.nhs.uk/SHMI>)

Supplementary Table 3: Twenty-five most common non-infection diagnoses in database

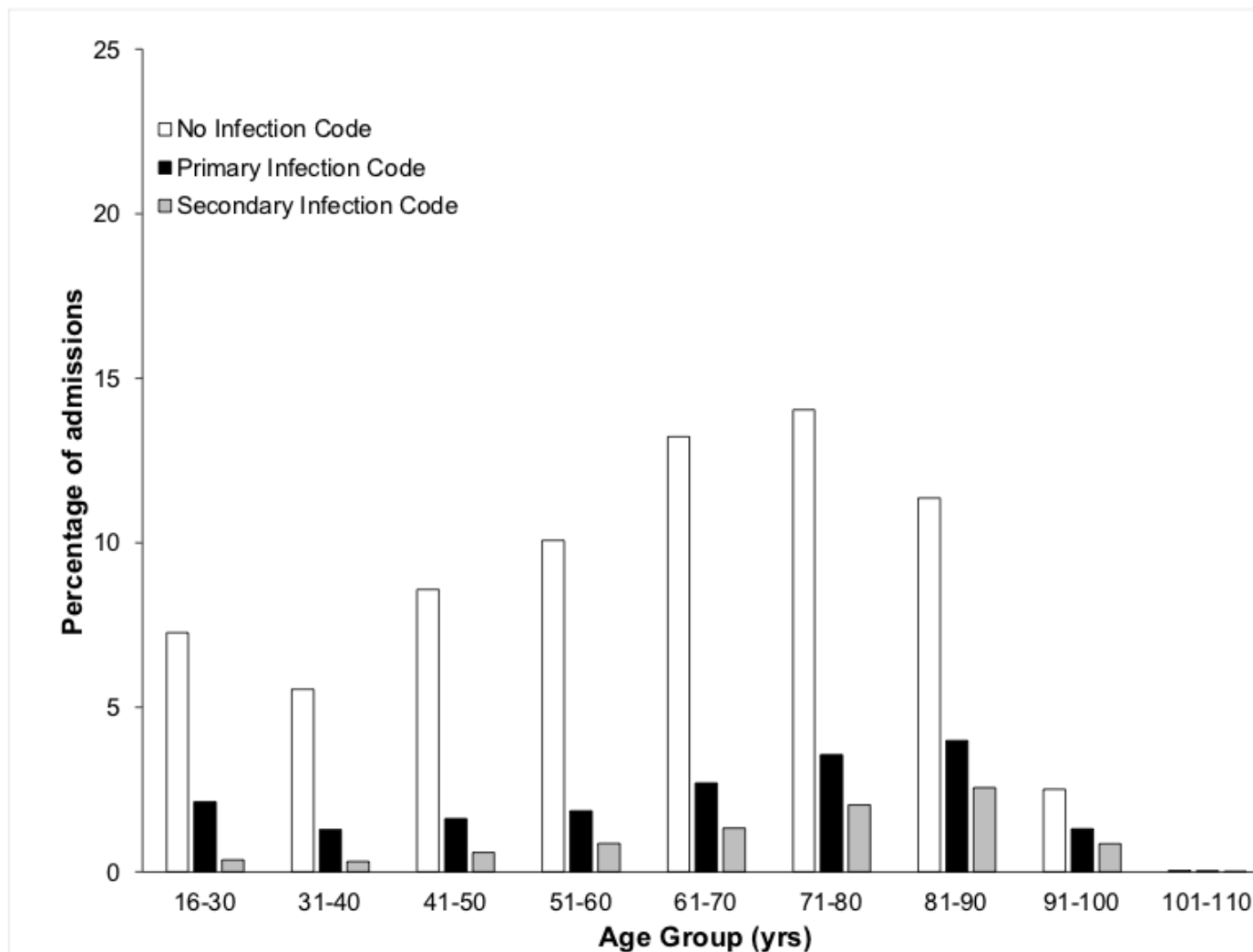
ICD-10 Code	Admissions (n)	ICD-10 name	Clinical Classifications Software (CCS) name	Mortality (%)
I48.X	4697	Atrial fibrillation and flutter	Cardiac dysrhythmias	4.75
R07.4	4428	Chest pain, unspecified	Nonspecific chest pain	0.90
R55.X	4171	Syncope and collapse	Syncope	3.33
M17.9	3954	Gonarthrosis, unspecified	Osteoarthritis	0.51
Z86.4	3792	Personal history of psychoactive substance abuse	Residual codes; unclassified	5.88
I63.9	3684	Cerebral infarction, unspecified	Acute cerebrovascular disease	5.05
R10.4	3543	Other and unspecified abdominal pain	Abdominal pain	1.47
R29.6	3391	Tendency to fall, not elsewhere classified	Other connective tissue disease	6.08
I10.X	3294	Essential (primary) hypertension	Essential hypertension	9.72
I21.9	3278	Acute myocardial infarction, unspecified	Acute myocardial infarction	5.74
M16.9	3223	Coxarthrosis, unspecified	Osteoarthritis	0.40
S72.00	3097	Fracture of neck of femur	Fracture of neck of femur (hip)	3.97
I25.1	3090	Atherosclerotic heart disease	Coronary atherosclerosis and other heart disease	1.33
I50.0	2677	Congestive heart failure	Congestive heart failure; nonhypertensive	12.44
Z86.7	2675	Personal history of diseases of the circulatory system	Residual codes; unclassified	5.50
J44.1	2534	Chronic obstructive pulmonary disease with acute exacerbation, unspecified	Chronic obstructive pulmonary disease and bronchiectasis	3.83
N17.9	2473	Acute renal failure, unspecified	Acute and unspecified renal failure	12.74
J45.9	2261	Asthma, unspecified	Asthma	2.43
K59.0	2130	Constipation	Other gastrointestinal disorders	2.3
K92.2	2112	Gastrointestinal haemorrhage, unspecified	Gastrointestinal hemorrhage	5.87
R07.3	2073	Other chest pain	Nonspecific chest pain	0.29
R10.3	2064	Pain localized to other parts of lower abdomen	Abdominal pain	0.34
C50.9	1997	Malignant neoplasm: Breast, unspecified	Cancer of breast	1.80
R06.0	1881	Dyspnoea	Other upper respiratory disease	5.90
Z92.1	1840	Personal history of long-term (current) use of anticoagulants	Residual codes; unclassified	4.84

ICD-10 codes were subsequently mapped to Clinical Coding Software (CCS) groups using tables^a available from NHS Digital^b

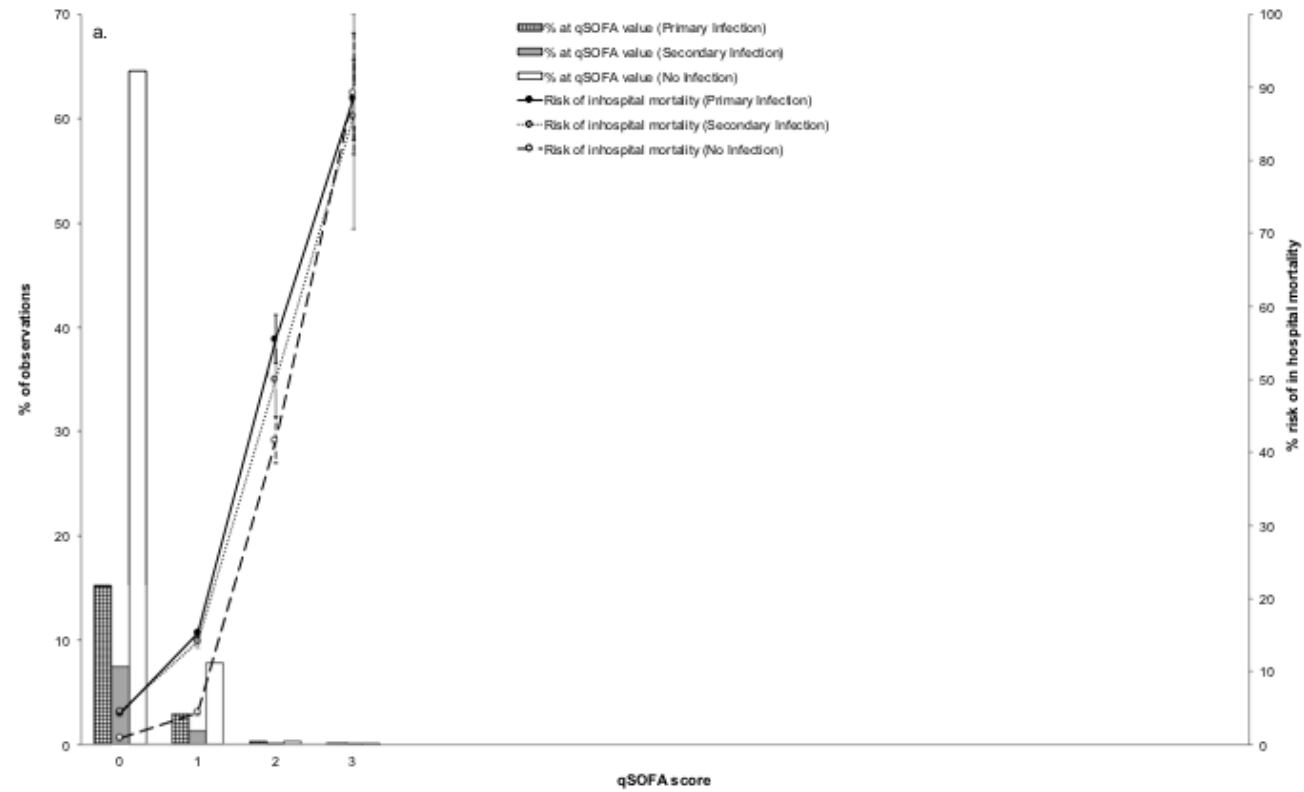
^aClinical Coding Software (CCS) groups (http://hcup-us.ahrq.gov/toolssoftware/icd_10/ccs_icd_10.jsp).

^bSummary Hospital-Level Indicator, NHS Digital (<http://content.digital.nhs.uk/SHMI>)

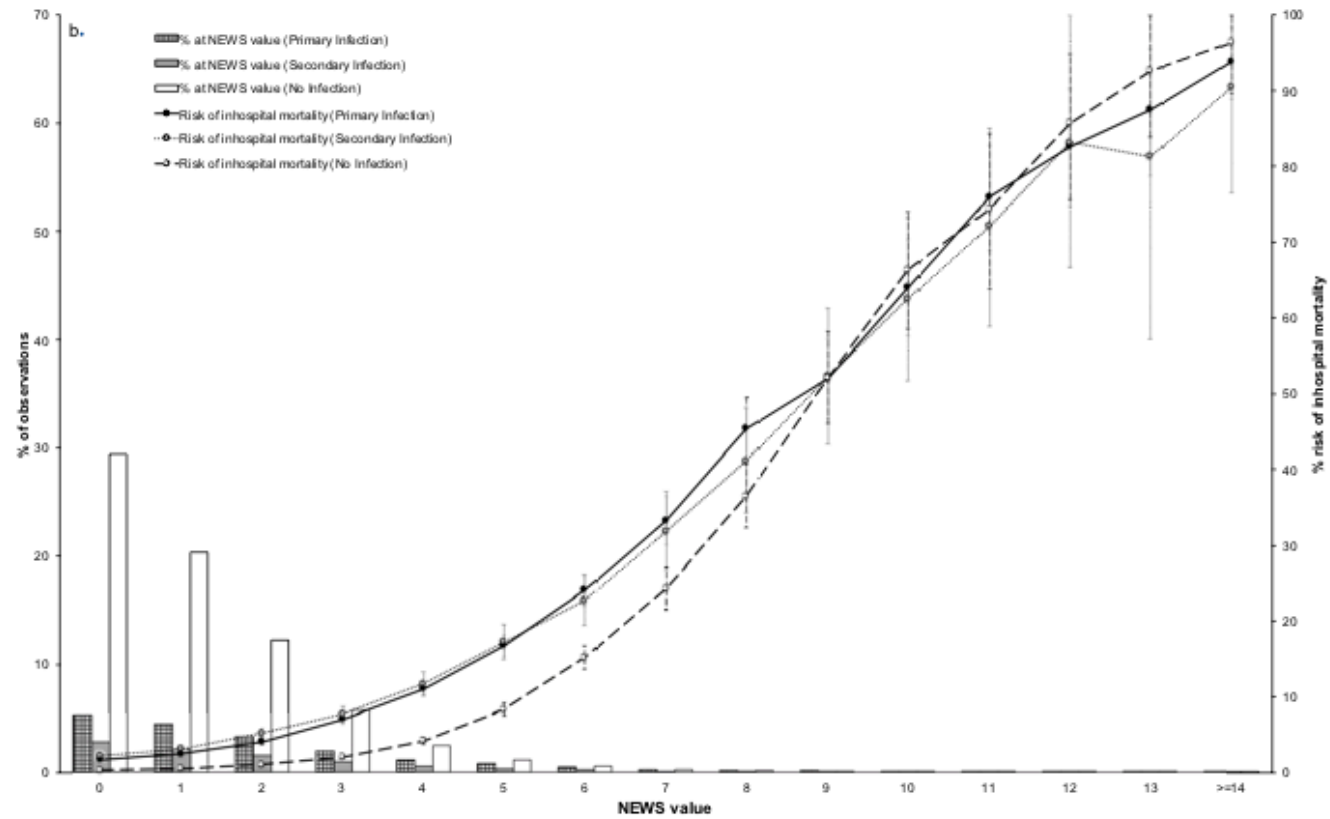
Supplementary Figure 1: The distribution of patient age, categorised by no infection code, or primary and secondary infection codes at any point during an admission.



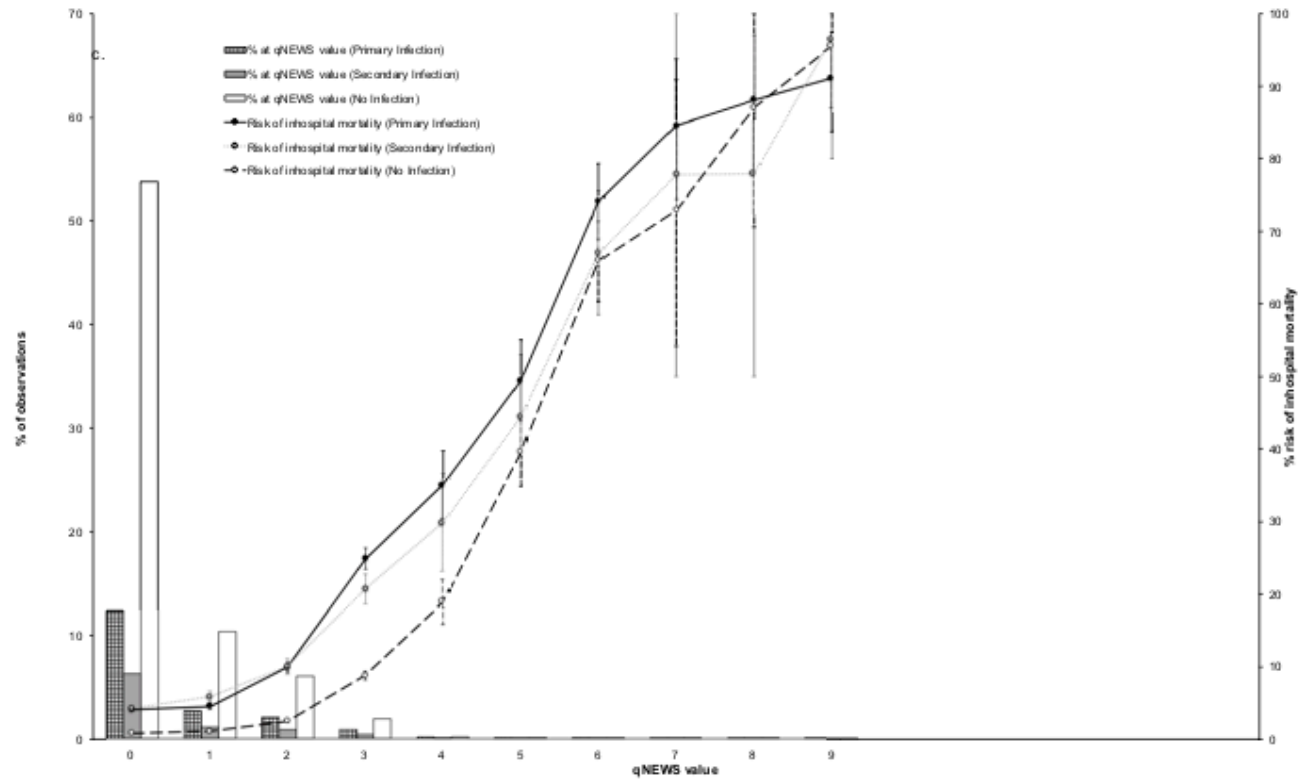
Supplementary Figure 2a. The distribution of quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) values and observed risk of observed risk of in-hospital death categorised by no, primary and secondary infection codes at any point during an admission.



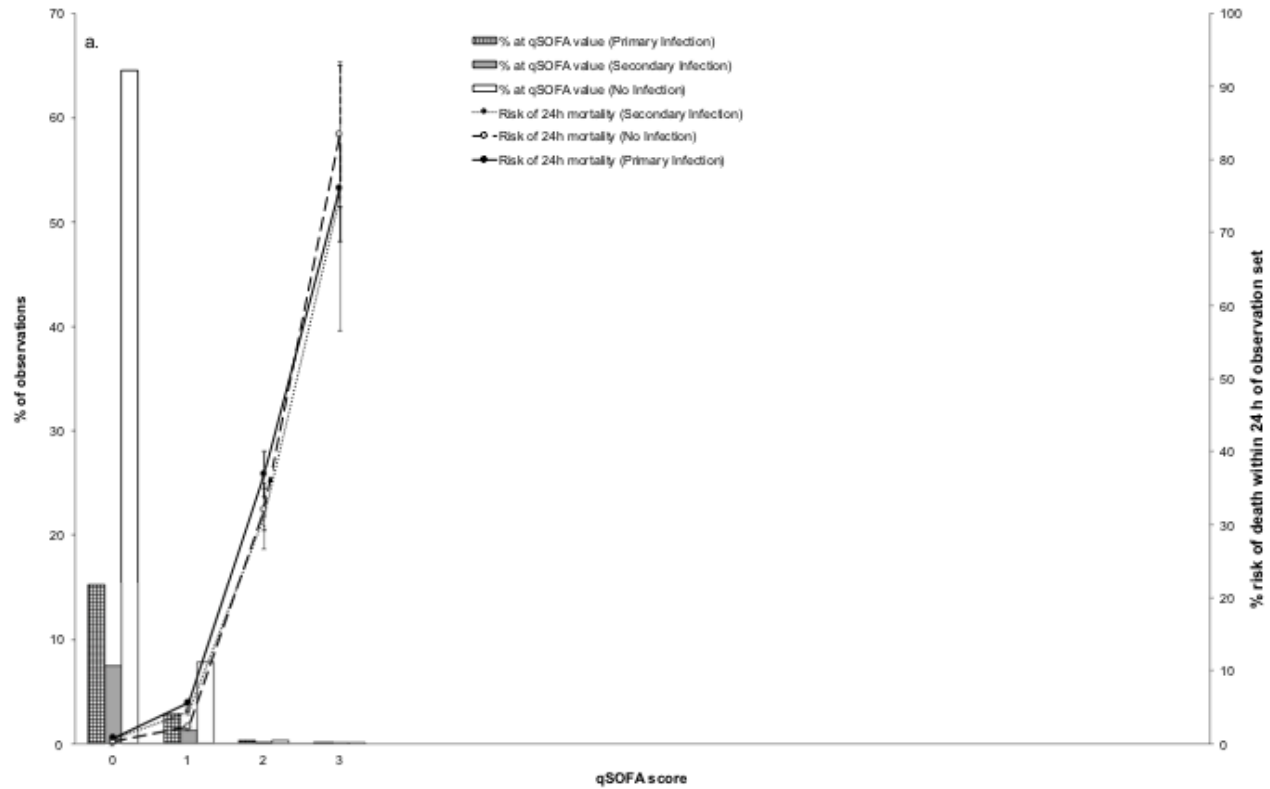
Supplementary Figure 2b. The distribution of National Early Warning Score (NEWS) (values and observed risk of observed risk of in-hospital death categorised by no, primary and secondary infection codes at any point during an admission.



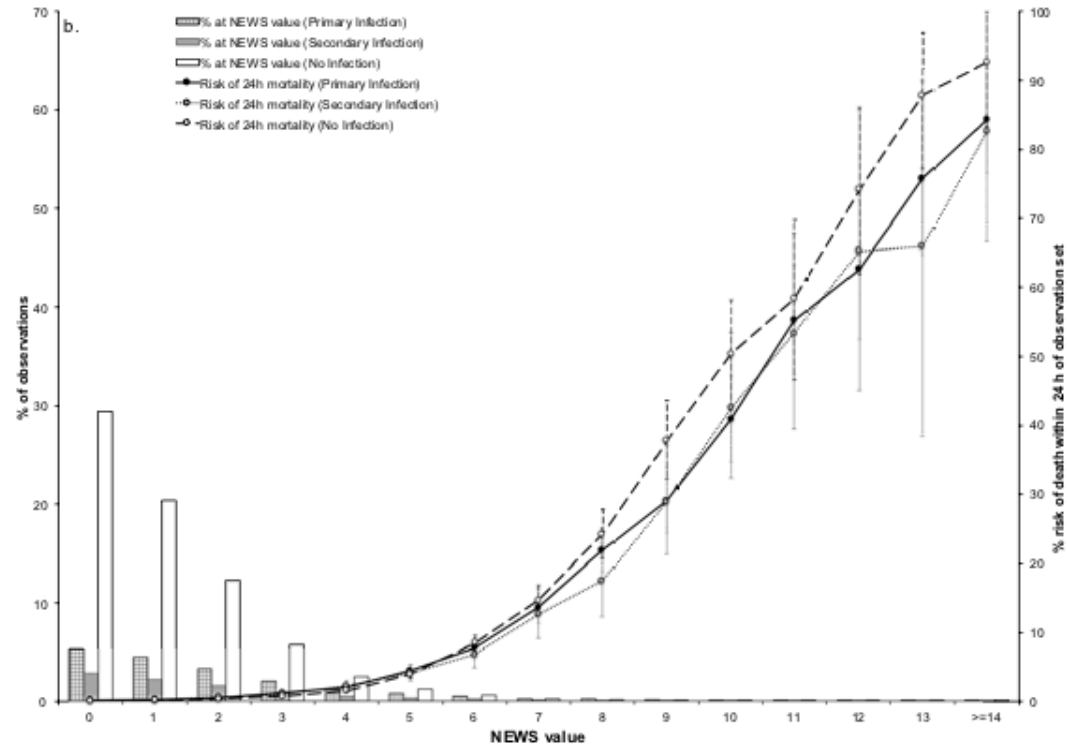
Supplementary Figure 2c. The distribution of quick National Early Warning Score (qNEWS) values and observed risk of observed risk of in-hospital death categorised by no, primary and secondary infection codes at any point during an admission.



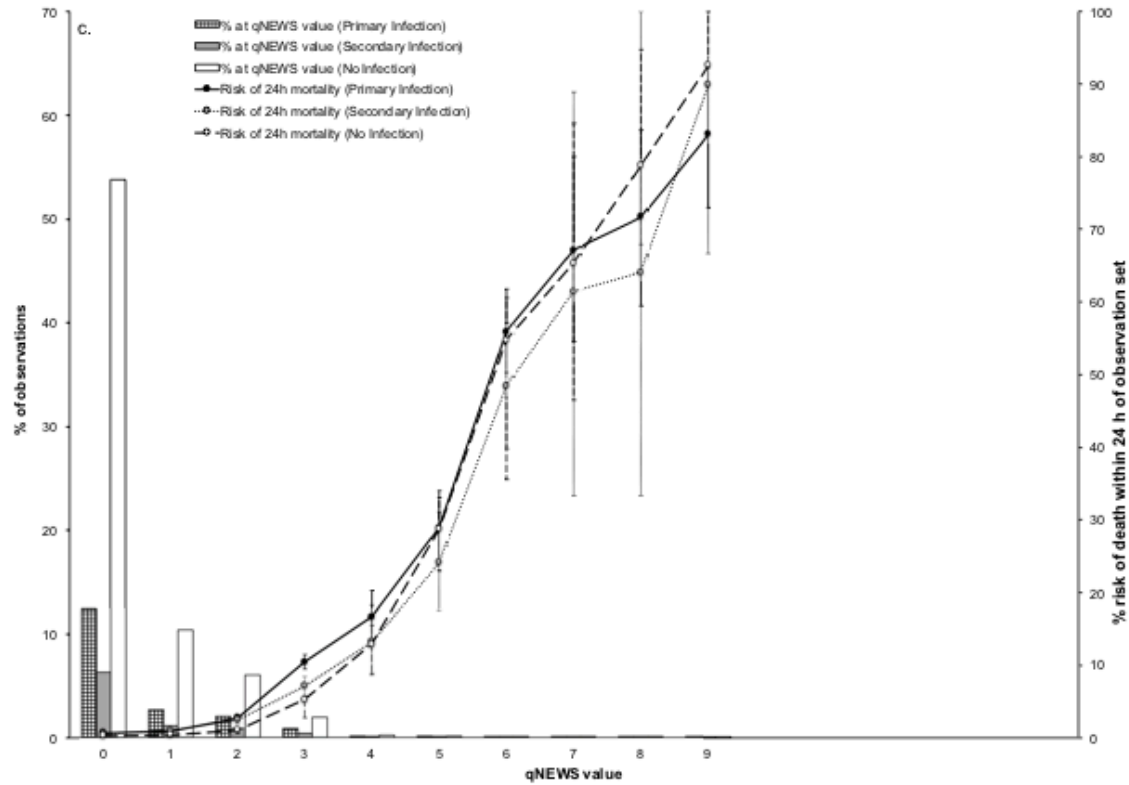
Supplementary Figure 3a. The distribution of quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) values and observed risk of death within 24h of an observation set categorised by no, primary and secondary infection codes at any point during an admission.



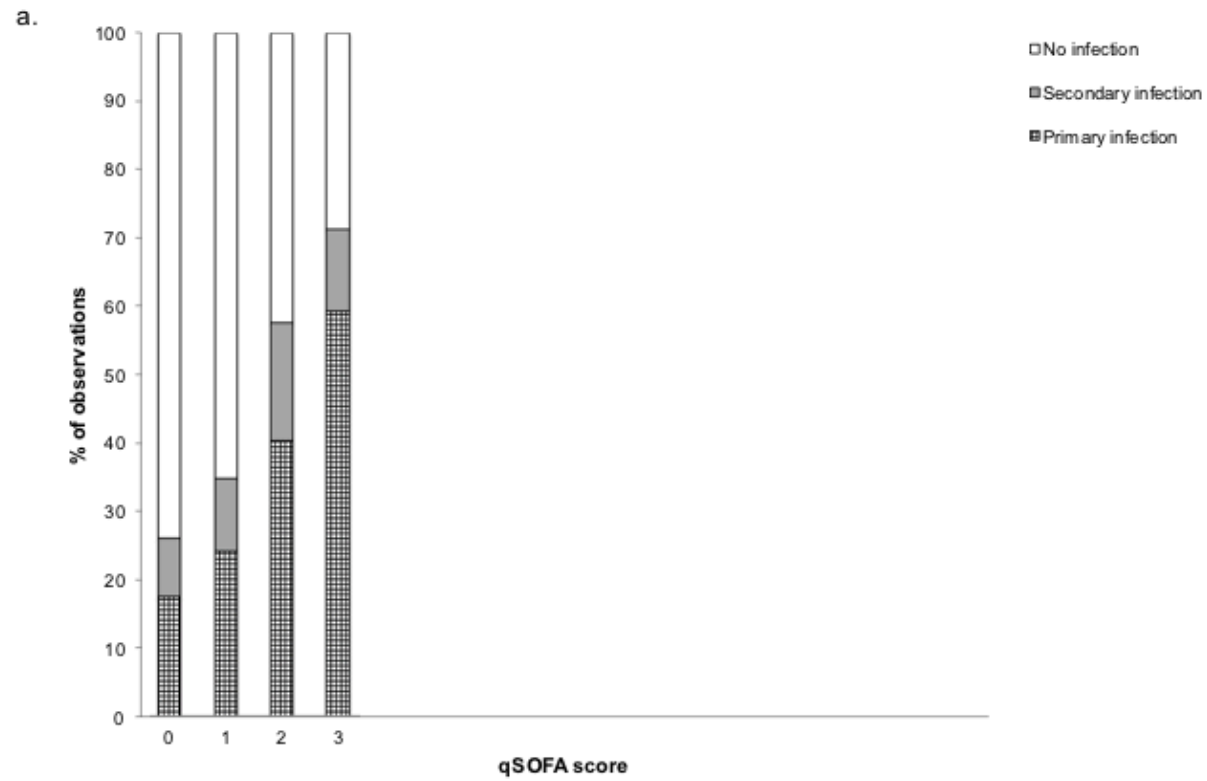
Supplementary Figure 3b. The distribution of National Early Warning Score (NEWS) values and observed risk of death within 24h of an observation set categorised by no, primary and secondary infection codes at any point during an admission.



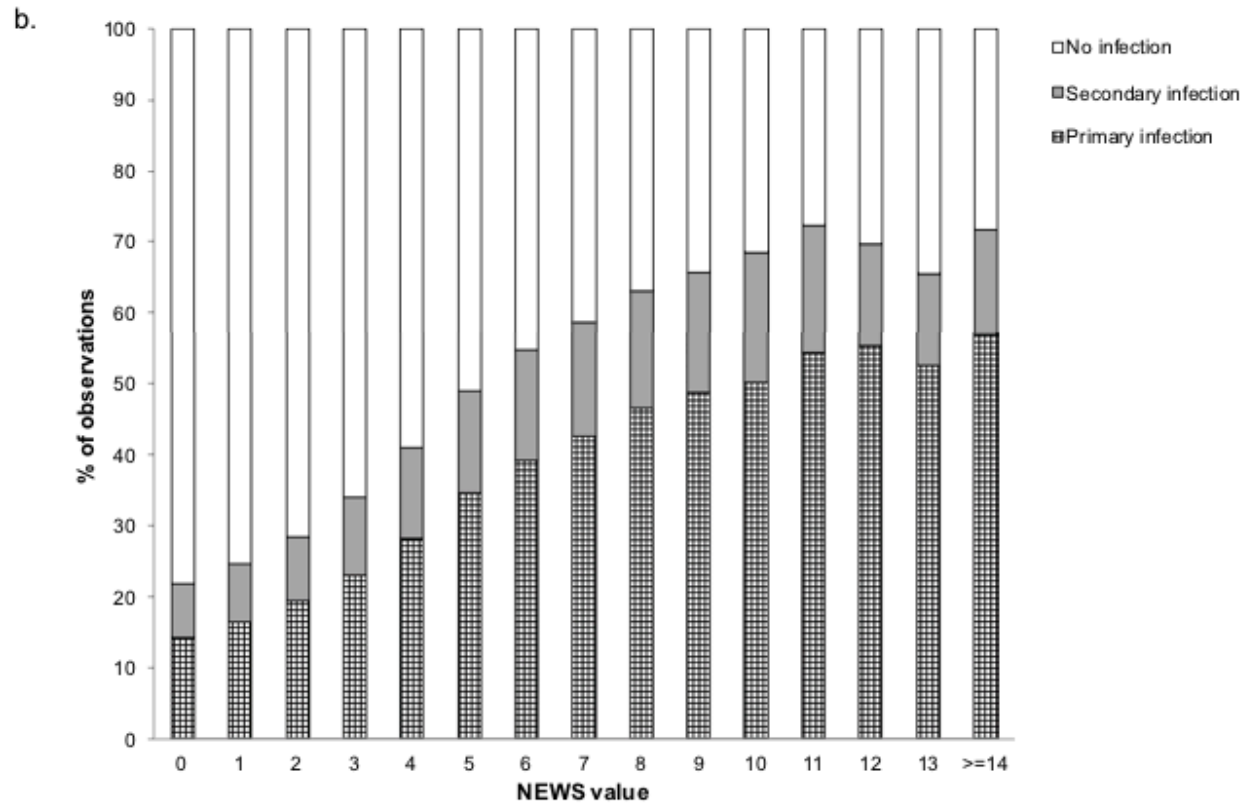
Supplementary Figure 3c. The distribution of quick National Early Warning Score (qNEWS) values and observed risk of death within 24h of an observation set categorised by no, primary and secondary infection codes at any point during an admission.



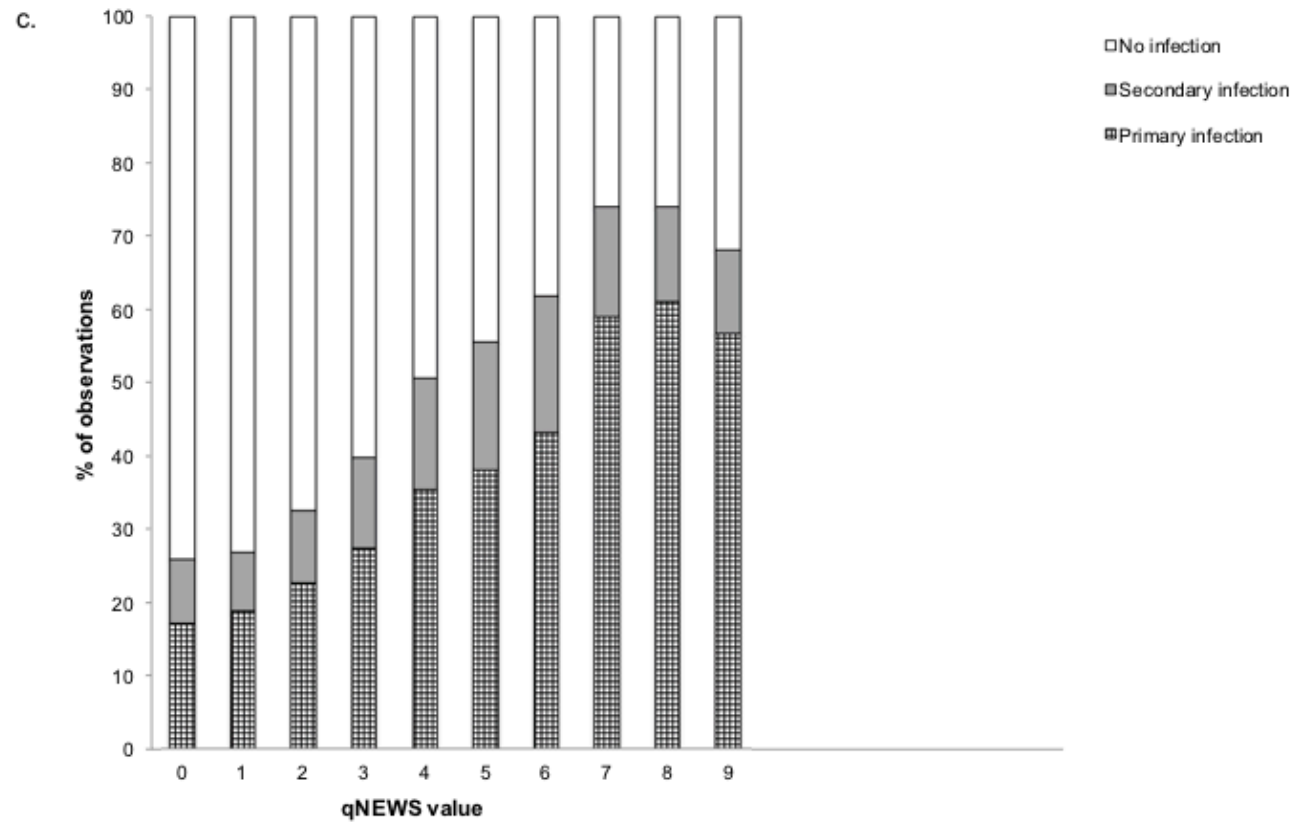
Supplementary Figure 4a. Plot of quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) values and percentage of admissions with primary infection, secondary infection and no infection.



Supplementary Figure 4b. Plot of National Early Warning Score (NEWS) values and percentage of admissions with primary infection, secondary infection and no infection.

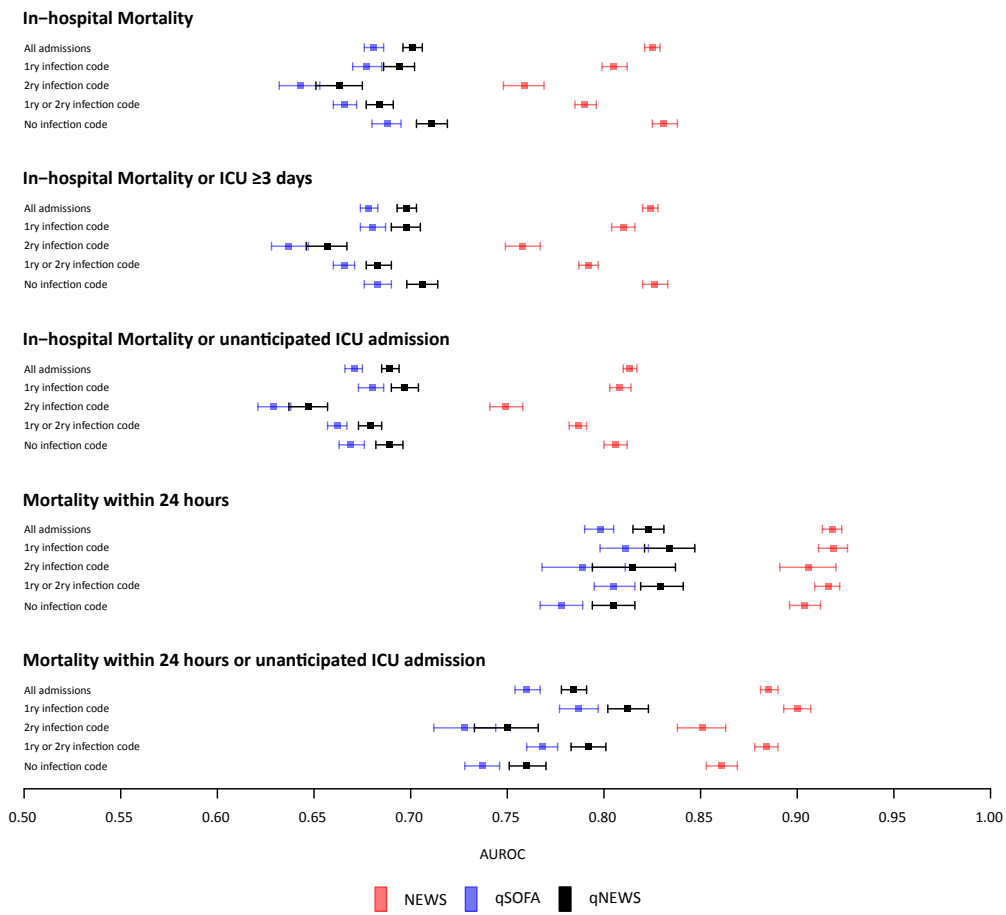


Supplementary Figure 4c. Plot of quick National Early Warning Score (qNEWS) values and percentage of admissions with primary infection, secondary infection and no infection.



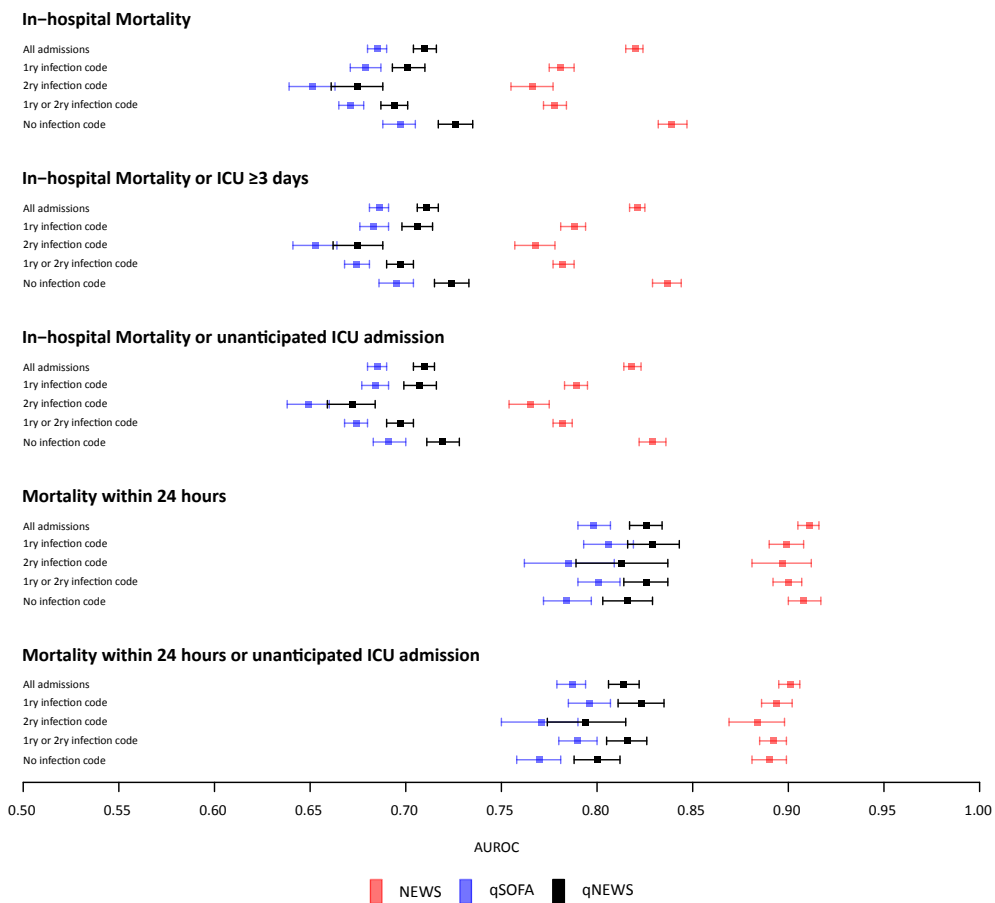
Supplementary Figure 5a. Pictorial display of area under the receiver operator characteristics curve (AUROC) values for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score (Figure 5a), the National Early Warning Score (NEWS) (Figure 5b) and the quick National Early Warning Score (qNEWS) (Figure 5c) for a range of outcomes for the all admissions group.

All admissions



Supplementary Figure 5b. Pictorial display of area under the receiver operator characteristics curve (AUROC) values for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score (Figure 5a), the National Early Warning Score (NEWS) (Figure 5b) and the quick National Early Warning Score (qNEWS) (Figure 5c) for a range of outcomes for the non-elective admissions to medicine group.

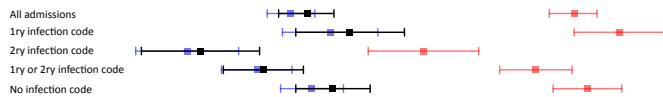
Non-elective admissions to medicine



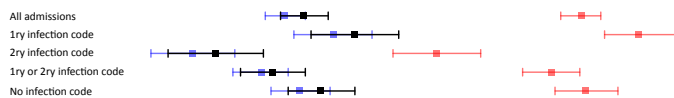
Supplementary Figure 5c. Pictorial display of area under the receiver operator characteristics curve (AUROC) values for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score (Figure 5a), the National Early Warning Score (NEWS) (Figure 5b) and the quick National Early Warning Score (qNEWS) (Figure 5c) for a range of outcomes for the for the non-elective admissions to surgery group.

Non-elective admissions to surgery

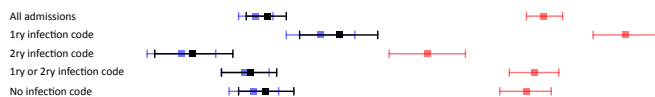
In-hospital Mortality



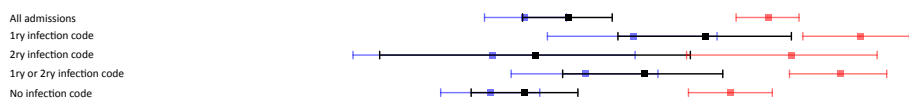
In-hospital Mortality or ICU ≥3 days



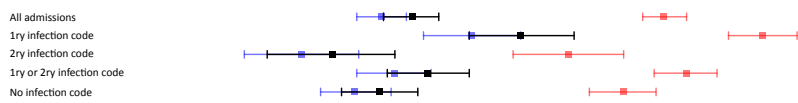
In-hospital Mortality or unanticipated ICU admission



Mortality within 24 hours



Mortality within 24 hours or unanticipated ICU admission

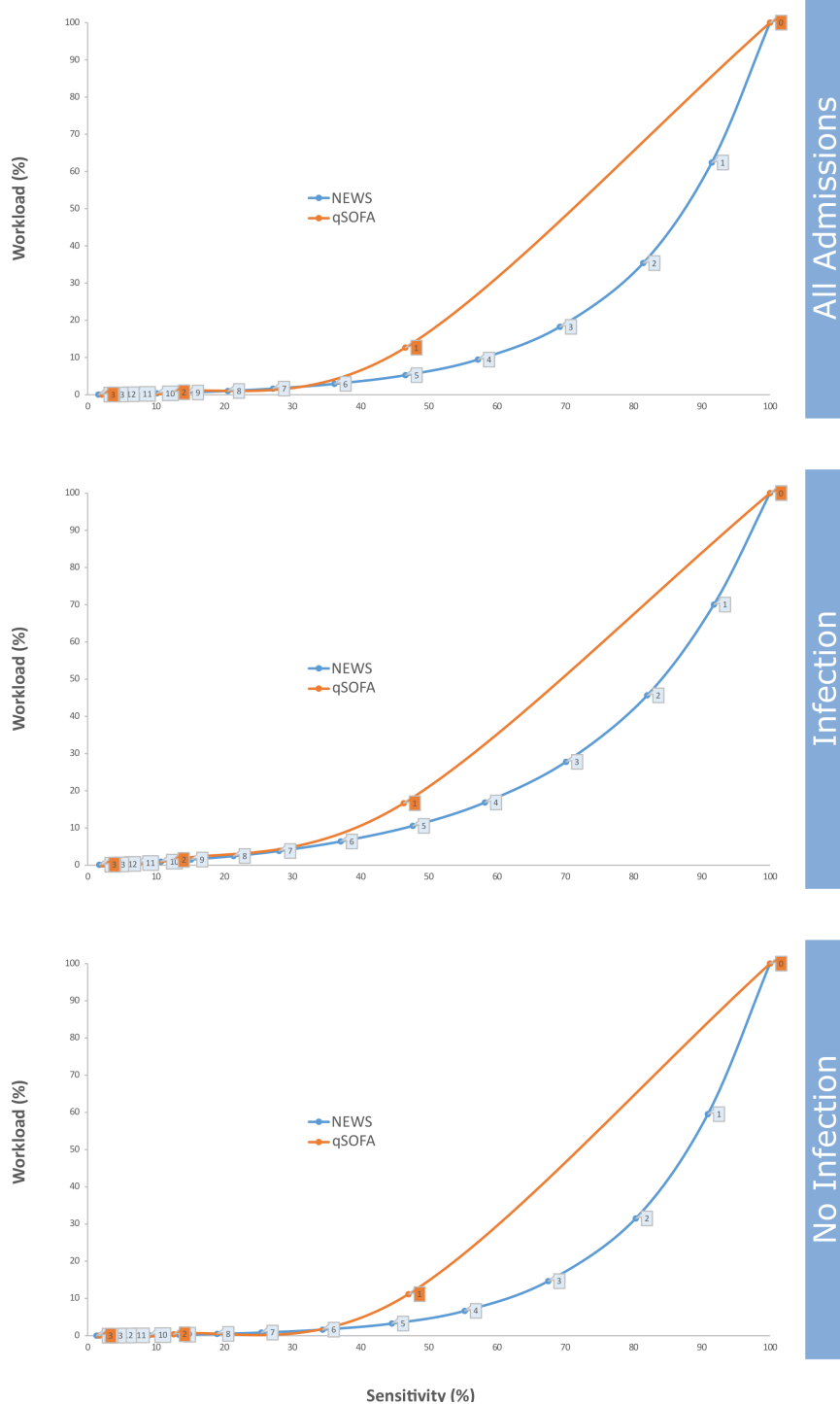


0.50 0.55 0.60 0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00

AUROC

NEWS qSOFA qNEWS

Supplementary Figure 6. Efficiency curves for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score and National Early Warning Score (NEWS) for the primary outcome of in-hospital death in a) all admissions b) admissions with infection c) admissions without infection. These plot workload (trigger rate) against the sensitivity (both as percentages) of qSOFA and NEWS. Each point on the efficiency curve for each score represents a score value from 0 to 3 (for qSOFA) and 0 to 20 (for NEWS), starting with a value of 0 at the top right. Trigger rate = $(\text{true positive} + \text{false positive}) / (\text{true positive} + \text{false positive} + \text{true negative} + \text{false negative})$. The closer the efficiency curve is to the lower right corner, the higher the efficiency of the test (i.e., more outcomes are detected for a lower trigger rate).



Supplementary Table 4: Area under the receiver operator characteristics curve for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score, the National Early Warning Score (NEWS) and the quick National Early Warning Score (qNEWS) for a range of outcomes. A comparison of performance between direct admissions and those via the emergency department (ED).

All admissions		qSOFA	NEWS	qNEWS
Outcome				
In-hospital Mortality	All admissions	0.681 (0.676-0.686)	0.825 (0.821-0.829)	0.701 (0.696-0.706)
	1 st infection code	0.677 (0.670-0.685)	0.805 (0.799-0.812)	0.694 (0.686-0.702)
	2 nd infection code	0.643 (0.632-0.653)	0.759 (0.748-0.769)	0.663 (0.651-0.675)
	1 st or 2 nd infection code	0.666 (0.660-0.672)	0.790 (0.785-0.796)	0.684 (0.677-0.691)
	No infection code	0.688 (0.680-0.695)	0.831 (0.825-0.838)	0.711 (0.703-0.719)
In-hospital Mortality or ICU \geq 3 days	All admissions	0.678 (0.674-0.683)	0.824 (0.820-0.828)	0.698 (0.693-0.703)
	1 st infection code	0.680 (0.674-0.687)	0.810 (0.804-0.816)	0.698 (0.690-0.705)
	2 nd infection code	0.637 (0.628-0.647)	0.758 (0.749-0.767)	0.657 (0.646-0.667)
	1 st or 2 nd infection code	0.666 (0.660-0.671)	0.792 (0.787-0.797)	0.683 (0.677-0.690)
	No infection code	0.683 (0.676-0.690)	0.826 (0.820-0.833)	0.706 (0.698-0.714)
Mortality within 24 hours	All admissions	0.798 (0.790-0.805)	0.918 (0.913-0.923)	0.823 (0.815-0.831)
	1 st infection code	0.811 (0.798-0.823)	0.919 (0.911-0.926)	0.834 (0.821-0.847)
	2 nd infection code	0.789 (0.768-0.811)	0.906 (0.891-0.920)	0.815 (0.794-0.837)
	1 st or 2 nd infection code	0.805 (0.795-0.816)	0.916 (0.909-0.922)	0.829 (0.819-0.841)
	No infection code	0.778 (0.767-0.789)	0.904 (0.896-0.912)	0.805 (0.794-0.816)

In-hospital Mortality or unanticipated ICU admission	All admissions	0.671 (0.666-0.675)	0.813 (0.810-0.817)	0.689 (0.685-0.694)
	1 st infection code	0.680 (0.673-0.686)	0.808 (0.803-0.814)	0.697 (0.690-0.704)
	2 nd infection code	0.629 (0.621-0.638)	0.749 (0.741-0.758)	0.647 (0.637-0.657)
	1 st or 2 nd infection code	0.662 (0.657-0.667)	0.787 (0.782-0.791)	0.679 (0.673-0.685)
	No infection code	0.669 (0.663-0.676)	0.806 (0.800-0.812)	0.689 (0.682-0.696)
Mortality within 24 hours or unanticipated ICU admission within 24 hours	All admissions	0.760 (0.754-0.767)	0.885 (0.881-0.890)	0.784 (0.778-0.791)
	1 st infection code	0.787 (0.777-0.797)	0.900 (0.893-0.907)	0.812 (0.802-0.823)
	2 nd infection code	0.728 (0.712-0.744)	0.851 (0.838-0.863)	0.750 (0.733-0.766)
	1 st or 2 nd infection code	0.768 (0.760-0.776)	0.884 (0.878-0.890)	0.792 (0.783-0.801)
	No infection code	0.737 (0.728-0.746)	0.861 (0.853-0.869)	0.760 (0.751-0.770)
Admissions via ED				
Outcome		qSOFA	NEWS	qNEWS
In-hospital Mortality	All admissions	0.691 (0.686-0.697)	0.830 (0.825-0.834)	0.713 (0.707-0.719)
	1 st infection code	0.684 (0.675-0.692)	0.800 (0.793-0.807)	0.702 (0.692-0.711)
	2 nd infection code	0.653 (0.640-0.666)	0.766 (0.754-0.778)	0.675 (0.661-0.689)
	1 st or 2 nd infection code	0.675 (0.668-0.682)	0.790 (0.784-0.796)	0.694 (0.686-0.701)
	No infection code	0.705 (0.696-0.714)	0.844 (0.836-0.851)	0.731 (0.721-0.740)
In-hospital Mortality or ICU \geq 3 days	All admissions	0.691 (0.686-0.696)	0.831 (0.827-0.836)	0.713 (0.707-0.719)
	1 st infection code	0.688 (0.680-0.696)	0.806 (0.800-0.813)	0.707 (0.698-0.716)
	2 nd infection code	0.652 (0.640-0.664)	0.769 (0.758-0.780)	0.675 (0.662-0.688)

	1 st or 2 nd infection code	0.677 (0.671-0.684)	0.794 (0.789-0.800)	0.697 (0.690-0.704)
	No infection code	0.701 (0.693-0.710)	0.841 (0.834-0.848)	0.726 (0.717-0.736)
Mortality within 24 hours	All admissions	0.803 (0.795-0.811)	0.917 (0.912-0.923)	0.829 (0.820-0.837)
	1 st infection code	0.813 (0.800-0.826)	0.913 (0.904-0.921)	0.837 (0.823-0.850)
	2 nd infection code	0.792 (0.768-0.816)	0.905 (0.889-0.921)	0.820 (0.795-0.844)
	1 st or 2 nd infection code	0.808 (0.797-0.820)	0.911 (0.904-0.919)	0.833 (0.820-0.845)
	No infection code	0.787 (0.775-0.799)	0.908 (0.899-0.917)	0.814 (0.801-0.826)
In-hospital Mortality or unanticipated ICU admission	All admissions	0.685 (0.681-0.690)	0.824 (0.820-0.828)	0.707 (0.702-0.713)
	1 st infection code	0.688 (0.680-0.696)	0.806 (0.799-0.812)	0.707 (0.699-0.716)
	2 nd infection code	0.645 (0.634-0.656)	0.762 (0.751-0.772)	0.666 (0.654-0.678)
	1 st or 2 nd infection code	0.675 (0.668-0.681)	0.791 (0.785-0.796)	0.694 (0.687-0.701)
	No infection code	0.690 (0.682-0.698)	0.827 (0.820-0.834)	0.714 (0.705-0.722)
Mortality within 24 hours or unanticipated ICU admission within 24 hours	All admissions	0.775 (0.768-0.782)	0.895 (0.890-0.900)	0.801 (0.793-0.808)
	1 st infection code	0.796 (0.785-0.808)	0.900 (0.893-0.908)	0.823 (0.811-0.834)
	2 nd infection code	0.744 (0.726-0.763)	0.865 (0.850-0.879)	0.770 (0.751-0.790)
	1 st or 2 nd infection code	0.781 (0.772-0.791)	0.889 (0.882-0.896)	0.807 (0.797-0.818)
	No infection code	0.753 (0.742-0.763)	0.879 (0.871-0.888)	0.779 (0.767-0.790)
Direct Admissions				
OUTCOME		qSOFA	NEWS	qNEWS

In-hospital Mortality	All admissions	0.653 (0.644- 0.662)	0.805 (0.796- 0.813)	0.672 (0.662- 0.682)
	1 st infection code	0.654 (0.639- 0.670)	0.800 (0.786- 0.813)	0.671 (0.653- 0.687)
	2 nd infection code	0.622 (0.603- 0.640)	0.741 (0.722- 0.760)	0.638 (0.617- 0.659)
	1 st or 2 nd infection code	0.642 (0.630- 0.653)	0.778 (0.767- 0.789)	0.657 (0.644- 0.670)
	No infection code	0.654 (0.641- 0.667)	0.806 (0.793- 0.818)	0.674 (0.659- 0.689)
In-hospital Mortality or ICU \geq 3 days	All admissions	0.647 (0.639- 0.655)	0.799 (0.792- 0.807)	0.665 (0.656- 0.674)
	1 st infection code	0.654 (0.641- 0.668)	0.802 (0.789- 0.814)	0.670 (0.655- 0.686)
	2 nd infection code	0.610 (0.595- 0.626)	0.738 (0.722- 0.754)	0.625 (0.607- 0.642)
	1 st or 2 nd infection code	0.635 (0.625- 0.646)	0.776 (0.766- 0.786)	0.650 (0.638- 0.661)
	No infection code	0.648 (0.636- 0.661)	0.797 (0.785- 0.809)	0.668 (0.654- 0.682)
Mortality within 24 hours	All admissions	0.774 (0.756- 0.791)	0.907 (0.895- 0.918)	0.800 (0.782- 0.819)
	1 st infection code	0.793 (0.763- 0.824)	0.920 (0.901- 0.938)	0.818 (0.785- 0.851)
	2 nd infection code	0.780 (0.731- 0.829)	0.904 (0.870- 0.934)	0.801 (0.749- 0.853)
	1 st or 2 nd infection code	0.789 (0.763- 0.815)	0.915 (0.898- 0.930)	0.813 (0.785- 0.840)
	No infection code	0.753 (0.730- 0.776)	0.890 (0.873- 0.907)	0.782 (0.757- 0.806)
In-hospital Mortality or unanticipated ICU admission	All admissions	0.638 (0.631- 0.645)	0.784 (0.777- 0.791)	0.652 (0.644- 0.660)
	1 st infection code	0.654 (0.641- 0.666)	0.799 (0.788- 0.810)	0.669 (0.654- 0.683)
	2 nd infection code	0.603 (0.589- 0.617)	0.728 (0.714- 0.743)	0.614 (0.598- 0.629)
	1 st or 2 nd infection code	0.631 (0.622- 0.641)	0.770 (0.761- 0.779)	0.643 (0.632- 0.654)

	No infection code	0.632 (0.621-0.643)	0.768 (0.757-0.779)	0.647 (0.635-0.659)
Mortality within 24 hours or unanticipated ICU admission within 24 hours	All admissions	0.720 (0.708-0.732)	0.851 (0.841-0.861)	0.740 (0.726-0.754)
	1 st infection code	0.750 (0.728-0.772)	0.886 (0.871-0.901)	0.774 (0.750-0.798)
	2 nd infection code	0.692 (0.664-0.721)	0.819 (0.796-0.842)	0.706 (0.674-0.737)
	1 st or 2 nd infection code	0.727 (0.710-0.745)	0.861 (0.848-0.874)	0.747 (0.727-0.765)
	No infection code	0.700 (0.682-0.717)	0.816 (0.800-0.832)	0.719 (0.700-0.738)

Supplementary Table 5: Area under the receiver operator characteristics curve for quick Sequential [Sepsis-related] Organ Failure Assessment (qSOFA) score, the National Early Warning Score (NEWS) and the quick National Early Warning Score (qNEWS) for a range of outcomes for all admissions, including those where there were no vital signs observations taken in the 24 hours prior to discharge.

All admissions		qSOFA	N
	Outcome		
In-hospital Mortality	All admissions	0.670 (0.666-0.674)	0
	1 st infection code	0.666 (0.660-0.672)	0
	2 nd infection code	0.636 (0.628-0.644)	0
	1 st or 2 nd infection code	0.655 (0.651-0.660)	0
	No infection code	0.677 (0.671-0.682)	0
In-hospital Mortality or ICU \geq 3 days	All admissions	0.669 (0.666-0.673)	0
	1 st infection code	0.669 (0.664-0.675)	0
	2 nd infection code	0.634 (0.627-0.642)	0
	1 st or 2 nd infection code	0.656 (0.652-0.661)	0
	No infection code	0.674 (0.668-0.680)	0
Mortality within 24 hours	All admissions	0.795 (0.788-0.802)	0
	1 st infection code	0.806 (0.793-0.818)	0
	2 nd infection code	0.783 (0.761-0.804)	0
	1 st or 2 nd infection code	0.800 (0.789-0.810)	0
	No infection code	0.777 (0.766-0.788)	0
In-hospital Mortality or unanticipated ICU admission	All admissions	0.665 (0.662-0.668)	0
	1 st infection code	0.670 (0.664-0.675)	0
	2 nd infection code	0.630 (0.622-0.637)	0
	1 st or 2 nd infection code	0.655 (0.650-0.659)	0
	No infection code	0.666 (0.661-0.671)	0
In-hospital Mortality or unanticipated ICU admission within 24 hours	All admissions	0.756 (0.750-0.762)	0
	1 st infection code	0.781 (0.772-0.790)	0
	2 nd infection code	0.722 (0.708-0.737)	0
	1 st or 2 nd infection code	0.762 (0.754-0.769)	0
	No infection code	0.732 (0.723-0.741)	0

Supplementary Table 6. Sensitivity, false positive rates and positive predictive values at each threshold of NEWS/qSOFA for the primary outcome of in-hospital mortality

Group	Threshold	NEWS			qSOFA		
		Sensitivity (%)	False positive rate (%)	Positive Predictive Value (%)	Sensitivity (%)	False positive rate (%)	Positive Predictive Value (%)
All admissions	0	100	100	0.638	100	100	1.72
All admissions	1	91.5	61.6	1.04	46.6	11.7	7.97
All admissions	2	81.4	34	2	12.5	0.326	48.7
All admissions	3	69.2	16.8	3.84	2.08	0.00787	88.5
All admissions	4	57.2	8.08	7.1			
All admissions	5	46.6	4.07	12.5			
All admissions	6	36.2	1.97	19.8			
All admissions	7	27.1	0.916	29.3			
All admissions	8	20.5	0.456	41.4			
All admissions	9	14.5	0.21	52			
All admissions	10	10.1	0.0936	64.5			
All admissions	11	6.78	0.0399	74.8			
All admissions	12	4.4	0.0167	83.6			

All admissions	13	2.76	0.00737	88.4			
All admissions	14	1.57	0.00288	94.1			
Admissions with a 1ry infection code	0	100	100	1.66	100	100	4.21
Admissions with a 1ry infection code	1	92.9	69.4	2.45	48.7	14.9	15.3
Admissions with a 1ry infection code	2	84.2	44	4.11	13.5	0.655	55.5
Admissions with a 1ry infection code	3	73.3	25.5	7.08	2.77	0.0261	88.6
Admissions with a 1ry infection code	4	61.8	14.5	11.1			
Admissions with a 1ry infection code	5	51.4	8.38	16.8			
Admissions with a 1ry infection code	6	40.6	4.46	24.1			
Admissions with a 1ry infection code	7	31	2.25	33.3			
Admissions with a 1ry infection code	8	23.8	1.21	45.4			
Admissions with a 1ry infection code	9	16.9	0.6	52			
Admissions with a 1ry infection code	10	12.1	0.278	64			
Admissions with a 1ry infection code	11	8.36	0.123	75.9			
Admissions with a 1ry infection code	12	5.42	0.0552	82.6			
Admissions with a 1ry infection code	13	3.39	0.0241	87.5			
Admissions with a 1ry infection code	14	2.01	0.0096	93.9			
Admissions with a 2ry infection code	0	100	100	2.19	100	100	4.53
Admissions with a 2ry infection code	1	89.3	66.6	3.15	41.2	13.8	14.1
Admissions with a 2ry infection code	2	77.3	41	5.23	10.1	0.639	50
Admissions with a 2ry infection code	3	63.2	23.3	7.76	1.18	0.0134	86.1
Admissions with a 2ry infection code	4	50.3	12.6	11.7			
Admissions with a 2ry infection code	5	39.5	6.93	17.2			
Admissions with a 2ry infection code	6	29.5	3.59	22.7			
Admissions with a 2ry infection code	7	21.7	1.74	31.8			

Admissions with a 2ry infection code	8	16.1	0.913	41.2			
Admissions with a 2ry infection code	9	11.4	0.439	52.3			
Admissions with a 2ry infection code	10	7.74	0.209	62.5			
Admissions with a 2ry infection code	11	4.85	0.0881	72.2			
Admissions with a 2ry infection code	12	2.88	0.035	83.1			
Admissions with a 2ry infection code	13	1.75	0.0189	81.2			
Admissions with a 2ry infection code	14	1.07	0.00795	90.5			
Admissions with either 1ry or 2ry infection code	0	100	100	1.84	100	100	4.32
Admissions with either 1ry or 2ry infection code	1	91.8	68.5	2.68	46.3	14.5	14.9
Admissions with either 1ry or 2ry infection code	2	82	43	4.47	12.5	0.65	53.8
Admissions with either 1ry or 2ry infection code	3	70.1	24.7	7.3	2.27	0.022	88.1
Admissions with either 1ry or 2ry infection code	4	58.2	13.9	11.3			
Admissions with either 1ry or 2ry infection code	5	47.6	7.91	16.9			
Admissions with either 1ry or 2ry infection code	6	37.1	4.18	23.7			
Admissions with either 1ry or 2ry infection code	7	28	2.09	32.9			
Admissions with either 1ry or 2ry infection code	8	21.4	1.11	44.3			
Admissions with either 1ry or 2ry infection code	9	15.2	0.548	52			
Admissions with either 1ry or 2ry infection code	10	10.7	0.255	63.6			
Admissions with either 1ry or 2ry infection code	11	7.25	0.112	75			
Admissions with either 1ry or 2ry infection code	12	4.61	0.0486	82.7			

<i>Admissions with either 1ry or 2ry infection code</i>	13	2.87	0.0224	86.3			
<i>Admissions with either 1ry or 2ry infection code</i>	14	1.71	0.00906	93.2			
<i>Admissions with no 1ry or 2ry infection code</i>	0	100	100	0.303	100	100	0.801
<i>Admissions with no 1ry or 2ry infection code</i>	1	90.9	59.1	0.507	47	10.7	4.29
<i>Admissions with no 1ry or 2ry infection code</i>	2	80.3	30.9	1.02	12.6	0.21	41.6
<i>Admissions with no 1ry or 2ry infection code</i>	3	67.5	13.9	2.06	1.74	0.00285	89.4
<i>Admissions with no 1ry or 2ry infection code</i>	4	55.3	6.01	4.21			
<i>Admissions with no 1ry or 2ry infection code</i>	5	44.6	2.7	8.34			
<i>Admissions with no 1ry or 2ry infection code</i>	6	34.4	1.18	15.2			
<i>Admissions with no 1ry or 2ry infection code</i>	7	25.5	0.499	24.3			
<i>Admissions with no 1ry or 2ry infection code</i>	8	19	0.223	36.5			
<i>Admissions with no 1ry or 2ry infection code</i>	9	13.4	0.0902	52.1			
<i>Admissions with no 1ry or 2ry infection code</i>	10	9.03	0.036	66.3			
<i>Admissions with no 1ry or 2ry infection code</i>	11	5.9	0.0143	74.4			
<i>Admissions with no 1ry or 2ry infection code</i>	12	4.01	0.00538	85.7			
<i>Admissions with no 1ry or 2ry infection code</i>	13	2.54	0.00202	92.7			
<i>Admissions with no 1ry or 2ry infection code</i>	14	1.31	0.000681	96.4			

