# Title page

## Title

Provision of critical care and mortality for deteriorating ward patients: a prospective observational cohort study in 48 NHS hospitals

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# Requested statements

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## Competing interests

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi\_disclosure.pdf and declare: SH and CS had financial support from the Wellcome Trust for the submitted work; no authors had financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

## Transparency declaration

The lead author\* affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

## Ethics committee approval

Ethical approval (reference 10/H0306/19) was provided by the NHS National Research Ethics Committee (Cambridgeshire 3) on 2 September 2010 for study protocol version 1.1.

## Clinical Trial Registration

The study was registered on the National Institute of Health Research (NIHR) research portfolio (No. 9139), and with ClinicalTrials.gov (No. NCT01099813).

## Role of the funder

Wellcome Trust, via a Clinical Research Training Fellowship (awarded to SH), and ICNARC (KR/DH), the London School of Hygiene and Tropical Medicine (SH/CS), the NIHR Clinical Research Network and the NIHR UCLH/UCL Biomedical Research Centre (MS). The funders of the study had no role in the study design; gathering, analysis, and interpretation of these data; writing of the report; and decision to submit the report for publication.

## Data sharing

Patient level data and full dataset and statistical code available from the corresponding author. Consent was not obtained, but permission to process patient data was approved by the National Information Governance Board Ethics & Confidentiality Committee (Reference ECC 1-02 (FT1)/2011), and all identifiable data have now been destroyed. The presented data are anonymised and risk of identification is low.

# What this paper adds

## What is already known on this topic

* Critical care provision in the UK is limited in comparison to health care systems in Europe and North America.
* Deteriorating patient pathways, the interface between the ward and critical care, have been a priority area for the National Health Service (NHS) since 2005 but existing data comes comes from small retrospective studies or voluntary reporting systems.

## What this study adds

* Ward patients assessed by critical care are immediately vulnerable: a third are in established organ failure, and 14% die within a week, even excluding those with treatment limits.
* Although a third (35%) of patients assessed are recommended critical care, 37% of these are not offered a bed, and delays to admission commonly exceed national guidelines
* One in twelve patients (8%) are assessed when the unit is already full: these patients are less likely to be offered critical care or admitted promptly, and are more likely to deteriorate pending admission.
* Bedside decision making for deteriorating patients is imperfect, and compromised by current critical care provision.

# Abstract

## Objectives

To describe the impact of delayed or refused critical care admission on outcomes of deteriorating ward patients

## Design

Prospective observational cohort study

## Setting

48 NHS hospitals

## Participants

15158 adult ward patients referred to, and assessed by, critical care during 2010-11

## Main outcome measures

Provision and timeliness of critical care, and mortality up to one year

## Results

Of 15158 ward patients assessed, 5164 (34%) were already in organ failure, with only 870 (6%) in receipt of organ support. 6759 (45%) were in the highest National Early Warning Score (NEWS) risk class giving an incidence of 17 high-risk referrals per hospital per month. 2141 (14%) patients with treatment limitation orders were declined critical care. Of the 13017 patients without treatment limits, 4976 (38%) were recommended for critical care, and 3375 (68%) were immediately offered admission (median time to admission 2 hours, IQR 1 to 4). The 1601 (32%) patients recommended for, but not immediately offered, critical care comprised 1021 (64%) who were admitted later (median time 12 hours, IQR 5 to 29), and 179 (11%) patients who died without admission. Decision-making varied by patient subgroup (odds ratio (OR) 0.60, 95%CI 0.53 to 0.69 for immediate admission if ≥80 years), and by hospital (median inter-hospital OR 2.11, 95%CI 1.81 to 2.42). For patients without treatment limits, 7-day, 90-day, and 1-year mortalities were 14%, 30%, and 39%, respectively. Survival varied between hospitals, even after adjustment for patient-specific risks (median inter-hospital hazard ratio (HR) 1.29, 95%CI 1.22-1.35). 1198 (8%) patients were assessed when critical care unit were less likely to be offered admission (OR 0.72, 95%CI 0.59 to 0.88), or admitted promptly (OR 0.27, 95%CI 0.19 to 0.37). Increased critical care occupancy was associated with greater physiological deterioration pending admission (p=0.01). An effect of occupancy on 90-day survival could not be excluded (HR 1.07, 95%CI 1.00 to 1.15).

## Conclusions

Deteriorating ward patients referred to critical care have a high mortality. Despite clinical recommendation for admission, a substantial minority die or deteriorate pending admission partly related to high critical care occupancy.

## Registration

[ClinicalTrials.gov](http://clinicaltrials.gov/show/NCT01099813) (No. NCT01099813).

# Introduction

Around 200 acute hospitals in England care for more than 11 million overnight hospital admissions per annum. Each patient spends an average of 5 days on a hospital ward where they undergo a process of continual triage, and those who deteriorate are referred to critical care. [1] This interface between the ward and critical care has been a priority area for the English National Health Service (NHS), but available data derive from qualitative work, small retrospective studies, or voluntary reporting systems [2-4].

Recent international reports suggest that critical care capacity can affect decision making for these patients. [5-7] The last significant funding increase for critical care in the NHS was in 2000, and, in 2010, the United Kingdom (UK) was still ranked 24 out of 28 European countries in terms of critical care provision. [8] Similar results are found when for comparisons with North American health care. [9] This implies that access to critical care in England may be relatively constrained, and that more referrals may be delayed or refused.

These constraints will particularly affect ward patients referred to critical care that already suffer an inpatient mortality two to three times higher than average. [10-12]

We set out to investigate the impact of, and circumstances surrounding delays in admission to critical care. Previous studies have typically limited themselves to comparisons of early versus late admissions, and have excluded by design those never admitted. This introduces survivorship bias (those who die before late admission), and an exclusion bias (those who survive without admission). Instead, we have prospectively followed all patients referred to critical care, traced subsequent critical care admission in the week after referral (the ‘efferent limb’ of a rapid response system), and performed survival follow-up to one-year.

# Methods

## Study design and participants

The (SPOT)light study was a prospective observational cohort study of the deteriorating ward patient referred for ward assessment by critical care. The physiological status of the patient at the time of the first bedside assessment by critical care was prospectively recorded along with the recommendation made at the end of the assessment. By linking the records generated at the time of the bedside assessment, to records in the Intensive Care National Audit & Research Centre’s Case Mix Programme database (ICNARC CMPD), the fact and timing of admission to critical care were identified. By linking to the NHS Information Service then survival status up to one year was obtained.

Patients were eligible if they were inpatients on general hospital wards who had been referred to, and assessed by, critical care. The ward assessment had to be performed at the bedside by a member of the critical care team. This team was defined broadly to include members of the critical care outreach team (CCOT), or members of the critical care medical or nursing staff. Only the first ward assessment for a given episode of illness was eligible; cardiac arrests, planned critical care admissions, and visits by the team solely for the purpose of retrieving a patient (where a decision to admit had already been made) were excluded.

Demographic information, the date, time and location of the visit, and the level of care at the time of the visit were recorded. [13] Patient physiology (vital signs, arterial blood gas and laboratory measurements) at the time of, or immediately preceding, the ward assessment was abstracted along with organ support, antibiotic therapy, and a subjective assessment of the likelihood of sepsis, and its source. The assessor finally reported the level of care he or she recommended, and the actual outcome of that recommendation at the initial assessment (immediate admission or ongoing ward care). Treatment limitation orders were recorded for those declined.

## Procedures

The study was registered on the National Institute for Health Research (NIHR) Clinical Research Network portfolio, and only hospitals participating in the CMP were eligible. Research teams at each hospital attended a Dataset Familiarization Course, and a data collection manual (containing definitions of items to be collected) was provided. The Clinical Trials Unit at ICNARC co-ordinated and provided support for research queries during the study.

Hospitals were asked to report all consecutive ward referrals to the critical care team. Contemporaneous data collection was promoted, but hospitals were also requested to identify and submit any missed referrals. Reporting was via a secure online web portal which performed real-time field and record level validation. Further on-line validation reports were completed by all hospitals before the database was locked in September 2012. Fact and date of death were then requested from the NHS Information Service. CCOT provision was reported by participating hospitals, and contemporaneous CMP data and Hospital Episode Statistics (HES) were used to define critical care provision, occupancy, and hospital characteristics. To inform completeness of capture of ward referrals and to quality control the study, we used the proportion of emergency ward admissions in the CMP successfully linked to the (SPOT)light database. Data quality was judged on a monthly basis, and only those months where linkage exceeded 80% were included.

## Statistical analysis

Survival was evaluated at 90-days. Sample size was calculated to evaluate mortality increases from delay to admission using estimates from 2007 ICNARC CMP data. The target sample size was 12,075–20,125 patients referred to critical care which allowed for delay to admission to occur in 10–40% of referrals and for mortality effect sizes between 5–10%.

From the physiology measurements at ward assessment, the ICNARC physiology score, the NHS National Early Warning Score (NEWS) and the Sequential Organ Failure Assessment (SOFA) score were calculated with missing values given zero weights as recommended. [14-16] The NEWS score can be used to define three risk classes (Low, Medium, and High) designed to trigger an escalating clinical response.

Prompt admission to critical care was defined as one occurring within four hours of ward assessment. [17]

The indicator of critical care unit occupancy was the difference between the maximum number of beds reported to ICNARC, and the number of actively treated patients occupying those beds at the time the ward patient was assessed. Bed pressure (occupancy) was defined as being high (zero or fewer beds available), medium (one or two beds available), or low (three or more beds available).

Incidence models were stratified by NEWS risk class. The unit of analysis was a study day so that daily fluctuations in lagged critical care occupancy could be examined. Estimation was via generalised estimating equations (GEE) with each hospital as a cluster, and day-by-day correlations modelled using a first order auto-regressive structure. Decision to admit to critical care, and promptness of admission, were modelled using multi-level logistic regression with patients nested within hospitals. Cox proportional hazards were used to model survival with a shared frailty factor for hospitals. The proportional hazards assumption was checked by inspecting plots of smoothed exponentiated standardised Schoënfeld residuals, and re-entering terms using time-varying co-efficients where necessary. Random effects are reported using the Median Odds Ratio (MOR), and the Median Hazard Ratio (MHR) using the bootstrap to generate 95% confidence intervals. These statistics represent the median difference when comparing patient outcomes from any two randomly selected hospitals. [18]

Categorical data were reported as counts and percentages, and continuous data as mean (SD) or median (IQR) values. Effect measures are reported with their 95% confidence intervals.

## Role of the funding source

The study was centrally funded by the Wellcome Trust, via a Clinical Research Training Fellowship (awarded to SH), and ICNARC (KR/DH), the London School of Hygiene and Tropical Medicine (SH/CS), the NIHR Clinical Research Network and the NIHR UCLH/UCL Biomedical Research Centre (MS). The funders of the study had no role in the study design; gathering, analysis, and interpretation of these data; writing of the report; and decision to submit the report for publication. The corresponding author had full access to all data (including statistical reports and tables); takes responsibility for the integrity of these data and the accuracy of the analysis; and takes final responsibility for the decision to submit for publication.

# Results

48 hospitals reported 20,893 visits for ward assessment over 435 study months. 2,694 visits (12.9%) did not meet the inclusion criteria including 1,860 (8.9%) repeat assessments, and 586 (2.8%) assessments for recent critical care discharges. Data linkage did not meet the quality control level (> 80%) for 66 (15%) study-months excluding a further 2,440 (11.7%) visits. Of the 15,759 patients remaining, 15,158 (96.1%) completed follow-up without error and were available for analysis (Figure 1). Final data linkage (ward visits to critical care admissions) was 93% complete.

## Participating hospitals

Participating hospitals comprised 10 teaching and 38 general hospitals collecting data for a median of 8 months (IQR 5 to 9 months) between September 2010 and December 2011. Each contributed a median of 252 patients (IQR 162 to 380). CCOTs operated 24 hours/day and 7 days/week in 14 (29%) hospitals, less than 24 hours/day in 19 (40%) hospitals, and less than 7 days/week in 13 (27%) hospitals. Two hospitals had no CCOT.

There was a median of 12 (IQR 9 to 18) adult general critical care beds per hospital (mixed Level 2 [typically intensive monitoring or single organ support], and Level 3 [ventilated or multiple organ support]), most often co-located in a single physical location (45 hospitals).

Bed pressure was high (zero or fewer available beds) at the time of 1198 (8%) ward assessments, medium (one or two beds available) for 3757 (25%) assessments, and low (three or more beds available) for the remaining 10197 (67%) assessments. Critical care occupancy fluctuated with time of the day, day of the week, and season of the year (supplementary Figure 1).

## Incidence of referrals for ward assessment by critical care

The mean baseline incidence of referrals to critical care (for a non-teaching hospital with 60,000 admissions per year and 24/7 CCOT provision) was 46 (95%CI 50 to 54) patients per month of whom 17 (95%CI 17 to 18) patients met the NEWS high risk criteria at assessment. This is equivalent to 8 unselected referrals or 3 NEWS high risk referrals per 1,000 overnight admissions.

With decreasing provision of critical care outreach, the number of patients assessed also fell (supplementary Table 1). Winter was busier (IRR 1.22, 95%CI 1.14 to 1.31), and weekends quieter (IRR 0.87, 95%CI 0.82 to 0.92) than the rest of the year. When a measure of case finding was included in the models (cases assessed per 1000 overnight hospital admissions), referral incidence increased initially but then began to plateau for those hospitals with referral rates in the highest quartile (supplementary Figure 2).

## Patient characteristics and outcomes

Table 1 presents the baseline data for all ward patients assessed. Sepsis was reported in 9296 patients (61%). Of these, the respiratory system was considered to be the source about half (4772, 51%). Organ failure, defined as a SOFA score greater than or equal to two, was present in 5164 of patients (34%). 1427 patients (9%) were in respiratory failure, 2931 (19%) were in renal failure, and 4636 (31%) were in cardiovascular shock. Organ support at the time of assessment was uncommon (870 patients, 6%).

2708 (18%) patients died during the 7-days following ward assessment. Mortality was heavily front-loaded with 1539 (57%) of these deaths occurring within the first 48 hours (supplementary Figure 3). There was a clear correlation between physiological severity and early (7-day) mortality using either ward based (NEWS) or critical care scoring systems (SOFA, ICNARC) (supplementary Figure 3). As an example, the 7-day mortality was 9% (328 deaths), 15% (629 deaths), and 26% (1734 deaths)for NEWS low, medium and high risk classes respectively.

The critical care assessors judged that 5321 patients (35%) required critical care. These patients had a higher physiological severity of illness (ICNARC physiology score 17.6 versus 14.3, 95% confidence interval for difference 3.0 to 3.5), and a greater 7-day mortality (19.6% versus 17.0%, difference 1.3% to 4.0%). There was a clear correlation between measured severity and the assessors’ judgements of need (supplementary Figure 5).

Overall mortality at 90-days was 35% (5337 patients), and at one year was 44% (6703 patients).

## Patient pathways following ward assessment by critical care

Patients were classified into three groups following the initial ward assessment: 2141 patients (14%) declined admission with treatment limits (pre-existing or newly-placed); 9471 patients (62%) declined admission without treatment limits (Ongoing ward care); and 3546 patients (23%) offered immediate critical care.

### Declined critical care with treatment limits

The 2141 patients with treatment limits had a 7-day mortality of 41% (881 deaths). The initial decision to decline admission was reversed in just 76 patients (4%) of whom 26 (34%) died within the week. Although the final 90-day mortality was substantial 65% (1402 deaths), 506 patients (24%) survived for at least year despite the decision.

Patients declined critical care with treatment limits were older (77 versus 66 years, 95%CI for difference 11 to 12 years), and more acutely unwell (17.1 versus 13.9 ICNARC physiology points, 95%CI for the difference 2.8 to 3.6) than those assigned Ongoing ward care. Critical care occupancy did not affect the proportion of patients declined admission with treatment limits (Table 2).

### Ongoing ward care

The 9471 patients for ongoing ward care had a 7-day mortality of 12% (1102 deaths). Most deaths (799 deaths 73%) occured on the ward but 303 deaths (27%) followed delayed critical care admission. The initial decision to decline critical care was reversed within the week for 1745 patients (18%), so a total of 2544 (27%) patients died or were admitted to critical care.

The ongoing ward care group included 1601 (17%) patients who had nonetheless been recommended critical care by the assessor. These patients had a higher 7-day mortality (18% versus 10%, 95% confidence interval for difference 5% to 9%), and were more likely to have the initial refusal reversed (36% versus 15%, risk difference 19% to 24%).

### Immediate critical care

The 3546 patients immediately accepted to critical care had a 7-day mortality of 20% (725 deaths). Just 42 (6%) of those deaths occurred before admission was arranged, but a further 254 patients (9%) were never admitted but survived nonetheless.

Those offered immediate admission were marginally younger (64.1 versus 65.6 years, 95%CI 0.8 to 2.2 years), but distinctly more unwell (18.1 versus 13.9 ICNARC physiology points, 95%CI 3.9 to 4.5) than the ongoing ward care group. As critical care occupancy at the time of the ward assessment increased, patients were less likely to be immediately accepted (Table 2, Cochran-Armitage test for trend p<0.0001).

## Delay to admission to critical care

The median delay between assessment and admission for patients immediately accepted was 2 hours (IQR 1 to 4) compared to 12 hours (IQR 5 to 29) for those whose initial refusal was subsequently reversed (median additional delay 9 hours, IQR 9 to 10) (Figure 2a). Thus prompt admission (within 4 hours) was delivered for 2277 patients (74%) when immediately accepted versus 256 (16%) when initially declined (risk difference 58%, 95%CI 56% to 60%).

For the subgroup of 580 ongoing ward care patients who had been recommended for critical care (by their assessor), but were initially declined, and later had that refusal reversed, the median delay to admission was 8 hours (IQR 3 to 22).

Increasing occupancy at assessment increased the median delay from 3 (low bed pressure), to 4 (medium pressure), to 6 hours (high pressure, Figure 2b, Jonckheere-Terpstra test for trend p=0.0004).

## Determinants of a decision to admit

We built a multi-level (patients nested within hospitals) logistic regression model to examine factors associated with a decision to admit for patients without treatment limits (Table 3). As with the univariate comparisons above, older patients were less likely to be admitted (patients over 80 years: odds ratio 0.60, 0.53 to 0.69), and more acutely unwell patients were more likely to be admitted (OR 1.07 per ICNARC physiology point, 95% confidence interval 1.06 to 1.07). Similarly, patients already receiving organ support (1.83, 1.55 to 2.16), or clinically judged to be peri-arrest (6.32, 5.18 to 7.70) were also more likely to be admitted.

Patients referred out-of-hours (7pm-7am), during the weekend, or during the winter were more likely to be offered critical care (odds ratios between 1.04 to 1.33), but those assessed when bed pressures were high (OR 0.70, 0.57 to 0.86), or medium (0.87, 0.77 to 0.98) were less likely to be accepted. We estimated, that in this sample, an additional 122 patients (95%CI 53 to 186) would have been immediately accepted had there been no limitations on critical care capacity.

The model also demonstrated significant hospital level variation with a MOR of 2.11 (95% confidence interval 1.81 to 2.42) which differed little to that estimated excluding patient predictors (MOR 2.18, 1.82 to 2.60). The MOR summarises the differences when comparing decision making for similar patients from any two randomly selected hospitals, and consistency when excluding patient level predictors suggests that it is a true hospital level difference.

## Determinants of prompt admission

The modelling was repeated but now with the delivery of admission to critical care within 4 hours (a prompt admission) as the outcome, and the decision to admit as an additional predictor (Table 3). In this analysis, we also excluded 358 (2.4%) patients whose admission was inevitably delayed urgent surgery.

The patient-level predictors of prompt admission were broadly similar to those for decisions to admit, with younger and sicker patients being admitted more promptly. However, patients assessed during the winter, while being more likely to be offered critical care, were less likely to be admitted promptly (OR 0.76, 0.64 to 0.90). The strongest predictor of prompt admission was a decision to admit at the initial bedside assessment (OR 69, 59 to 81). Even though the decision to admit was included in the model, bed pressure still had a marked effect (high pressure: 0.27, 0.19 to 0.37) and hospital level variation persisted (MOR 1.89, 1.63 to 2.21).

## Determinants of 90-day mortality

Amongst patients without treatment limits, there were 372 deaths (3%) by the end of the first day, 1742 (13%) by the end of the first week, 3130 (24%) by the 30 days, and 3946(30%) by 90 days (proportions from Kaplan-Meier failure function).

A series of models were fitted with 90-day survival as the dependent variable for patients without treatment limits. The final best model (Table 4) incorporated a time-varying effect for measured physiological severity and reported peri-arrest status such that their effects were attenuated after the first week (supplementary Figure 6).

Other patient level risk factors were consistent with the existing literature on outcomes in similar patients: older patients, and those with sepsis (other than genito-urinary) had worse survival. [19] Patients assessed during the winter months, over the weekend, and out-of-hours did not have a significantly worse adjusted survival than baseline.

Critical care occupancy did not affect adjusted mortality in the multi-level model (high pressure: hazard ratio 1.03, 95% confidence interval 0.90 to 1.17). A single level model (supplementary Table 2), constructed in case occupancy was mediated through rather than confounded by the effect of the hospital, similarly could not exclude a null effect (hazard ratio 1.07, 1.00 to 1.15, p=0.06).

The full multi-level model demonstrated significant hospital level variation in survival (MHR 1.28, 1.22 to 1.34) which was little altered by adjustment for patient level risk factors (MHR 1.29, 1.22 to 1.35).

Repeating the survival model in the subgroup recommended to critical care at the initial assessment produced similar effects albeit with less precision (supplementary Table 2).

# Discussion

## Key findings

We describe the events following initial bedside assessment by critical care of more than 15000 ward patients in 48 acute NHS hospitals. Nearly half (45%) of these patients were defined as being at high risk by current guidelines[14]. A third (33%) were assessed while the critical care unit was under-strain (two or fewer beds available), and 1 in 12 (8%) were assessed when the unit was completely full.

Critical care capacity affected bedside decision-making, and, despite adjustment for patient specific risk factors, the threshold for admission varied between hospitals, and across age groups. As a consequence, affected patients were less likely to be admitted to critical care, and more likely to die on the ward without critical care. This was true regardless of the recommendation made by the bedside assessor. Those who were admitted either had that admission delayed directly (delayed immediate critical care), or indirectly (later reversal of an initial refusal). Even for those immediately offered a bed, one in four were delayed more than four hours. Compared to the international literature this four hour target is not strict. [6,7]

The mortality rate for all patients assessed was high, and not dissimilar to that for critical care inpatients although only a minority were admitted. [15,20] Around one in three patients died within 90-days, and nearly one half did not survive a year. Early (7-day) mortality is elevated even for low risk patients whether that risk is defined objectively by NEWS class, or subjectively by the bedside assessor. This risk is heavily front-loaded with around half of deaths in the first week, and half of those deaths in the first 48 hours implying that the opportunity for intervening is narrow. We did not observe a weekend or out-of-hours effect on risk adjusted survival.

We could not show a direct effect of occupancy on mortality in our primary analysis. However, we adjusted for hospital, and, if part of the effect of being in a ‘good’ hospital is mediated through how critical care occupancy is managed, then this difference would have been inappropriately ‘adjusted away’. In our single level model, the effect of occupancy on mortality was greater; thus we cannot confidently exclude occupancy as having a clinically important effect. Notably, we did observe significant changes in process measures (delay to admission, and physiological deterioration while waiting) that would be consistent with this hypothesis.

## Strengths and limitations

This is the largest prospective study of deteriorating ward patients to date, with hospitals contributing from across the spectrum of the NHS. There are three main strengths. Firstly, we followed all patients referred not just those eventually admitted. This ‘denominator’ data exposes the demand for critical care arising from inpatient wards, and the ongoing process of triage performed by all critical care teams. With two notable exceptions[6,7], similar studies only follow those eventually admitted. [21-25] Evaluations of decision making without sight of those referred and refused cannot report on patients who die without critical care admission, or survive despite initial refusal: survival and exclusion bias respectively. We demonstrate that such patients are numerous: most deaths in the first week occur on the ward — even amongst those without treatment limitations.

Secondly, we linked the precise time of the bedside assessment to the contemporaneous occupancy of the critical care unit, and to reveal the effect of resource limitation on patient pathways. Thirdly, we completed follow-up to one year. While the main message is that mortality is an early problem, and that interventions must be timely, we also note that one in four patients with a treatment limitation orders survive a full year without critical care. This suggests a need for humility before refusing admission on the grounds of long term prognosis.

Some limitations also deserve highlighting. We used real time data collection in order to capture assessments and decisions, and consequently, not all hospitals managed to submit complete data at all times. However, we used the proportion of emergency ward admissions in the CMP successfully linked to the (SPOT)light database as a metric to track completeness, and tested our findings by varying this threshold. Raising the minimum standard from 80% to 90% increased the median proportion of eligible admissions from 93% to 97% without consistent difference in any result other than a fall in precision as the sample size was reduced.

The second weakness is structural rather than operational. In defining our population as those referred, we were blind to the process that leads to referral (commonly known as the afferent limb of the critical care response). [26] There exists both an unobserved population of potential referrals, and an unobserved period of deterioration prior to the actual referral. While these are valid targets for intervention, observation would require a briefer, narrower, and less generalisable study design. [10]

## Comparison with other studies

There are no similar studies of ward patients referred to critical care in the UK. However it would appear that the incidence of referrals we report is much lower than in other comparable health care systems (around 8 versus 25–50 referrals per 1,000 inpatient admissions). [26-28] Despite our smaller and presumably more selected population, we observe a similar mortality — although direct comparisons remain difficult because the reporting metrics differ (hospital mortality versus 30-day survival). For additional context, it is worth comparing the overall 61% one year survival for the ward patients referred to critical care to that for UK patients diagnosed with lung (30%), colorectal (75%) and breast cancer (95%).[29]

With respect to occupancy, the rates we observe vastly exceed those seen in US Veteran’s Affairs hospitals, but are not dissimilar to those in France or Canada. [5-7] However, the delays to admission in this study are markedly worse (2 and 12 hours versus 1 and 5 hours for direct and indirect admissions respectively). National audit data suggests that delayed ICU discharges for study hospitals are increasing[30], and we also know that hospital inpatient capacity in the UK is constrained. [9] Blocked discharges from the ICU to the ward that in turn delay new admissions might well be expected to cause such intransigent delays.

## Conclusions and implications for practice and future research

We conclude that ward patients referred to critical care are numerous, and vulnerable. The opportunity for intervention is brief, and there is important variation in practice between hospitals. The bedside assessment is an effective but imperfect triage tool, as the mortality even in those not recommended for admission is high. Given that we already excluded patients with treatment limitations, it is of concern that around half of these early deaths occur without a trial of critical care.

A substantial proportion of patients assessed and recommended for critical care are not offered a bed, and these refusals increase when capacity is limited. Expanding critical care bed numbers would first and foremost benefit this group. However, it might also create a virtuous circle. Earlier admission may lead to shorter stays thereby improving flow through critical care as well as outcomes. Identifying those patients who should be admitted promptly is already the top priority for both clinicians and patients. [31] What we have contributed we hope, is firm evidence in support of this.

# References

1 Hospital Episode Statistics. *hscicgovuk*

2 Luettel D, Beaumont K, Healey F. Recognising and responding appropriately to early signs of deterioration in hospitalised patients. National Patient Safety Agency 2007.

3 McQuillan P, Pilkington S, Allan A, *et al.* Confidential inquiry into quality of care before admission to intensive care. *BMJ* 1998;**316**:1853–8.

4 Cullinane M, Findlay G, Hargraves LS. An Acute Problem?: A Report of the National Confidential Enquiry Into Patient Outcome and Death. National Confidential Enquiry into Perioperative Deaths 2005.

5 Chen LM, Render M, Sales A, *et al.* Intensive care unit admitting patterns in the Veterans Affairs health care system. *Arch Intern Med* 2012;**172**:1220–6. doi:10.1001/archinternmed.2012.2606

6 Stelfox HT, Hemmelgarn BR, Bagshaw SM, *et al.* Intensive Care Unit Bed Availability and Outcomes for Hospitalized Patients With Sudden Clinical Deterioration. *Arch Intern Med* 2012;**172**:467–74. doi:10.1001/archinternmed.2011.2315

7 Robert R, Reignier J, Tournoux-Facon C, *et al.* Refusal of intensive care unit admission due to a full unit: impact on mortality. *American Journal of Respiratory and Critical Care Medicine* 2012;**185**:1081–7. doi:10.1164/rccm.201104-0729OC

8 Rhodes A, Ferdinande P, Flaatten H, *et al.* The variability of critical care bed numbers in Europe. *Intensive Care Med* 2012;**38**:1647–53. doi:10.1007/s00134-012-2627-8

9 Wunsch H, Angus DC, Harrison DA, *et al.* Variation in critical care services across North America and Western Europe. *Crit Care Med* 2008;**36**:2787–93–e1–9. doi:10.1097/CCM.0b013e318186aec8

10 Simchen E, Sprung CL, Galai N, *et al.* Survival of critically ill patients hospitalized in and out of intensive care. *Crit Care Med* 2007;**35**:449–57. doi:10.1097/01.CCM.0000253407.89594.15

11 Buist MD, Moore GE, Bernard SA, *et al.* Effects of a medical emergency team on reduction of incidence of and mortality from unexpected cardiac arrests in hospital: preliminary study. *BMJ* 2002;**324**:387–90. doi:10.1136/bmj.324.7334.387

12 Clark D, Armstrong M, Allan A, *et al.* Imminence of death among hospital inpatients: Prevalent cohort study. *Palliat Med* 2014;**28**:474–9. doi:10.1177/0269216314526443

13 Eddleston JM, Goldhill DR, Morris J. Levels of critical care for adult patients. Intensive Care Society 2009.

14 National Early Warning Score (NEWS): Standardising the assessment of acute-illness severity in the NHS. 2012;:1–30.

15 Harrison DA, Parry GJ, Carpenter JR, *et al.* A new risk prediction model for critical care: the Intensive Care National Audit & Research Centre (ICNARC) model. *Crit Care Med* 2007;**35**:1091–8. doi:10.1097/01.CCM.0000259468.24532.44

16 Vincent JL, Moreno R, Takala J, *et al.* The SOFA (Sepsis-related Organ Failure Assessment) score to describe organ dysfunction/failure. On behalf of the Working Group on Sepsis-Related Problems of the European Society of Intensive Care Medicine. *Intensive Care Med* 1996;**22**:707–10.

17 Core Standards for Intensive Care Units. Intensive Care Society (UK) 2013.

18 Bengtsson T, Dribe M. Quantifying the Family Frailty Effect in Infant and Child Mortality by Using Median Hazard Ratio (MHR). *Historical Methods: A Journal of Quantitative and Interdisciplinary History* 2010;**43**:15–27. doi:10.1080/01615440903270299

19 Harrison DA, Brady AR, Rowan K. Case mix, outcome and length of stay for admissions to adult, general critical care units in England, Wales and Northern Ireland: the Intensive Care National Audit & Research Centre Case Mix Programme Database. *Crit Care* 2004;**8**:R99–111. doi:10.1186/cc2834

20 Harrison DA, Lone NI, Haddow C, *et al.* External validation of the Intensive Care National Audit & Research Centre (ICNARC) risk prediction model in critical care units in Scotland. *BMC Anesthesiol* 2014;**14**:116. doi:10.1186/1471-2253-14-116

21 O'Callaghan DJ, Jayia P, Vaughan-Huxley E, *et al.* An observational study to determine the effect of delayed admission to the intensive care unit on patient outcome. *Crit Care* 2012;**16**:R173. doi:10.1186/cc11650

22 Restrepo MI, Mortensen EM, Rello J, *et al.* Late admission to the ICU in patients with community-acquired pneumonia is associated with higher mortality. *Chest* 2010;**137**:552–7. doi:10.1378/chest.09-1547

23 Renaud B, Santin A, Coma E, *et al.* Association between timing of intensive care unit admission and outcomes for emergency department patients with community-acquired pneumonia. *Crit Care Med* 2009;**37**:2867–74. doi:10.1097/CCM.0b013e3181b02dbb

24 Chalfin DB, Trzeciak S, Likourezos A, *et al.* Impact of delayed transfer of critically ill patients from the emergency department to the intensive care unit. *Crit Care Med* 2007;**35**:1477–83. doi:10.1097/01.CCM.0000266585.74905.5A

25 Simpson HK, Clancy M, Goldfrad C, *et al.* Admissions to intensive care units from emergency departments: a descriptive study. *Emerg Med J* 2005;**22**:423–8. doi:10.1136/emj.2003.005124

26 Jones DA, DeVita MA, Bellomo R. Rapid-response teams. *N Engl J Med* 2011;**365**:139–46. doi:10.1056/NEJMra0910926

27 Bell MB, Konrad D, Granath F, *et al.* Prevalence and sensitivity of MET-criteria in a Scandinavian University Hospital. *Resuscitation* 2006;**70**:66–73. doi:10.1016/j.resuscitation.2005.11.011

28 Simchen E, Sprung CL, Galai N, *et al.* Survival of critically ill patients hospitalized in and out of intensive care units under paucity of intensive care unit beds. *Crit Care Med* 2004;**32**:1654–61.

29 Coleman MP, Forman D, Bryant H, *et al.* Cancer survival in Australia, Canada, Denmark, Norway, Sweden, and the UK, 1995-2007 (the International Cancer Benchmarking Partnership): an analysis of population-based cancer registry data. *Lancet* 2011;**377**:127–38. doi:10.1016/S0140-6736(10)62231-3

30 Annual Quality Report 2014/15 for adult critical care. London: 2016.

31 Reay H, Arulkumaran N, Brett SJ. Priorities for future intensive care research in the UK: results of a James Lind Alliance Priority Setting Partnership. *Journal of the Intensive Care Society* 2014;**15**:288–96.

# Tables

Table 1

|  |  |  |
| --- | --- | --- |
|  | All patients (n=15,158) | |
| Age (years) | 66.8 | (17.7) |
| Sex |  |  |
| Male | 7861 | (51.9%) |
| Female | 7297 | (48.1%) |
| Sepsis diagnosis |  |  |
| Chest | 4772 | (31.5%) |
| Abdominal | 1502 | (9.9%) |
| Genito-urinary | 1037 | (6.8%) |
| Unspecified | 1985 | (13.1%) |
| Not septic | 5862 | (38.7%) |
| Organ dysfunction | 5164 | (34.1%) |
| Organ support | 870 | (5.7%) |
| Severity of illness |  |  |
| SOFA score | 3.0 | (2.0--4.0) |
| NEWS score | 6.0 | (4.0--9.0) |
| ICNARC score | 15.0 | (10.0--20.0) |
| Recommended for critical care | 2141 | (32.8%) |
| Outcome following assessment | | |
| Ward care with treatment limits | 2141 | (14.1%) |
| Active ward care | 9471 | (63.5%) |
| Immediate critical care | 3375 | (22.3%) |
| Critical care admission |  |  |
| Prompt (within 4 hours) | 2593 | (17.1%) |
| During 7-day follow-up | 5071 | (33.5%) |
| Mortality |  |  |
| 7-day | 2708 | (17.9%) |
| 28-day | 4281 | (28.2%) |
| 90-day | 5337 | (35.2%) |

Table 1: Characteristics of study patients. Data are presented as mean (SD), median (IQR) or number (%). ICNARC, SOFA, and NEWS refer to severity of illness scores derived from vital signs, and laboratory tests available at the time of the bedside assessment on the ward.

Table 2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Bed pressure | | | | | |  |
|  | High (0 beds or fewer) | | Medium (1 or 2 beds) | | Low (3 or more beds) | | p-value |
| Patients assessed (% of sample) | 1198 | (8%) | 3757 | (25%) | 10197 | (67%) |  |
| Ward recommendation | 401 | (33.5%) | 1280 | (34.1%) | 3636 | (35.7%) | 0.0377 |
| Pathways |  |  |  |  |  |  |  |
| Ward care with treatment limits | 172 | (14.4%) | 577 | (15.4%) | 1392 | (13.7%) | 0.0570 |
| Active ward care | 826 | (68.9%) | 2413 | (64.2%) | 6226 | (61.1%) | <0.0001 |
| Immediate critical care | 200 | (16.7%) | 767 | (20.4%) | 2579 | (25.3%) | <0.0001 |
| Critical care admission |  |  |  |  |  |  |  |
| Delay to admission (hours) | 6.0 | (3.0--17.2) | 4.0 | (1.0--11.0) | 3.0 | (1.0--9.0) | 0.0016 |
| Prompt admission (within 4 hours) | 84 | (7.0%) | 437 | (11.6%) | 1792 | (17.6%) | <0.0001 |
| During 7-day follow-up | 288 | (24.0%) | 1102 | (29.3%) | 3680 | (36.1%) | <0.0001 |
| ICNARC physiology score |  |  |  |  |  |  |  |
| at ward assessment | 15.0 | (10.0--20.0) | 15.0 | (10.0--20.0) | 15.0 | (10.0--20.0) | 0.7328 |
| increase pending admission | 4.0 | (-2.0--10.2) | 3.0 | (-3.0--9.0) | 3.0 | (-3.0--8.0) | 0.0100 |
| 7-day mortality |  |  |  |  |  |  |  |
| Overall | 224 | (18.7%) | 692 | (18.4%) | 1791 | (17.6%) | 0.1717 |
| Without critical care admission | 166 | (13.9%) | 467 | (12.4%) | 1062 | (10.4%) | <0.0001 |

Table 2: Effect of bed pressure following the bedside assessment on the recommendation made for critical care, the decision to admit, the timing of that admission, and the change in physiological severity between assessment and admission. Overall 7-day mortality, and deaths without critical care are also reported. Trends are tested using the Cochrane-Armitage test for categorical outcomes, and by evaluating continuous variables in a linear regression model.

Table 3

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Immediately accepted | | | Prompt admission (within 4 hours) | | |
|  | Odds ratio (95% CI) | | p-value | Odds ratio (95% CI) | | p-value |
| Age category (years) |  |  |  |  |  |  |
| 18-39 | Reference | | | | | |
| 40-59 | 0.89 | (0.76--1.04) | 0.152 | 0.86 | (0.67--1.10) | 0.228 |
| 60-79 | 0.76 | (0.66--0.89) | <0.001 | 0.80 | (0.67--0.95) | 0.011 |
| 80+ | 0.51 | (0.43--0.60) | <0.001 | 0.62 | (0.50--0.76) | <0.001 |
| Male | 1.02 | (0.94--1.12) | 0.592 | 1.14 | (1.00--1.30) | 0.057 |
| Sepsis diagnosis |  |  |  |  |  |  |
| Not septic | Reference | | | | | |
| Unspecified sepsis | 1.12 | (0.98--1.30) | 0.103 | 0.89 | (0.72--1.11) | 0.322 |
| Genito-urinary sepsis | 1.11 | (0.92--1.34) | 0.262 | 1.08 | (0.82--1.43) | 0.595 |
| Abdominal sepsis | 1.37 | (1.18--1.59) | <0.001 | 0.83 | (0.65--1.05) | 0.124 |
| Chest sepsis | 1.25 | (1.12--1.40) | <0.001 | 1.13 | (0.96--1.34) | 0.133 |
| Pre-existing organ support | 1.83 | (1.55--2.16) | <0.001 | 1.32 | (1.05--1.67) | 0.019 |
| ICNARC physiology score | 1.07 | (1.06--1.08) | <0.001 | 1.02 | (1.01--1.03) | <0.001 |
| Reported to be peri-arrest | 6.32 | (5.18--7.70) | <0.001 | 1.98 | (1.55--2.54) | <0.001 |
| Assessment timing |  |  |  |  |  |  |
| Out-of-hours (7pm-7am) | 1.47 | (1.33--1.61) | <0.001 | 1.79 | (1.56--2.07) | <0.001 |
| Saturday/Sunday | 1.15 | (1.04--1.27) | 0.006 | 1.06 | (0.91--1.23) | 0.467 |
| Winter (Dec-Mar) | 1.19 | (1.07--1.33) | 0.002 | 0.76 | (0.64--0.90) | 0.001 |
| Bed pressure |  |  |  |  |  |  |
| Low (3 or more beds) | Reference | | | | | |
| Medium (1-2 beds) | 0.89 | (0.79--1.00) | 0.055 | 0.58 | (0.49--0.70) | <0.001 |
| High (0 or fewer beds) | 0.72 | (0.59--0.88) | 0.001 | 0.27 | (0.19--0.37) | <0.001 |
| Accepted at initial visit |  |  |  | 69.07 | (58.75--81.21) | <0.001 |
| Hospital level variation |  |  |  |  |  |  |
| Median Odds Ratio | 2.11 | (1.81--2.42) |  | 1.89 | (1.63--2.21) |  |

Table 3: Association between patient level predictors, and decision to admit to critical care (left hand column) or prompt admission (right hand column) in a multi-level logistic regression model with patients nested within hospitals. The Median Odds Ratio (MOR) indicates the median difference in the baseline odds between patients from any two randomly selected hospitals, and allows the effect of the hospital to be compared on the same scale as patient level predictors. The decision to admit is included in the model of prompt admission.

Table 4

|  |  |  |  |
| --- | --- | --- | --- |
|  | Hazard ratio (95% CI) | | p-value |
| Age category (years) |  |  |  |
| 18-39 | *Reference* | | |
| 40-59 | 2.05 | (1.67--2.55) | <0.001 |
| 60-79 | 3.28 | (2.65--4.19) | <0.001 |
| 80+ | 5.00 | (4.10--6.49) | <0.001 |
| Male | 1.08 | (0.99--1.17) | 0.066 |
| Sepsis diagnosis |  |  |  |
| Not septic | *Reference* | | |
| Unspecified sepsis | 1.15 | (1.02--1.32) | 0.050 |
| Genito-urinary sepsis | 0.69 | (0.57--0.81) | <0.001 |
| Abdominal sepsis | 0.97 | (0.85--1.10) | 0.368 |
| Chest sepsis | 1.29 | (1.19--1.41) | <0.001 |
| Pre-existing organ support | 1.07 | (0.96--1.22) | 0.183 |
| ICNARC physiology score |  |  |  |
| Day 0-6 effect | 1.11 | (1.10--1.12) | <0.001 |
| Day 7+ modifier | 0.90 | (0.90--0.91) | <0.001 |
| Reported to be peri-arrest |  |  |  |
| Day 0-6 effect | 1.43 | (1.14--1.81) | 0.010 |
| Day 7+ modifier | 0.76 | (0.50--1.03) | 0.110 |
| Assessment timing |  |  |  |
| Out-of-hours (7pm-7am) | 1.04 | (0.94--1.14) | 0.256 |
| Saturday/Sunday | 1.08 | (0.98--1.17) | 0.099 |
| Winter (Dec-Mar) | 1.01 | (0.91--1.12) | 0.413 |
| Bed pressure |  |  |  |
| Low (3 or more beds) | *Reference* | | |
| Medium (1-2 beds) | 1.03 | (0.93--1.14) | 0.305 |
| High (0 or fewer beds) | 1.03 | (0.90--1.17) | 0.352 |
| Hospital level variation |  |  |  |
| Median Hazard Ratio | 1.28 | (1.22--1.34) |  |

Table 4: Association between patient level predictors, and 90-day survival with patients nested within hospitals. The Median Hazard Ratio (MHR) indicates the median difference in the baseline hazard between patients from any two randomly selected hospitals, and allows the effect of the hospital to be compared on the same scale as patient level predictors.

# Figures

Figure 1

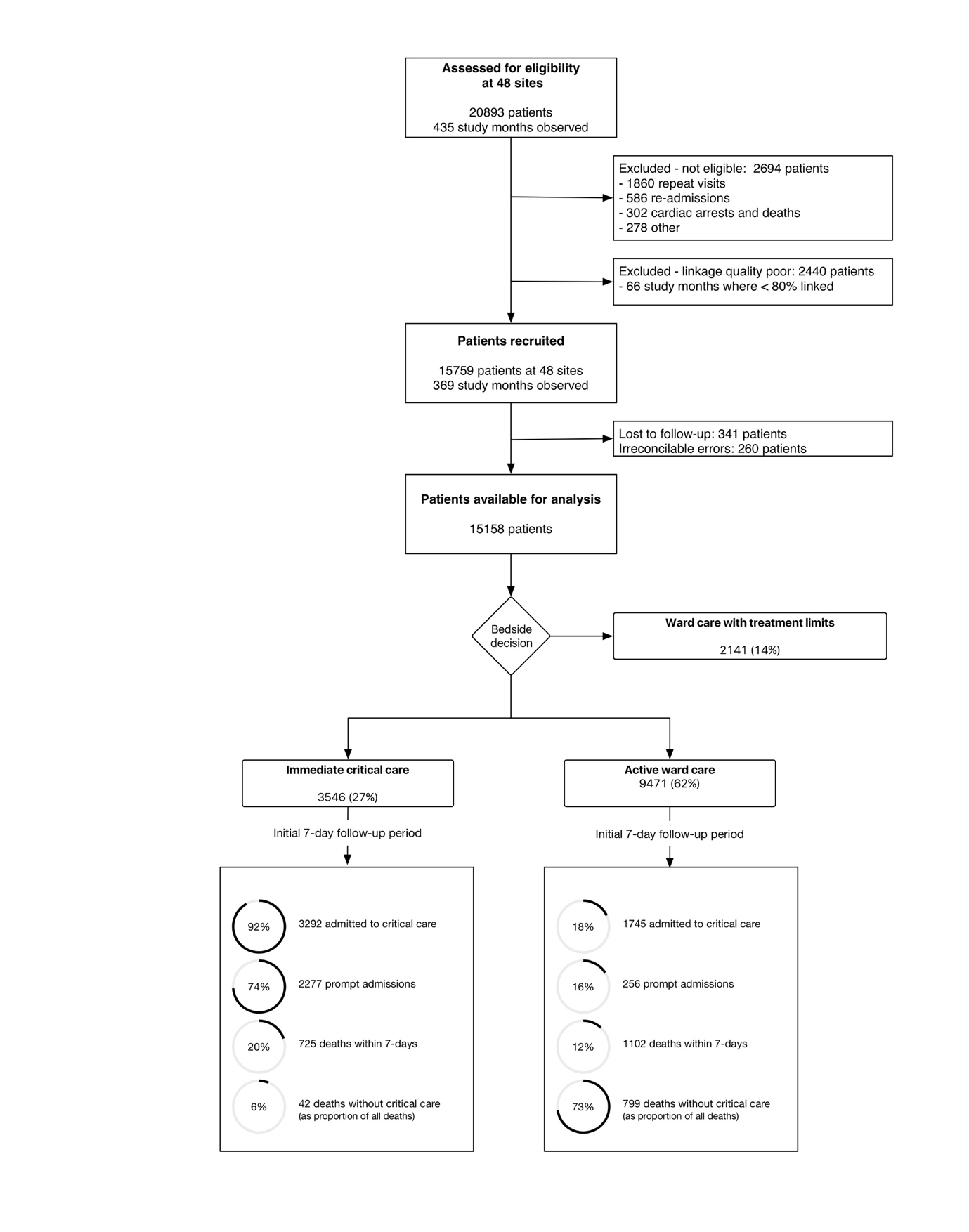


Figure 1: Ward referrals assessed for eligibility at participating hospitals, reasons for exclusion, and the decision made on ward assessment by critical care with first week outcomes.

Figure 2

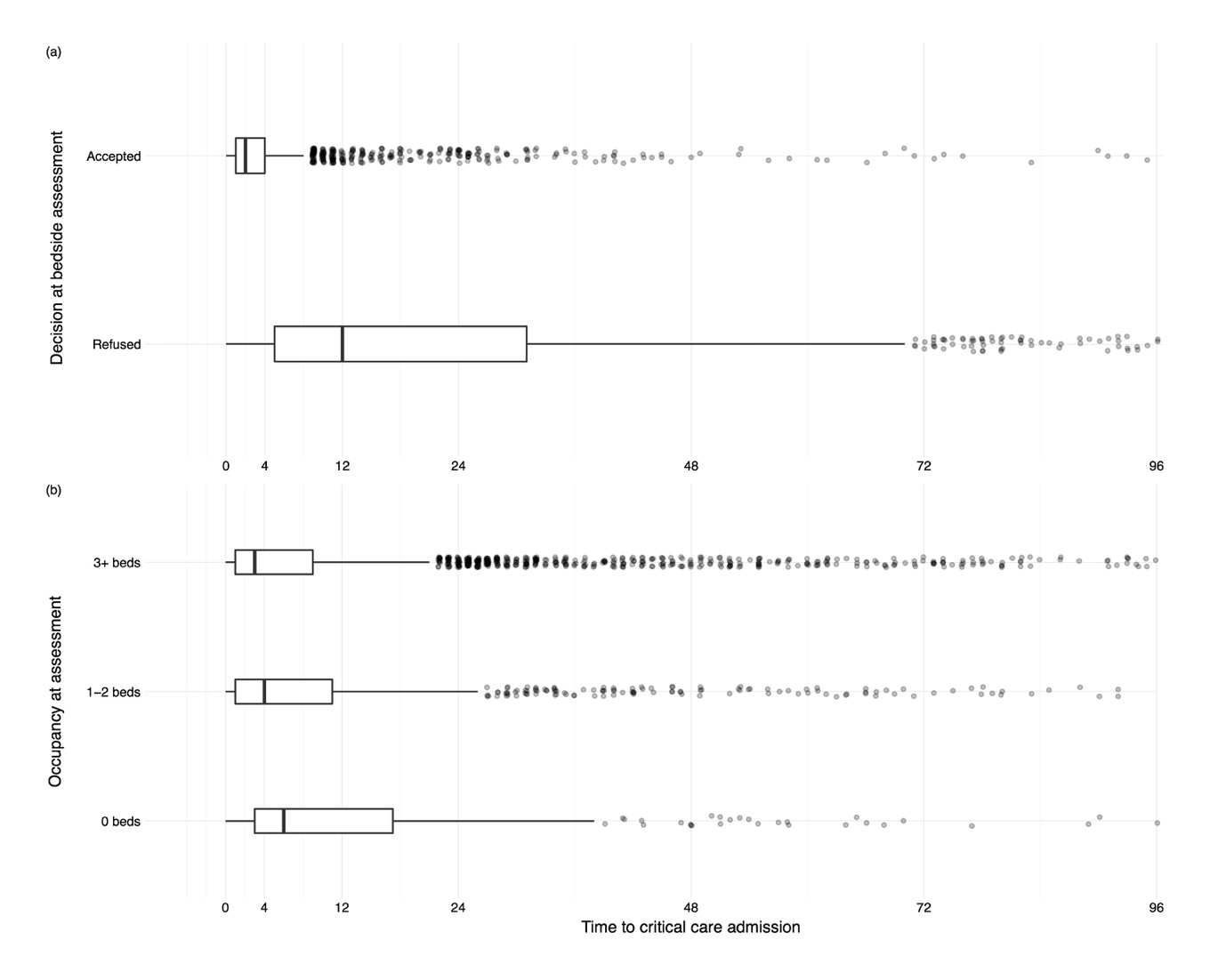


Figure 2: Time to admission to critical care following bedside assessment for the deteriorating ward patient by (A) the decision at the bedside assessment, and (B) by critical care occupancy.

# Supplementary Tables

## Supplementary Table 1

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | All patients | | |  | NEWS High Risk patients | | |
|  | IRR (95%CI) | | p-value |  | IRR (95%CI) | | p-value |
| Teaching hospital | 1.085 | (1.014, 1.161) | 0.018 |  | 1.113 | (1.027, 1.207) | 0.009 |
| Admissions (per 1,000 overnight admissions) | 1.003 | (1.002, 1.004) | <0.001 |  | 1.005 | (1.004, 1.006) | <0.001 |
| Critical care outreach provision |  |  |  |  |  |  |  |
| None | 0.558 | (0.486, 0.640) | <0.001 |  | 0.631 | (0.536, 0.743) | <0.001 |
| Less than 7 days/week | 0.574 | (0.534, 0.616) | <0.001 |  | 0.628 | (0.577, 0.685) | <0.001 |
| 7 days/week | 0.697 | (0.655, 0.742) | <0.001 |  | 0.726 | (0.672, 0.783) | <0.001 |
| 24 hours/day 7 days/week | Reference | | |  | Reference | | |
| Critical care beds | 0.988 | (0.984, 0.992) | <0.001 |  | 0.989 | (0.984, 0.994) | <0.001 |
| Winter (Dec-Mar) | 1.091 | (1.031, 1.155) | 0.003 |  | 1.183 | (1.105, 1.266) | <0.001 |
| Weekend | 0.83 | (0.800, 0.860) | <0.001 |  | 0.867 | (0.818, 0.918) | <0.001 |
| Baseline incidence | 1.655 | (1.531, 1.788) |  |  | 0.557 | (0.523, 0.593) |  |

Supplementary Table 1: Baseline incidence (patients referred to and assessed by critical care per day) for participating hospitals for all patients, and for the subgroup meeting the National Early Warning Score (NEWS) High Risk criteria, and hospital and timing level factors affecting the rate.

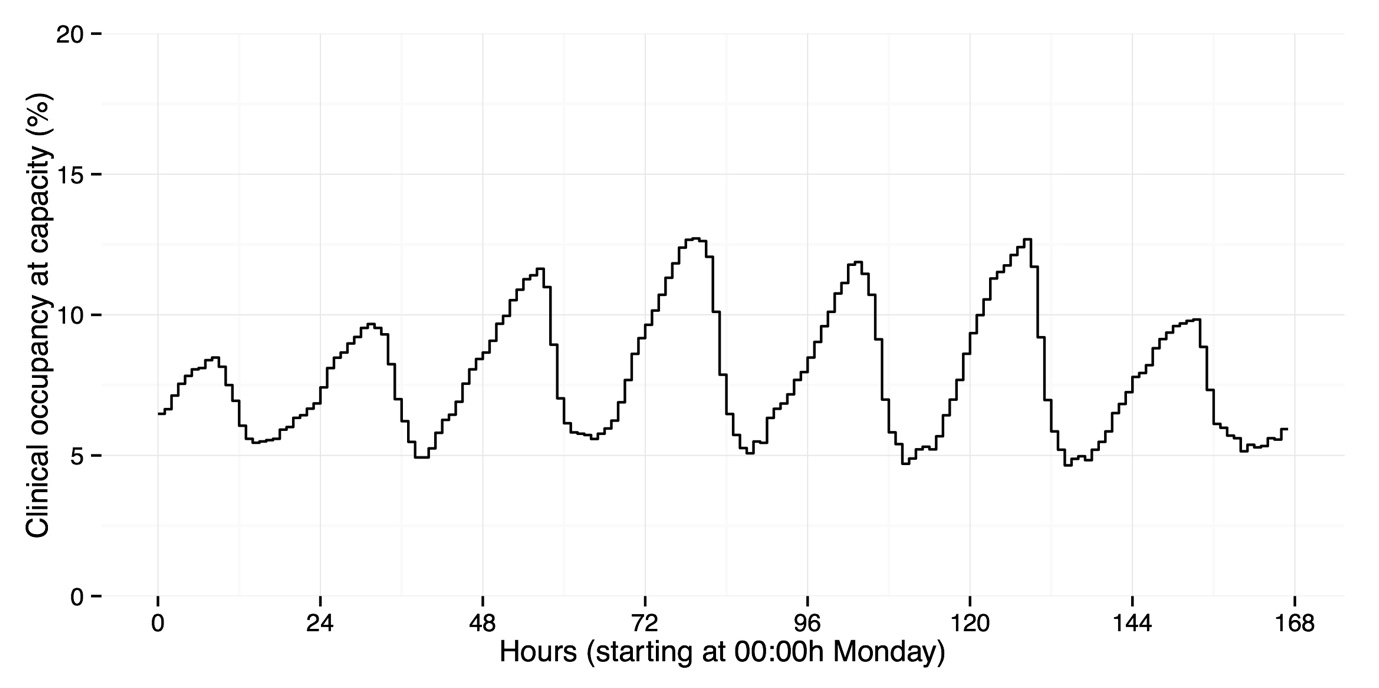
Supplementary Table 2

|  |  |  |  |
| --- | --- | --- | --- |
|  | Hazard ratio (95% CI) | | p-value |
| Age category (years) |  |  |  |
| 18-39 | *Reference* | | |
| 40-59 | 1.98 | (1.65--2.37) | <0.001 |
| 60-79 | 3.07 | (2.59--3.64) | <0.001 |
| 80+ | 4.44 | (3.74--5.28) | <0.001 |
| Male | 1.08 | (1.01--1.15) | 0.016 |
| Sepsis diagnosis |  |  |  |
| Not septic | *Reference* | | |
| Unspecified sepsis | 1.14 | (1.03--1.26) | 0.011 |
| Genito-urinary sepsis | 0.67 | (0.57--0.77) | <0.001 |
| Abdominal sepsis | 0.96 | (0.85--1.08) | 0.465 |
| Chest sepsis | 1.30 | (1.21--1.40) | <0.001 |
| Pre-existing organ support | 1.10 | (0.98--1.24) | 0.110 |
| ICNARC physiology score |  |  |  |
| Day 0-6 effect | 1.07 | (1.06--1.07) | <0.001 |
| Day 7+ modifier | 0.97 | (0.96--0.98) | <0.001 |
| Reported to be peri-arrest |  |  |  |
| Day 0-6 effect | 1.62 | (1.38--1.90) | <0.001 |
| Day 7+ modifier | 0.62 | (0.48--0.80) | <0.001 |
|  |  |  |  |
| Assessment timing |  |  |  |
| Out-of-hours (7pm-7am) | 0.97 | (0.90--1.03) | 0.294 |
| Saturday/Sunday | 1.06 | (0.99--1.14) | 0.102 |
| Winter (Dec-Mar) | 1.04 | (0.97--1.12) | 0.253 |
| Bed pressure |  |  |  |
| Low (3 or more beds) | *Reference* | | |
| Medium (1-2 beds) | 1.11 | (0.99--1.25) | 0.086 |
| High (0 or fewer beds) | 1.07 | (1.00--1.15) | 0.060 |

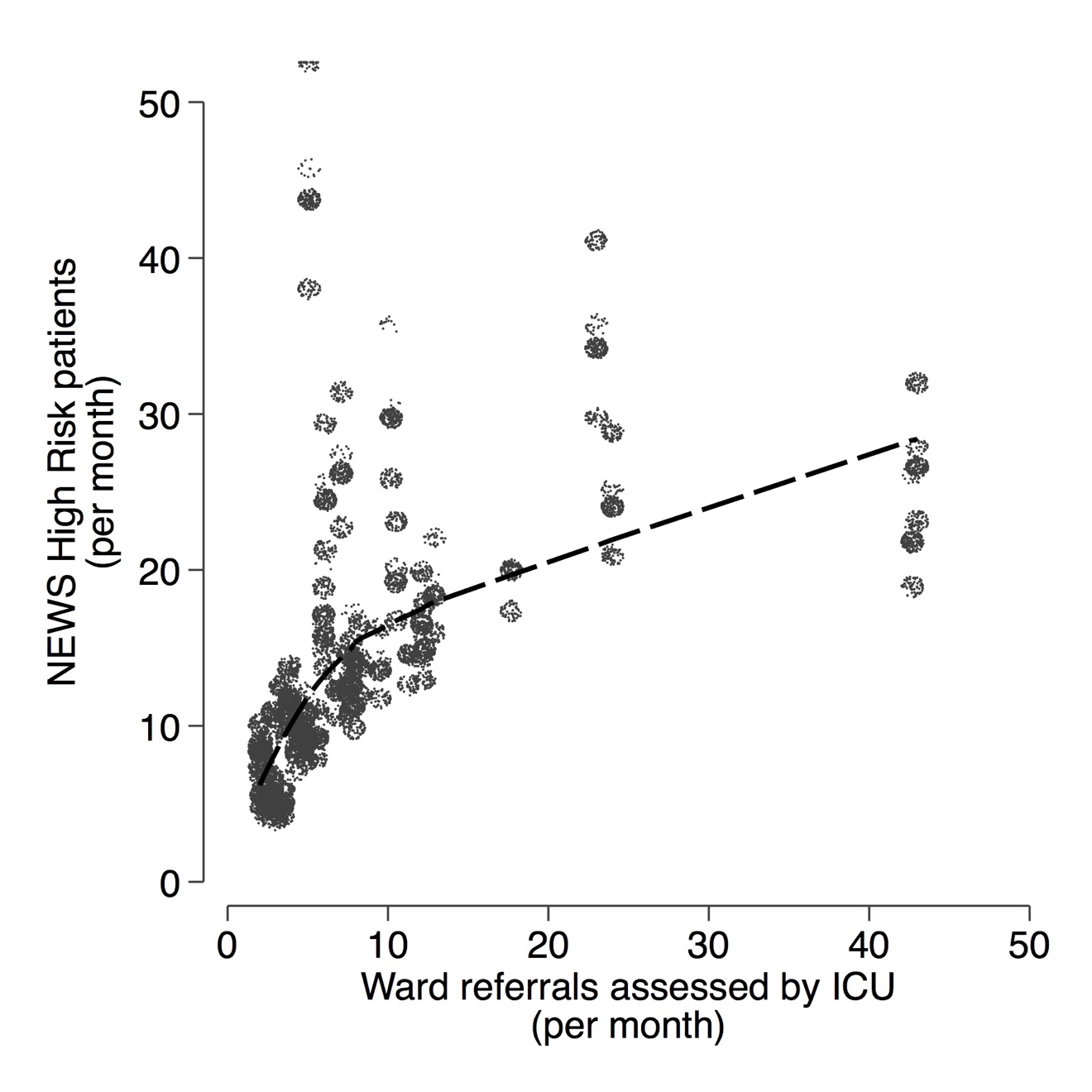
Supplementary Table 2: Association between patient level predictors, and 90-day survival in a single level model to permit evaluation of effects that might be mediated, rather than confounded by, the hospital. For example, if poor survival occurs because a hospital runs critical care at full capacity then the effect of bed pressure would be underestimated in a multi-level model that attributed some of the mortality difference to the hospital effect instead.

# Supplementary Figures

Supplementary Figure 1

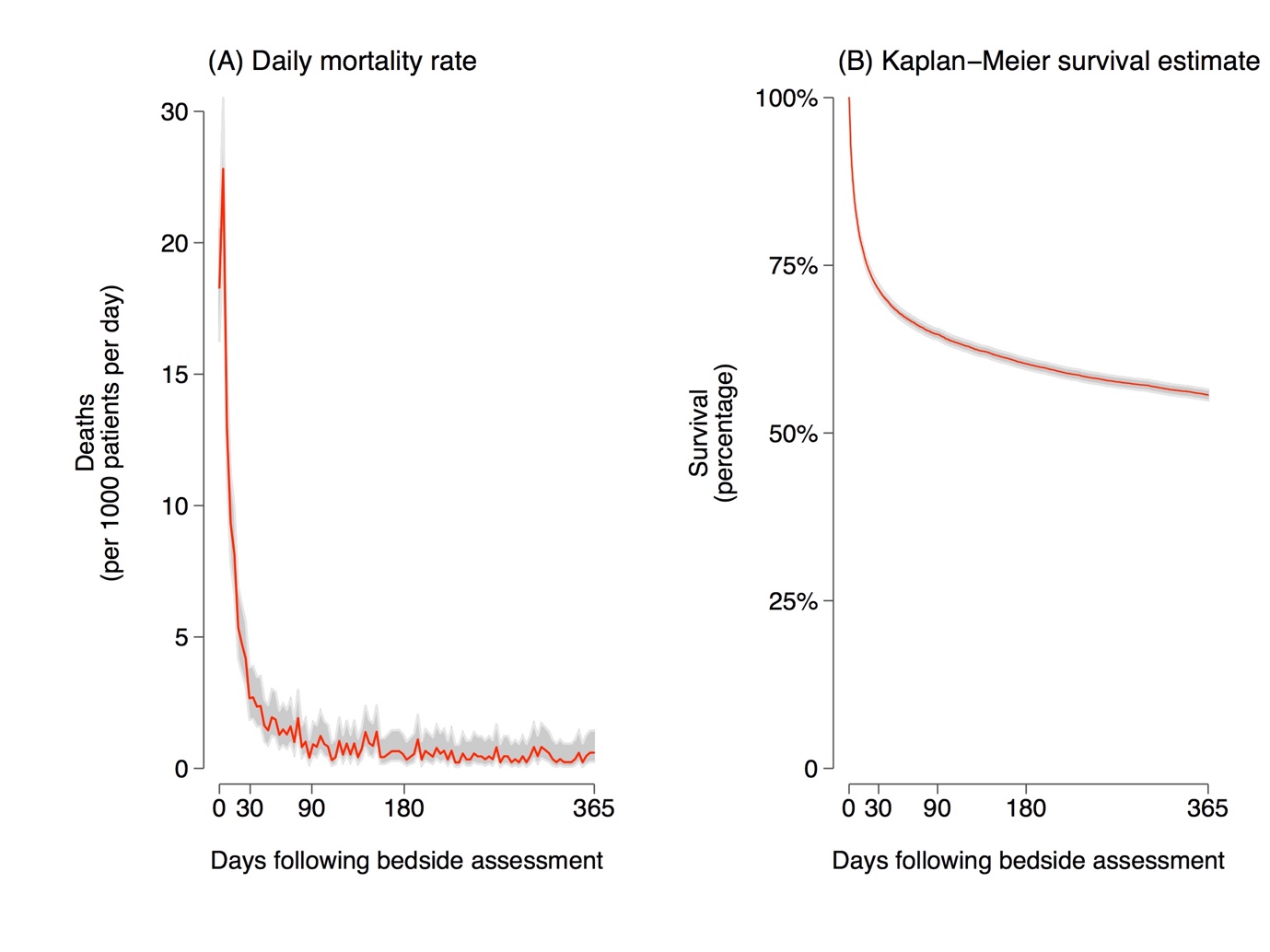
  
Supplementary Figure 1: Mean proportion of units fully occupied by time of day and day of week averaged over all periods and units observed in the study.

Supplementary Figure 2



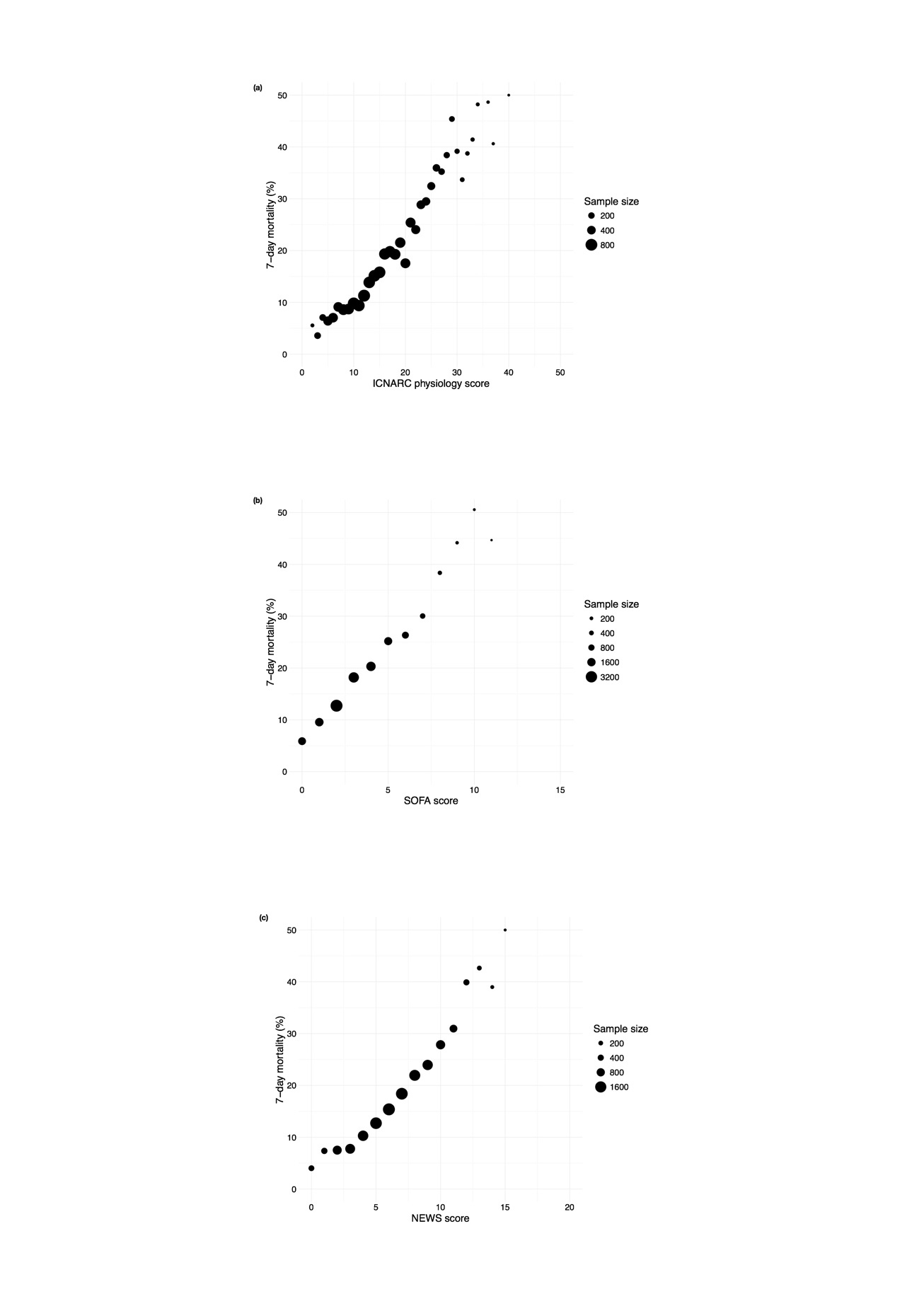
Supplementary Figure 2: Patients reported meeting the National Early Warning Score (NEWS) High Risk criteria plotted against all ward referrals to the ICU (per month) suggesting that as case finding increases the proportion of high risk cases found falls.

Supplementary Figure 3



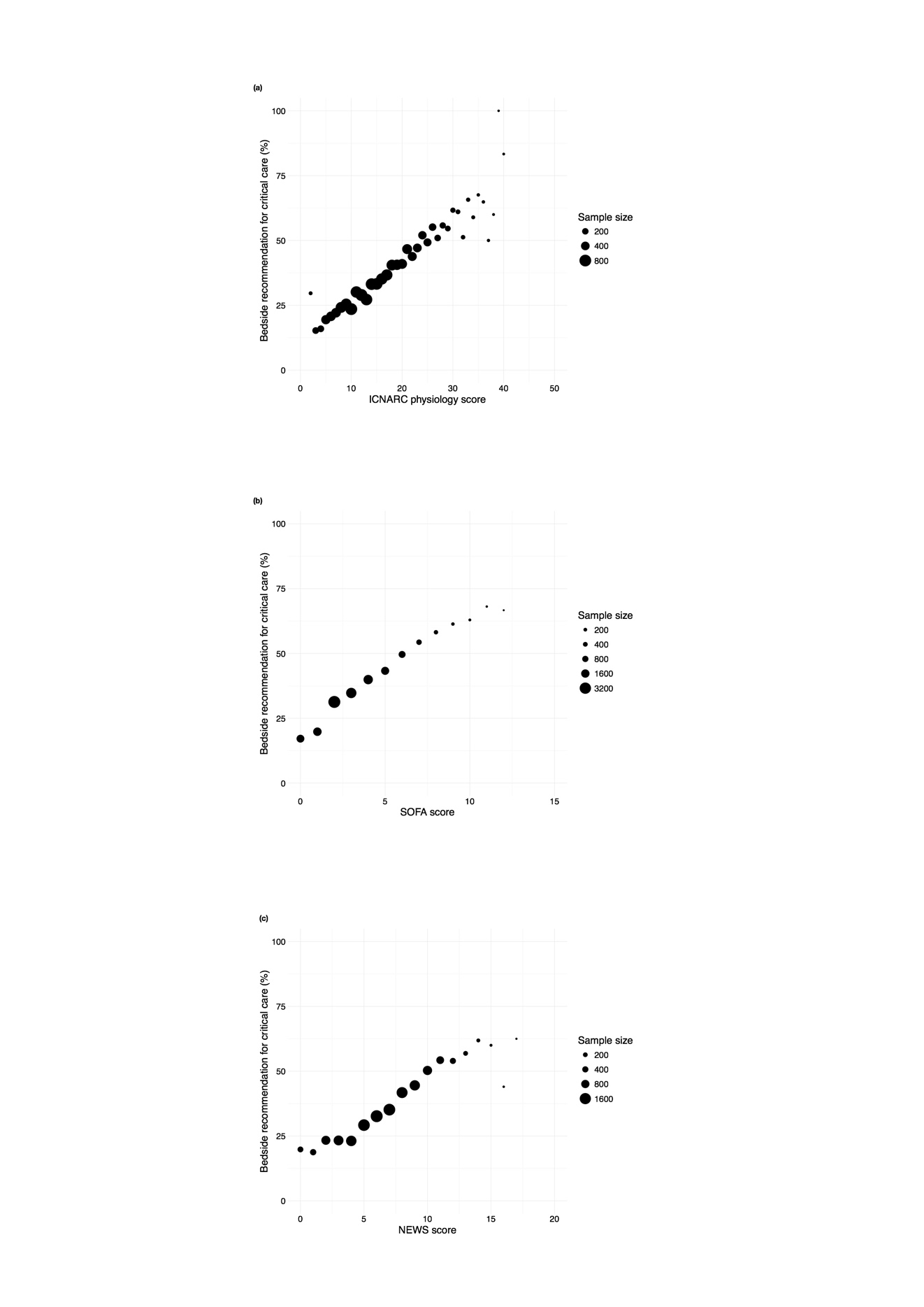
Supplementary Figure 3: Daily mortality rate (a) and survival curve (b) for all patients showing that the period of greatest risk immediately follows referral, and and then falls rapidly.

Supplementary Figure 4



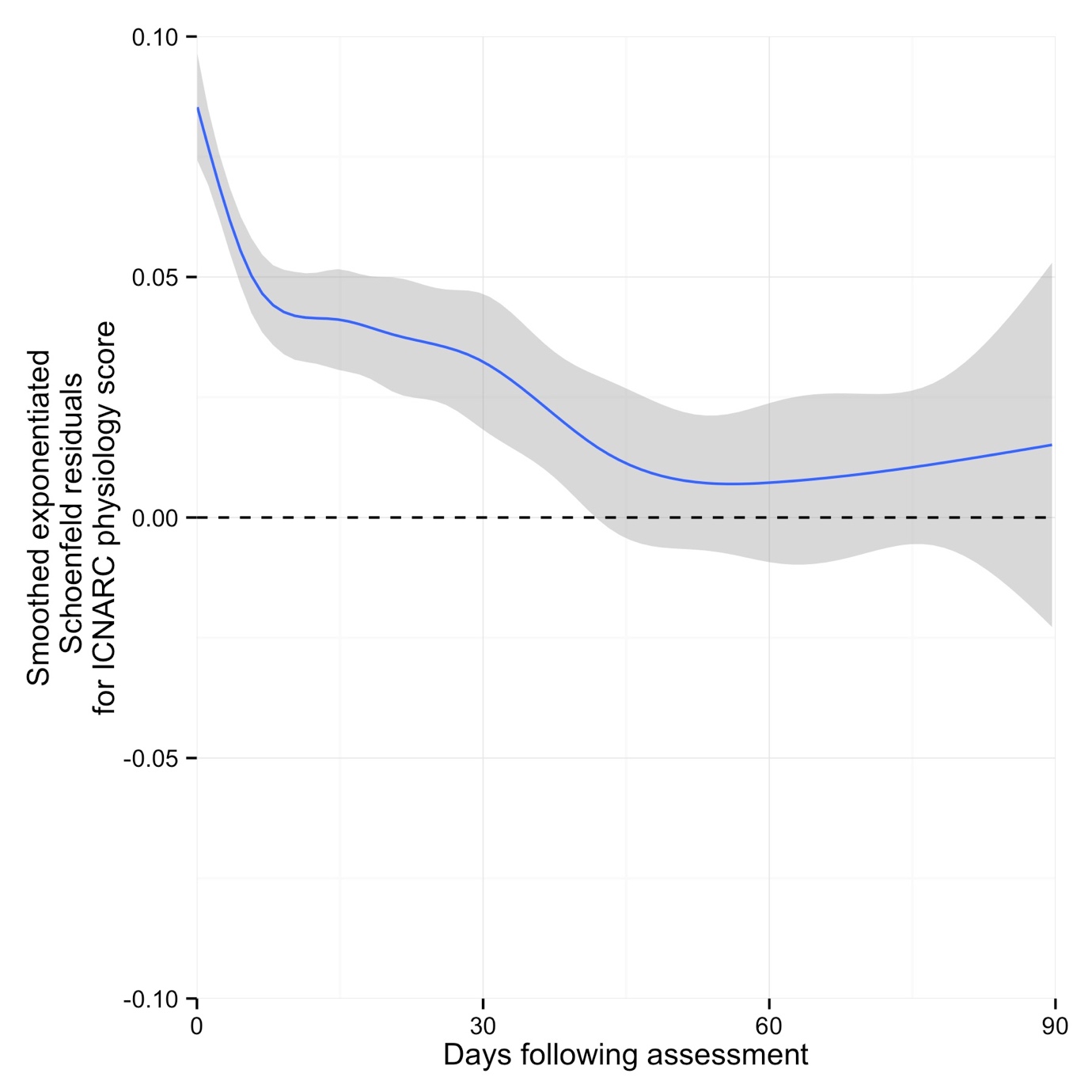
Supplementary Figure 4: Relationship between measured severity of illness and acute (7-day) mortality for (a) the ICNARC physiology score (b) the SOFA score, and (c) the NEWS score.

Supplementary Figure 5



Supplementary Figure 5: Relationship between measured severity of illness and the recommendation for critical care made at the ward assessment for (a) the ICNARC physiology score (b) the SOFA score, and (c) the NEWS score.

Supplementary Figure 6



Supplementary Figure 6: Plots of smoothed exponentiated standardised Schoënfeld residuals for the ICNARC physiology score in the 90-day survival model demonstrating that the proportional hazards assumption is violated because of differential early effect on survival.