CRITICAL CARE

Association between day and time of admission to critical care and acute hospital outcome for unplanned admissions to adult general critical care units: cohort study exploring the 'weekend effect'

N. Arulkumaran[1], D. A. Harrison[2] and S. J. Brett[1],*

[1]Centre for Perioperative Medicine and Critical Care Research, Imperial College Healthcare NHS Trust, Hammersmith Hospital, Du Cane Road, London W12 0HS, UK and [2]Intensive Care National Audit and Research Centre, Napier House, 24 High Holborn, London WC1V 6AZ, UK

*Corresponding author. Department of Anaesthetics and Intensive Care, Hammersmith Hospital, Du Cane Road, London W12 0HS, UK. E-mail: stephen.brett@imperial.ac.uk

Abstract

Background. We aimed to identify any association between day and time of admission to critical care and acute hospital outcome.

Methods. We conducted a cohort study using prospectively collected data from the national clinical audit of adult critical care. We included 195 428 unplanned admissions from 212 adult general critical care units in England, Wales and Northern Ireland, between April 1, 2013 and March 31, 2015 in the analysis.

Results. Hourly admission rates for unplanned admissions varied more than three-fold during the 24 h cycle. Overall acute hospital mortality was 26.8%. Before adjustment, acute hospital mortality was similar between weekends and weekdays but was significantly lower for admissions at night compared with the daytime (-3.4%, -3.8 to -3.0%; $P<0.001$). After adjustment for casemix, there remained no difference between weekends and weekdays (-0.0%, -0.4 to $+0.3\%$; $P=0.87$) or between nighttime and daytime (-0.2%, -0.5 to $+0.1\%$; $P=0.21$). Delays in admission were reported for 4.3% of admissions and were slightly more common during weekdays than weekends and in the daytime than at night. Delayed admission was associated with a small increase in acute hospital mortality, but adjusting for this did not affect the estimates of the effect of day and time of admission.

Conclusions. The day of week and time of admission have no influence on patient mortality for unplanned admissions to adult general critical care units within the UK. Ways to improve critical care and hospital systems to minimize delays in admission and potentially improve outcomes need to be ascertained in future research.

Key words: critical care; delivery of health care; mortality

Critically ill patients are a vulnerable group who benefit from timely admission to a critical care unit. Critically ill patients may present at any time of day, thus critical care unit staffing levels and resources should be adequate throughout a 24 h period, weekends,

Editor's key points

- Patients admitted to hospital outside normal working hours typically have acute illnesses that increase risk.
- Poor outcomes can occur because of underlying acute illness (casemix), reduced quality of care, or both.
- Statistical adjustment is required to account for casemix when exploring the potential impact of quality of care.
- This study could not identify a 'weekend effect' of critical care in the UK.

and holidays. A number of organizational factors are associated with patient outcome; these include improved outcomes with 'closed' models of critical care,[1] presence of dedicated intensivists (consultants with dedicated sessions in intensive care as opposed to non-specialist or generalist physicians),[2–4] high-intensity intensivist staffing,[5,6] and adequate nursing numbers.[7] Nonetheless, the number of doctors present on the critical care unit, availability of accredited intensivists, and accessibility of diagnostic and surgical services may vary at different times of day and at weekends compared with weekdays.[8] It is imperative to ascertain whether out-of-hours services are adequate to cover emergency care without any adverse impact on outcome for patients. As such, the effect of day and time of admission to the hospital or critical care unit on mortality has been the subject of recent scrutiny and controversy. Organizational factors that may contribute to variations in care throughout the working week should be identified.

A systematic review of 10 studies (eight examining nighttime admissions to critical care and six examining weekend admissions) concluded that nighttime admission was not associated with an increase in mortality, although patients admitted throughout the weekend had an increased risk of death compared with patients admitted during the week.[9] The authors acknowledged significant heterogeneity in studies, which was an inevitable consequence of pooled data from eight different countries. Differences in health-care delivery between countries limit the application to influence health-care policy within a specific country. Within the UK, the effect of day and time of admission on outcome has been examined in 56 250 critical care unit admissions from 1995 to 2000. After adjustment for casemix, neither time of day nor day of week was associated with any differences in mortality.[10]

We report an up-to-date analysis of the association between day and time of admission to critical care and hospital outcome for unplanned (emergency) admissions to adult general critical care units in the UK. The objective was to identify any current association between day and time of admission to critical care and acute hospital outcome.

Methods

The study was performed on an anonymized extract from an existing national clinical audit database and thus did not require specific National Health Service (NHS) research ethics review under current UK guidance. The study was approved by the Intensive Care National Audit and Research Centre (ICNARC) Data Access Advisory Group (approval no. DAAG 161148). The ICNARC Case Mix Programme (CMP) has approval under Section 251 of the NHS Act 2006 to process patient identifiable data without consent (approval no. PIAG 2-10(f)/2005). We registered the study on ClinicalTrials.gov (NCT02751164) and uploaded the analysis plan on April 19, 2016 before any data extraction or analysis.

Data

Data were extracted from the ICNARC CMP database. We included data from NHS adult general critical care units in England, Wales and Northern Ireland. Data from specialist units, such as neurosciences and cardiothoracic units, and standalone high-dependency units (independent high-dependency care units without the ability to provide facilities for invasive mechanical ventilation) were excluded. We included admissions throughout a 2 yr period from April 1, 2013 to March 31, 2015. This time period was selected to reflect current clinical practice and address the study question with a high level of precision, and thus no power calculation was undertaken.

We included all patients aged 16 yr or older with unplanned admission to the critical care unit (i.e. excluding admissions from an operating theatre after elective or scheduled surgery, planned local medical admissions, planned transfers, and repatriations). Exclusion criteria were readmission of the same patient to the critical care unit during the same acute hospital stay, transfer from another critical care unit, transfer from another acute hospital, admission for organ donation, and if there were missing data on time of admission, acute hospital outcome, or on key confounders (age, location before admission, primary reason for admission, all physiological variables). For patients who were admitted to the critical care unit more than once during the same acute hospital stay, only the first admission was included to ensure that outcomes were independent.

The primary exposure variable was the day and time of admission to the critical care unit, dividing the week into 14 time periods. It was not possible to correct for any possible confounders relating to variation in organizational factors; a pragmatic approach of dividing the day into routine working hours (08.00–17.59 h) and out of hours (18.00–07.59 h the next day) for both weekdays (Monday–Friday) and weekends (Saturday–Sunday) was adopted. The selected time frames were identified to represent approximate working schedules of medical staff on shift work patterns in UK critical care units. The primary outcome was acute hospital mortality, defined as death before ultimate discharge from acute hospital.

The key potential confounders, identified a priori and adjusted for in the analysis, included age, severe conditions in the past medical history (APACHE II illness severity score definitions), prior functional dependency (categorized as none, some, or total assistance with activities of daily living), number of days from hospital admission to critical care unit admission, location before admission, cardiopulmonary resuscitation (CPR) within 24 h before admission to critical care, primary reason for admission to critical care (by body system), and acute severity of illness (ICNARC Physiology Score).[11] Continuous data were entered as linear terms. Both age and physiology score have previously been shown to have approximately linear effects in the development of the ICNARC model. Details on confounding factors are found in the statistical analysis plan (Appendix 1). Long-term outcome data were not available.

Delayed admission to the critical care unit was also explored as a potential mediator of the effect of day and time of admission on outcome. Delayed admission to the critical care unit was defined as the patient for admission remaining outside the critical care unit for at least 1 h despite a decision to admit being made and documented in the patient notes after formal referral and agreement by appropriate staff with authority to admit to the unit. The duration of the delay was defined as the interval between the time of the documented

decision to admit to the actual time of admission. Delayed admissions were further subcategorized as a delay of >4 h *vs* ≤4 h. Trained data collectors gathered these data as part of routine data collection.

Missing data

Based on previous analyses of the ICNARC CMP database, levels of missing data were anticipated to be very low. Patients missing the primary outcome or key confounders (age, location before admission, or primary reason for admission) were therefore excluded from the analysis. Patients missing other binary or categorical confounders or mediators were assumed to be in the lowest risk category (i.e. no severe conditions in past medical history, no assistance with daily activities, no CPR, and no delay). Following standard approaches, missing physiological parameters were assumed to be normal and assigned zero points in the ICNARC Physiology Score (except for patients missing all physiology, who were excluded).[11]

Statistical analyses

Continuous data are presented as the mean (SD) or median (interquartile range) as stated; categorical data are presented as the number (%) within each category. In accordance with reporting guidelines, descriptive tables were not subjected to statistical testing.[12]

We fitted three multilevel logistic regression models on the outcome of acute hospital mortality (each including a random effect of critical care unit), as follows: (i) an unadjusted model with a single covariate of day and time of admission; (ii) an adjusted model, adjusting for the key potential confounders identified above; and (iii) a model including an additional covariate of delayed admission (no delay, ≤4 h delay, or >4 h delay) to evaluate mediation of the effect of day and time of admission by delay.

The output of each model is presented as odds ratios with 95% confidence intervals (CIs) and *P*-values. The variation in acute hospital mortality by day and time of admission is presented as the post-estimation marginal predicted mortality (holding all other covariates at the values observed in the data set, and with zero random effect). The marginal predicted mortality for a given day and time of admission category provides an estimate of the mortality that would be expected (in an average critical care unit) if all patients in the data set had been admitted during that time period.

We conducted the following hypothesis tests on each model: (i) the global effect of day and time of admission (test of homogeneity); (ii) a comparison of weekend (Saturday 08.00 h–Monday 07.59 h) *vs* weekday (Monday 08.00 h–Saturday 07.59 h); (iii) a comparison of nighttime *vs* daytime; (iv) a comparison of weekend daytime *vs* weekday daytime; and (v) a comparison of weekend nighttime (Saturday–Sunday 18.00–07.59 h the next day) *vs* weekday nighttime (Monday–Friday 18.00–07.59 h the next day).

Results of the hypothesis tests are reported as the *P*-value (Wald test) and the absolute risk difference with 95% CI (based on linear combinations of the marginal predicted mortalities).

All analyses were performed with Stata/SE version 13.0 (StataCorp LP, College Station, Texas, USA).

Patient involvement

The choice of research question was informed by a recent James Lind Alliance Priority Setting Partnership, which identified 'How can patients who may benefit from intensive care be identified early and admitted to the ICU [intensive care unit] at the right time?' as the highest priority uncertainty to address in critical care research.[13] No patients were involved in developing plans for design, implementation of the study, or advising on interpretation and writing up of results.

Results

Between April 1, 2013 and March 31, 2015, 300 469 admissions to 216 adult general critical care units were recorded in the ICNARC CMP. Of these, 1397 (0.5%) were of patients <16 yr old, and 78 797 (26.2%) admissions were planned. Of the 220 275 unplanned admissions, 24 874 (11.3%) met exclusion criteria, leaving 195 428 admissions in the final analysis (Fig. 1). Exclusions because of missing data are reported in Fig. 1. As the missing rate was only 0.5% (<0.1% for exposure, 0.3% for outcome, and 0.2% for confounders), we have not broken these down by exposure category.

The mean age of patients admitted was 60 yr, with a mean APACHE II score of 17 (Table 1). Approximately one-quarter of patients had some degree of prior dependency. Overall, 4% of patients received in-hospital CPR during the 24 h before admission and a further 4% had out-of-hospital CPR. The greatest proportion of patients was admitted with a primary respiratory pathology (25.5% of all admissions).

Hourly admission rates for unplanned admissions varied more than three-fold during the 24 h cycle, with the highest rate at 19.00 h and the lowest around 08.00 h. The evening peaks were lower at the weekend than during the week (Fig. 2). Overall, similar proportions of patients were admitted to the critical care unit from the ward/obstetric area/intermediate care area and from the emergency department (38 and 37%, respectively) with the remaining 25% admitted from the operating theatre (after emergency or urgent surgery). The proportions of admissions from different prior locations varied during the week, with admissions from the ward most common during weekday daytimes, admissions from the emergency department most common during weekend nights, and admissions from the operating theatre most common during weekday nights.

Delays in admission >1 h were reported for 4.3% of admissions. Delays were slightly more common during weekdays than the weekend and slightly more common in the daytime than at night. Of those patients presenting between 08.00 and 17.59 h on a weekday, 4.7% experienced delayed admission compared with 3.5% of patients on weekends from 18.00 to 07.59 h the next day.

Overall, 18.8% of patients died within the critical care unit and 26.8% of patients died within hospital. Age, severe conditions in the past medical history, prior dependency, number of days from hospital admission to critical care unit admission, location before admission, CPR within 24 h before admission, primary reason for admission, and acute severity of illness (ICNARC Physiology Score) were all independent risk factors for acute hospital mortality (Table 2). The variables included in the analysis were selected on the basis that they predict mortality in the ICNARC CMP. The population in this study represents a significant subset of the ICNARC CMP, and thus, this finding is expected. Delays in admission to the critical care unit of up to 4 h (odds ratio 1.08, 95% CI 1.10–1.17) and delays of >4 h (1.17, 1.04–1.32) were associated with an increased risk of death (P=0.004).

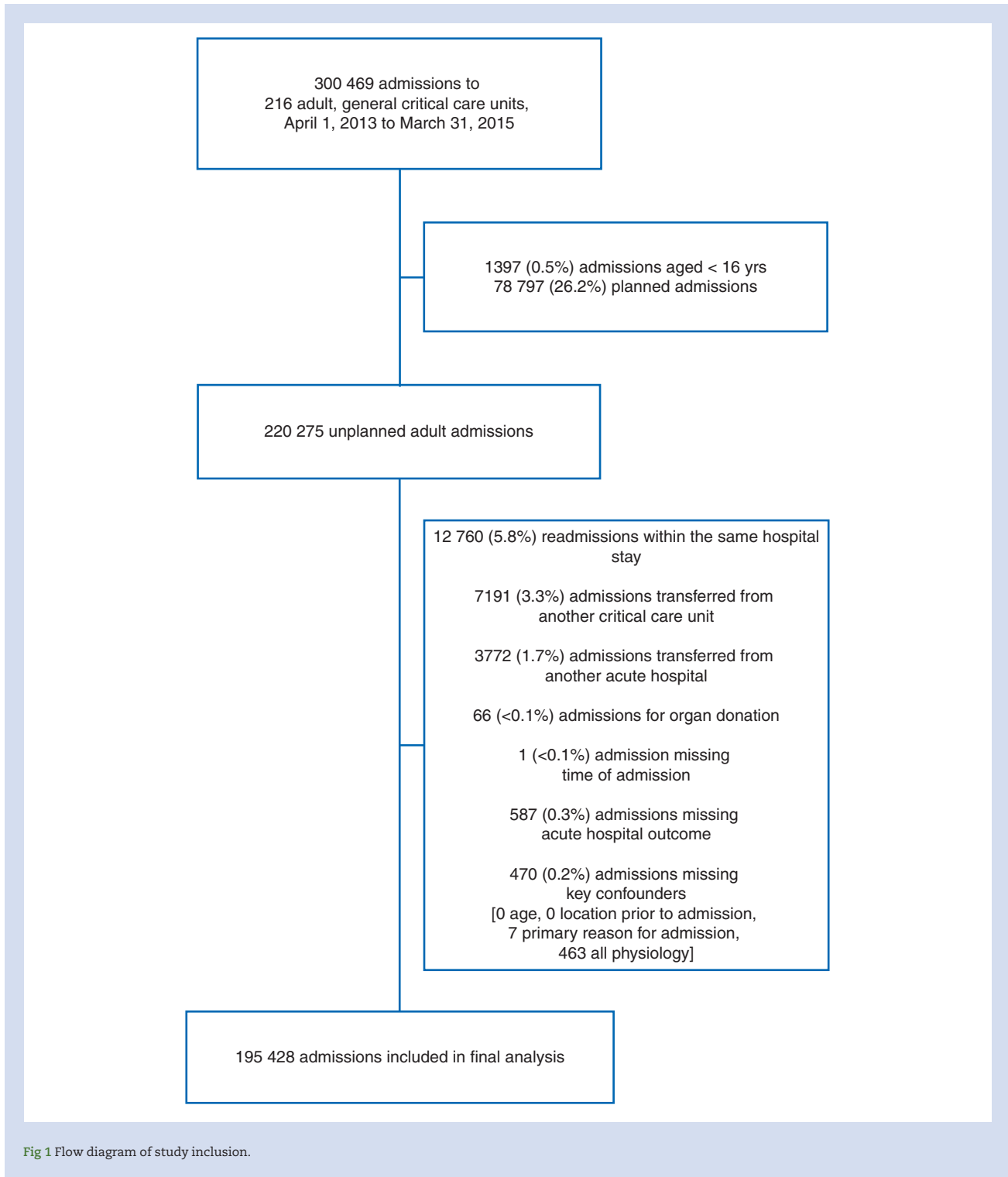Before adjustment (Model 1), acute hospital mortality was not significantly different between weekends and weekdays

300 469 admissions to
216 adult, general critical care units,
April 1, 2013 to March 31, 2015

1397 (0.5%) admissions aged < 16 yrs
78 797 (26.2%) planned admissions

220 275 unplanned adult admissions

12 760 (5.8%) readmissions within the same hospital stay

7191 (3.3%) admissions transferred from another critical care unit

3772 (1.7%) admissions transferred from another acute hospital

66 (<0.1%) admissions for organ donation

1 (<0.1%) admission missing time of admission

587 (0.3%) admissions missing acute hospital outcome

470 (0.2%) admissions missing key confounders
[0 age, 0 location prior to admission, 7 primary reason for admission, 463 all physiology]

195 428 admissions included in final analysis

Fig 1 Flow diagram of study inclusion.

(absolute risk difference for weekend *vs* weekday +0.3%, 95% CI −0.1 to +0.8%; P=0.15; Table 3). However, mortality was significantly lower for admissions at night compared with the daytime (absolute risk difference −3.4%, 95% CI −3.8 to −3.0%;

P<0.001). After adjustment for casemix (Model 2), there remained no difference in acute hospital mortality between weekends and weekdays (absolute risk difference −0.0%, 95% CI −0.4 to +0.3%; P=0.87), and the difference for nighttime *vs* daytime

Table 1 Patient characteristics for all patients included in the study and by day and time of admission to the critical care unit. CPR, cardiopulmonary resuscitation; ICNARC, Intensive Care National Audit and Research Centre

	All patients	By day and time of admission to the critical care unit			
		Monday–Friday 08.00–17.59 h	Saturday–Sunday 08.00–17.59 h	Monday–Friday 18.00–07.59 h the next day	Saturday–Sunday 18.00–07.59 h the next day
Number of admissions (rate per critical care unit h^{-1})	195 428 (0.056)	53 785 (0.051)	19 597 (0.047)	89 256 (0.061)	32 790 (0.056)
Age [years; mean (SD)]	60.7 (18.5)	61.4 (18.0)	60.2 (18.8)	60.8 (18.5)	59.5 (19.1)
Sex [n (%)]					
Male	107 047 (54.8)	29 409 (54.7)	10 921 (55.7)	48 611 (54.5)	18 106 (55.2)
Female	88 381 (45.2)	24 376 (45.3)	8676 (44.3)	40 645 (45.5)	14 684 (44.8)
Severe conditions in the past medical history [n (%)]					
Severe cardiovascular disease	3577 (1.8)	1083 (2.0)	367 (1.9)	1575 (1.8)	552 (1.7)
Severe respiratory disease	5852 (3.0)	1721 (3.2)	636 (3.3)	2516 (2.8)	979 (3.0)
End-stage renal failure	4377 (2.3)	1424 (2.7)	385 (2.0)	1899 (2.1)	669 (2.1)
Severe liver disease	6203 (3.2)	1833 (3.4)	657 (3.4)	2698 (3.0)	1015 (3.1)
Haematological malignancy	4659 (2.4)	1438 (2.7)	507 (2.6)	2025 (2.3)	689 (2.1)
Metastatic disease	4708 (2.4)	1302 (2.4)	425 (2.2)	2255 (2.5)	726 (2.2)
Immunocompromise	12 979 (6.7)	3847 (7.2)	1320 (6.8)	5813 (6.6)	1999 (6.1)
Prior dependency [n (%)]					
Able to live without assistance in daily activities	141 919 (73.1)	38 271 (71.6)	14 172 (72.8)	65 197 (73.5)	24 279 (74.6)
Some (minor or major) assistance with daily activities	49 986 (25.7)	14 549 (27.2)	5056 (26.0)	22 465 (25.3)	7916 (24.3)
Total assistance with all daily activities	2239 (1.2)	660 (1.2)	235 (1.2)	991 (1.1)	353 (1.1)
Days from acute hospital admission to critical care unit admission [n (%)]					
0	98 803 (50.6)	26 720 (49.7)	10 480 (53.5)	44 224 (49.5)	17 379 (53.0)
1	40 528 (20.7)	9774 (18.2)	3327 (17.0)	20 296 (22.7)	7131 (21.7)
2	14 572 (7.5)	4305 (8.0)	1524 (7.8)	6502 (7.3)	2241 (6.8)
3–7	24 613 (12.6)	7654 (14.2)	2612 (13.3)	10 680 (12.0)	3667 (11.2)
8 or more	16 912 (8.7)	5332 (9.9)	1654 (8.4)	7554 (8.5)	2372 (7.2)
Location before admission to the critical care unit [n (%)]					
Emergency department or not in hospital	72 293 (37.0)	18 560 (34.5)	7409 (37.8)	32 769 (36.7)	13 555 (41.3)
Theatre (emergency or urgent surgery)	49 640 (25.4)	11 458 (21.3)	4073 (20.8)	26 098 (29.2)	8011 (24.4)
Ward, obstetric area, or intermediate care area	73 495 (37.6)	23 767 (44.2)	8115 (41.4)	30 389 (34.0)	11 224 (34.2)
CPR within 24 h before admission to the critical care unit [n (%)]					
No CPR	179 731 (92.0)	48 998 (91.1)	17 757 (90.6)	82 869 (92.8)	30 107 (91.8)
In-hospital CPR	7612 (3.9)	2370 (4.4)	810 (4.1)	3168 (3.5)	1264 (3.9)
Out-of-hospital CPR	8085 (4.1)	2417 (4.5)	1030 (5.3)	3219 (3.6)	1419 (4.3)
Body system of primary reason for admission to the critical care unit [n (%)]					
Cardiovascular	31 030 (15.9)	9419 (17.5)	3084 (15.7)	13 633 (15.3)	4894 (14.9)
Dermatological	2080 (1.1)	548 (1.0)	165 (0.8)	980 (1.1)	387 (1.2)
Endocrine, thermoregulation, or poisoning	17 928 (9.2)	4452 (8.3)	1874 (9.6)	8276 (9.3)	3326 (10.1)
Gastrointestinal	43 574 (22.3)	10 615 (19.7)	3839 (19.6)	21 838 (24.5)	7282 (22.2)
Genitourinary	18 487 (9.5)	5053 (9.4)	1783 (9.1)	8686 (9.7)	2965 (9.0)
Haematological or immunological	2840 (1.5)	897 (1.7)	303 (1.5)	1223 (1.4)	417 (1.3)

Table 1. (continued)

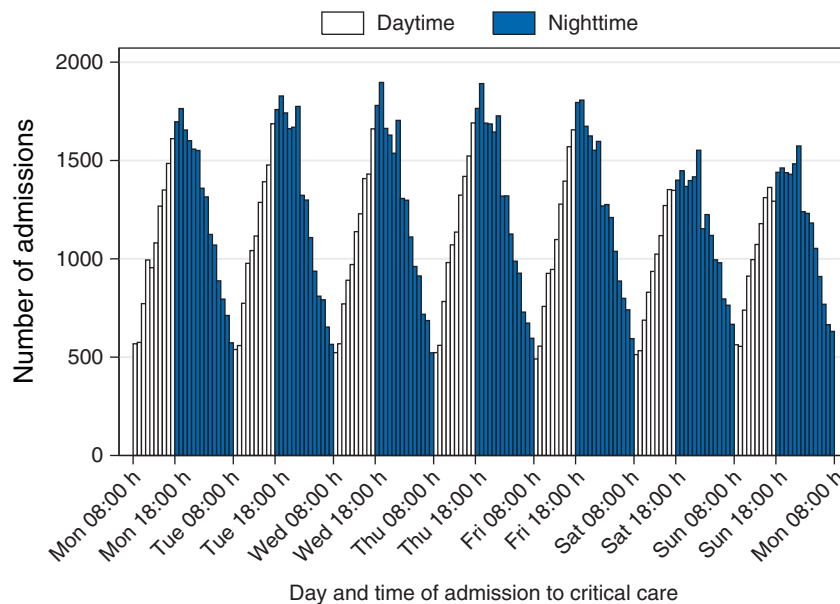|	All patients	By day and time of admission to the critical care unit			
		Monday–Friday 08.00–17.59 h	Saturday–Sunday 08.00–17.59 h	Monday–Friday 18.00–07.59 h the next day	Saturday–Sunday 18.00–07.59 h the next day
Musculoskeletal	6458 (3.3)	1654 (3.1)	607 (3.1)	3215 (3.6)	982 (3.0)
Neurological	23 259 (11.9)	6305 (11.7)	2358 (12.0)	10 552 (11.8)	4044 (12.3)
Respiratory	49 772 (25.5)	14 842 (27.6)	5584 (28.5)	20 853 (23.4)	8493 (25.9)
ICNARC Physiology Score [mean (SD)]	18.8 (9.5)	19.2 (9.7)	19.5 (9.6)	18.4 (9.3)	18.8 (9.5)
APACHE II Score [mean (SD)]	16.8 (7.3)	17.3 (7.2)	17.2 (7.3)	16.5 (7.2)	16.5 (7.4)
Delayed admission to the critical care unit [n (%)]					
No delay	187 133 (95.8)	51 264 (95.3)	18 812 (96.0)	85 417 (95.7)	31 640 (96.5)
≤4 h delay	6198 (3.2)	1829 (3.4)	588 (3.0)	2882 (3.2)	899 (2.7)
>4 h delay	2,097 (1.1)	692 (1.3)	197 (1.0)	957 (1.1)	251 (0.8)
Duration of delay [h; median (quartiles)]	3 (2, 5)	3 (2, 5)	2 (1, 5)	3 (2, 4)	2 (1, 4)
Critical care unit outcome [n (%)]					
Alive	158 662 (81.2)	42 722 (79.4)	15 579 (79.5)	73 676 (82.5)	26 685 (81.4)
Dead	36 766 (18.8)	11 063 (20.6)	4018 (20.5)	15 580 (17.5)	6105 (18.6)
Critical care unit length of stay [h; median (quartiles)]					
Survivors	68 (33, 141)	74 (31, 150)	76 (45, 149)	65 (31, 136)	66 (36, 133)
Non-survivors	49 (18, 130)	51 (19, 136)	52 (19, 129)	46 (17, 129)	46 (17, 122)
Acute hospital outcome [n (%)]					
Alive	143 149 (73.2)	38 252 (71.1)	13 954 (71.2)	66 718 (74.7)	24 225 (73.9)
Dead	52 279 (26.8)	15 533 (28.9)	5643 (28.8)	22 538 (25.3)	8565 (26.1)
Acute hospital length of stay [days; median (quartiles)]					
Survivors	14 (7, 29)	15 (8, 30)	15 (8, 30)	14 (7, 29)	13 (6, 28)
Non-survivors	7 (2, 17)	7 (2, 17)	6 (2, 17)	7 (2, 17)	6 (2, 16)

Fig 2 Number of admissions by day and time of admission to critical care (1 h categories).

was completely removed (absolute risk difference −0.2%, 95% CI −0.5 to +0.1%; *P*=0.21). Adjusting for delayed admission (Model 3) did not affect any of the other model estimates, including the effect of day and time (Table 3).

After adjustment, the marginal predicted acute hospital mortality varied from 26.5 to 27.4% during the week, consistent with chance variation (*P*-value for test of homogeneity, *P*=0.61; Fig. 3).

Discussion

We have demonstrated that day of week and time of admission have no influence on patient mortality for unplanned admissions to adult general critical care units within the UK. This is consistent with previous findings from the UK from 1995–2000.[10] However, unlike the previous analysis, we omitted elective or scheduled surgery from this analysis because we were concerned primarily with the effect of 'out-of-hours' service provision on unplanned admissions. A major strength of our study is the size and completeness of routinely collected data and the availability of detailed clinical data with which we were able to undertake risk adjustment for several major known confounders associated with illness severity at the time of admission.

A systematic review of 10 studies showed that patients admitted to critical care throughout the weekend had an increased risk of death (odds ratio 1.08; 1.04–1.13) compared with patients admitted during the week;[9] although this result was attributable primarily to two studies.[14] [15]

Other studies not included in that review have also described an increased risk of death among patients admitted out of hours and at weekends.[16] [17] Although data from other countries provide useful insight, differences in definition of daytime and nighttime shifts, presence or absence of a nighttime resident doctor, nurse working patterns, casemix, and differences in health-care policy between countries may contribute to differences in outcome. For instance, Barnett and colleagues[14] had specific exclusion criteria of burns and 'some but not all' elective surgery. Uusaro and colleagues[15] note that the physician on call 'most often does not work in the ICU on a daily basis', as possible explanation to variation in outcome between weekdays and weekends.

The 'weekend effect' has also been described in various cohorts of critically ill patients. In-hospital cardiac arrests attended by the hospital-based resuscitation team during nights and weekends have substantially worse outcomes than during weekday daytimes in UK hospitals.[18] Likewise, emergency surgical admissions have greater odds of death if admitted during the weekend,[19] and trauma patients may have a greater risk of death if admitted during the weekend compared with a weekday.[20] It is difficult to determine whether an apparent difference demonstrated in mortality is likely to result in publication bias.

Retrospective observational studies of unselected hospital admissions to UK hospitals demonstrate a considerable increase in risk of subsequent 30 day mortality compared with admission on a Wednesday (the day of the week with the lowest mortality).[21] [22] However, patients already in hospital did not have an increased risk of dying during the weekend. The differences in weekend-to-weekday mortality ratios were confirmed by an independent study that used the same data set as the second study (Hospital Episode Statistic data set from 2013–2014),[23] although there was no association between mortality and with hospital specialist (consultant) staffing levels.[23] The finding that weekend hospital admission has a higher mortality than weekday admission has been challenged,[24] and inaccurate coding in routine administrative data has also resulted in an artifactual increase in weekend mortality rate among acute stroke patients in the UK.[25]

Table 2 Multilevel logistic regression models evaluating the association between day and time of admission to the critical care unit and acute hospital mortality. CI, confidence interval; CPR, cardiopulmonary resuscitation; ICNARC, Intensive Care National Audit and Research Centre

	Model 1 (unadjusted)		Model 2 (adjusted)		Model 3 (mediated)	
	Odds ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value
Day and time of admission		<0.001		0.61		0.62
Mon 08.00–17.59 h	Reference		Reference		Reference	
Mon 18.00 h–Tue 07.59 h	0.81 (0.77, 0.86)		0.97 (0.91, 1.04)		0.97 (0.91, 1.04)	
Tue 08.00–17.59 h	0.96 (0.90, 1.02)		0.99 (0.92, 1.07)		0.99 (0.92, 1.07)	
Tue 18.00 h–Wed 07.59 h	0.80 (0.76, 0.85)		0.96 (0.90, 1.03)		0.96 (0.90, 1.03)	
Wed 08.00–17.59 h	0.94 (0.89, 1.00)		0.96 (0.89, 1.03)		0.96 (0.89, 1.03)	
Wed 18.00 h–Thu 07.59 h	0.77 (0.73, 0.81)		0.94 (0.88, 1.01)		0.94 (0.88, 1.01)	
Thu 08.00–17.59 h	0.89 (0.84, 0.95)		0.95 (0.88, 1.02)		0.95 (0.88, 1.02)	
Thu 18.00 h–Fri 07.59 h	0.76 (0.72, 0.80)		0.94 (0.88, 1.01)		0.94 (0.88, 1.01)	
Fri 08.00–17.59 h	0.90 (0.85, 0.96)		0.94 (0.87, 1.01)		0.94 (0.87, 1.01)	
Fri 18.00 h–Sat 07.59 h	0.76 (0.72, 0.80)		0.93 (0.87, 1.00)		0.93 (0.87, 1.00)	
Sat 08.00–17.59 h	0.90 (0.85, 0.96)		0.93 (0.86, 1.01)		0.93 (0.86, 1.01)	
Sat 18.00 h–Sun 07.59 h	0.81 (0.77, 0.86)		0.95 (0.88, 1.01)		0.95 (0.89, 1.02)	
Sun 08.00–17.59 h	0.96 (0.90, 1.02)		1.00 (0.92, 1.08)		1.00 (0.92, 1.08)	
Sun 18.00 h–Mon 07.59 h	0.82 (0.78, 0.87)		0.95 (0.88, 1.01)		0.95 (0.89, 1.02)	
Age (per 10 yr increase)			1.36 (1.35, 1.37)	<0.001	1.36 (1.35, 1.37)	<0.001
Severe conditions in the past medical history (present vs not)						
Severe cardiovascular disease			1.27 (1.16, 1.38)	<0.001	1.27 (1.16, 1.38)	<0.001
Severe respiratory disease			1.47 (1.37, 1.57)	<0.001	1.47 (1.37, 1.57)	<0.001
End-stage renal failure			0.72 (0.67, 0.78)	<0.001	0.72 (0.67, 0.78)	<0.001
Severe liver disease			3.00 (2.80, 3.22)	<0.001	3.00 (2.80, 3.22)	<0.001
Haematological malignancy			1.63 (1.51, 1.77)	<0.001	1.63 (1.51, 1.77)	<0.001
Metastatic disease			2.20 (2.04, 2.38)	<0.001	2.20 (2.04, 2.38)	<0.001
Immunocompromise			1.31 (1.24, 1.38)	<0.001	1.31 (1.24, 1.38)	<0.001
Prior dependency				<0.001		<0.001
Able to live without assistance in daily activities			Reference		Reference	
Some (minor or major) assistance with daily activities			1.56 (1.51, 1.61)		1.56 (1.51, 1.61)	
Total assistance with all daily activities			2.00 (1.79, 2.25)		2.00 (1.79, 2.25)	
Days from acute hospital admission to critical care unit admission				<0.001		<0.001
0			Reference		Reference	
1			1.03 (0.99, 1.08)		1.03 (0.99, 1.07)	
2			1.20 (1.13, 1.27)		1.20 (1.13, 1.26)	
3–7			1.49 (1.42, 1.56)		1.49 (1.42, 1.56)	
8 or more			2.26 (2.15, 2.37)		2.25 (2.14, 2.37)	
Location before admission to the critical care unit				<0.001		<0.001
Emergency department or not in hospital			Reference		Reference	
Theatre (emergency or urgent surgery)			0.66 (0.63, 0.69)		0.66 (0.63, 0.69)	
Ward, obstetric area, or intermediate care area			1.22 (1.17, 1.27)		1.23 (1.18, 1.28)	
CPR within 24 h before admission to the critical care unit				<0.001		<0.001
No CPR			Reference		Reference	
In-hospital CPR			2.05 (1.93, 2.19)		2.05 (1.92, 2.19)	
Out-of-hospital CPR			3.22 (3.00, 3.45)		3.21 (3.00, 3.45)	
Primary reason for admission to the critical care unit				<0.001		<0.001
85 categories of body system and pathological/physiological process			Not shown		Not shown	
ICNARC Physiology Score (per 5 point increase)			1.95 (1.93, 1.97)	<0.001	1.95 (1.93, 1.97)	<0.001
Delayed admission to the critical care unit						0.004
No delay					Reference	
≤4 h delay					1.08 (1.01, 1.17)	
>4 h delay					1.17 (1.04, 1.32)	
Unit-level random effects		<0.001		<0.001		<0.001
SD (95% CI)	0.22 (0.20, 0.25)		0.20 (0.17, 0.22)		0.20 (0.17, 0.22)	
Intracluster correlation coefficient (95% CI)	0.015 (0.012, 0.019)		0.012 (0.009, 0.015)		0.012 (0.009, 0.015)	

Table 3 Absolute risk difference for prespecified model contrasts. CI, confidence interval

	Model 1 (unadjusted)		Model 2 (adjusted)		Model 3 (mediated)	
	Risk difference [% (95% CI)]	P-value	Risk difference [% (95% CI)]	P-value	Risk difference ([% (95% CI)]	P-value
Weekend *vs* weekday	+0.3 (−0.1 to +0.8)	0.15	−0.0 (−0.4 to +0.3)	0.87	−0.0 (−0.4 to +0.3)	0.92
Nighttime *vs* daytime	−3.4 (−3.8 to −3.0)	<0.001	−0.2 (−0.5 to +0.1)	0.21	−0.2 (−0.5 to +0.1)	0.22
Weekend daytime *vs* weekday daytime	−0.2 (−0.9 to +0.6)	0.66	−0.0 (−0.6 to +0.6)	0.96	−0.0 (−0.6 to +0.6)	0.98
Weekend nighttime *vs* weekday nighttime	+0.9 (+0.3 to +1.4)	0.003	−0.0 (−0.5 to +0.4)	0.85	−0.0 (−0.5 to +0.4)	0.90
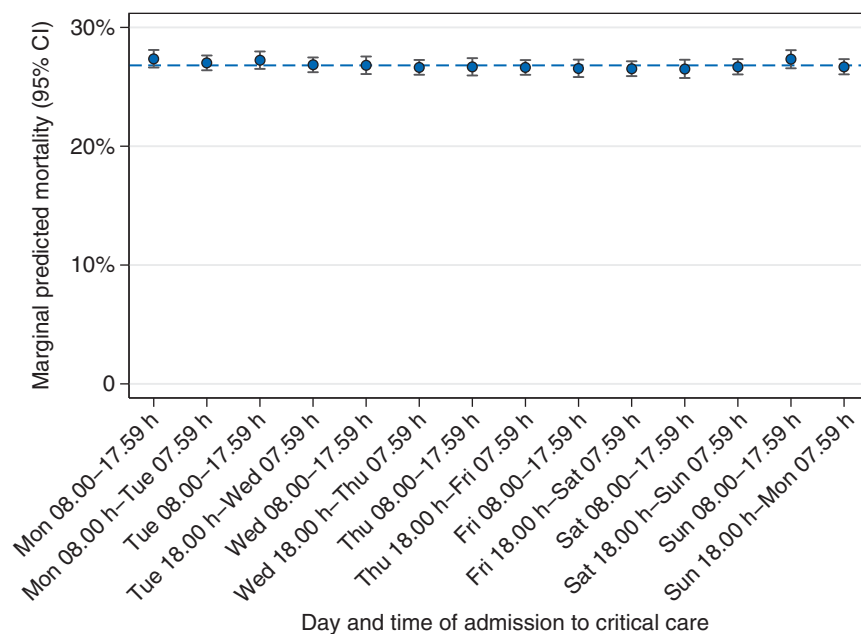
Fig 3 Risk-adjusted acute hospital mortality by day and time of admission to critical care. Post-estimation marginal predicted mortality [with 95% confidence interval (CI)], holding all other covariates at the values observed in the data set and zero random effect.

The main limitation of our study is that we lack data on the working patterns of the critical care units contributing. Both nurse-to-patient ratio and physician-to-patient ratio have previously been related to patient mortality within critical care.[26] The lack of effect of time of critical care admission on mortality may be somewhat attributable to the presence of a dedicated doctor at all times on the critical care unit,[27] along with standardized minimal nurse staffing levels. Previous research using the ICNARC CMP database found no association between patterns of senior intensivist staffing and mortality in the UK.[8] Other variables that are known to affect mortality among critically ill patients, including time of discharge to the ward, caseload, and level of training of the admitting physician, were beyond the scope of the present study.

We acknowledge that any differences in the standard of care in resuscitation and stabilization of the critically ill patient initiated before the patient being admitted to the unit is likely to have an effect on mortality, and no data were available for patients who did not survive initial resuscitation and thus were not admitted to intensive care. The focus in the present paper is on the effect of variation in delivery of critical care rather than on pre-admission care. If grossly inadequate pre-ICU care did exist, resulting in the sickest patients dying before ICU admission, this may account for our findings. However, variables associated with illness severity at the point of admission were collected and may correct for any differences in care before ICU admission. As a delay between the decision to admit and the admission is likely to be influenced by the workload and staffing of the critical care unit, rather than by suboptimal pre-admission care, we would consider it a mediator rather than a confounder for this comparison.

We speculate that although a proportion of critical care units may have fewer staff overnight and at weekends, the 'critical level' of staffing is met to ensure that high-quality care is delivered, with no consequent variation in mortality between weekends and weekdays or between daytime and nighttime.

Although we have limited data on what happens before critical care unit admission, we did observe an adverse effect of delayed admission to the critical care unit. Such findings, which may reflect the 'system' or availability of resources, are not unique to our study and provide a clear opportunity to improve services.[28][29] The reasons for delayed admission, however, are not recorded within the routine data used and are beyond the scope of the present study. Ways to improve interaction between critical care and the rest of the hospital-wide systems to minimize delays in admission and potentially improve outcomes need to be ascertained in future research.

In summary, a small proportion of patients experienced delays in admission, which were associated with increased mortality; these warrant further investigation. After risk adjustment using detailed clinical data, there was no difference in acute hospital mortality for unplanned admissions to adult general critical care units between weekends and weekdays or between daytime and nighttime.

Authors' contributions

Conception of the study idea and drafting the manuscript: N.A.

Study design and critical revision the manuscript for important intellectual content: N.A., D.A.H., S.J.B.

Drafting the statistical analysis plan and performance of the analyses: D.A.H.

Had full access to all the data in the study, take responsibility for the integrity of the data and the accuracy of the data analysis, and are the guarantors: D.A.H., S.J.B.

Declaration of interest

N.A. is Chair of the Intensive Care Society Trainee Committee and a member of the Intensive Care Society Council. D.A.H. is a member of the Intensive Care Society Research Committee. S.J.B. was President of the Intensive Care Society until December 2016.

Funding

References

1. Carson SS, Stocking C, Podsadecki T, et al. Effects of organizational change in the medical intensive care unit of a teaching hospital: a comparison of 'open' and 'closed' formats. *JAMA* 1996; **276**: 322–8

2. Blunt MC, Burchett KR. Out-of-hours consultant cover and case-mix-adjusted mortality in intensive care. *Lancet* 2000; **356**: 735–6

3. Brown JJ, Sullivan G. Effect on ICU mortality of a full-time critical care specialist. *Chest* 1989; **96**: 127–9

4. Goh AY, Lum LC, Abdel-Latif ME. Impact of 24 hour critical care physician staffing on case-mix adjusted mortality in paediatric intensive care. *Lancet* 2001; **357**: 445–6

5. Gajic O, Afessa B, Hanson AC, et al. Effect of 24-hour mandatory versus on-demand critical care specialist presence on quality of care and family and provider satisfaction in the intensive care unit of a teaching hospital. *Crit Care Med* 2008; **36**: 36–44

6. Pronovost PJ, Angus DC, Dorman T, et al. Physician staffing patterns and clinical outcomes in critically ill patients: a systematic review. *JAMA* 2002; **288**: 2151–62

7. Kane RL, Shamliyan TA, Mueller C, Duval S, Wilt TJ. The association of registered nurse staffing levels and patient outcomes: systematic review and meta-analysis. *Med Care* 2007; **45**: 1195–204

8. Wilcox ME, Harrison DA, Short A, Jonas M, Rowan KM. Comparing mortality among adult, general intensive care units in England with varying intensivist cover patterns: a retrospective cohort study. *Crit Care* 2014; **18**: 491

9. Cavallazzi R, Marik PE, Hirani A, et al. Association between time of admission to the ICU and mortality: a systematic review and metaanalysis. *Chest* 2010; **138**: 68–75

10. Wunsch H, Mapstone J, Brady T, Hanks R, Rowan K. Hospital mortality associated with day and time of admission to intensive care units. *Intensive Care Med* 2004; **30**: 895–901

11. Harrison DA, Parry GJ, Carpenter JR, Short A, Rowan K. A new risk prediction model for critical care: the Intensive Care National Audit & Research Centre (ICNARC) model. *Crit Care Med* 2007; **35**: 1091–8

12. Vandenbroucke JP, von Elm E, Altman DG, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *Epidemiology* 2007; **18**: 805–35

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

14. Barnett MJ, Kaboli PJ, Sirio CA, Rosenthal GE. Day of the week of intensive care admission and patient outcomes: a multisite regional evaluation. *Med Care* 2002; **40**: 530–9

15. Uusaro A, Kari A, Ruokonen E. The effects of ICU admission and discharge times on mortality in Finland. *Intensive Care Med* 2003; **29**: 2144–8

16. Bhonagiri D, Pilcher DV, Bailey MJ. Increased mortality associated with after-hours and weekend admission to the intensive care unit: a retrospective analysis. *Med J Aust* 2011; **194**: 287–92

17. Kuijsten HA, Brinkman S, Meynaar IA, et al. Hospital mortality is associated with ICU admission time. *Intensive Care Med* 2010; **36**: 1765–71

18. Robinson EJ, Smith GB, Power GS, et al. Risk-adjusted survival for adults following in-hospital cardiac arrest by day of week and time of day: observational cohort study. *BMJ Qual Saf* 2016; **25**: 832–41

19. Ozdemir BA, Sinha S, Karthikesalingam A, et al. Mortality of emergency general surgical patients and associations with hospital structures and processes. *Br J Anaesth* 2016; **116**: 54–62

20. Carr BG, Reilly PM, Schwab CW, et al. Weekend and night outcomes in a statewide trauma system. *Arch Surg* 2011; **146**: 810–7

21. Freemantle N, Ray D, McNulty D, et al. Increased mortality associated with weekend hospital admission: a case for expanded seven day services? *Br Med J* 2015; **351**: h4596

22. Freemantle N, Richardson M, Wood J, *et al*. Weekend hospitalization and additional risk of death: an analysis of inpatient data. *J R Soc Med* 2012; **105**: 74–84

23. Aldridge C, Bion J, Boya A, *et al*. Weekend specalist intensity and admission mortality in acute hospital trusts in England: a cross-sectional study. *Lancet* 2016; **388**: 178–86

24. Meacock R, Anselmi L, Kristensen SR, Doran T, Sutton M. Higher mortality rates amongst emergency patients admitted to hospital at weekends reflect a lower probability of admission. *J Health Serv Res Policy* Advance Access published on May 6, 2016, doi: 10.1177/1355819616649630

25. Li L, Rothwell P; Oxford Vascular Study. Biases in detection of apparent "weekend effect" on outcome with administrative coding data: population based study of stroke. *Br Med J* 2016; **353**: i2648

26. Neuraz A, Guerin C, Payet C, *et al*. Patient mortality is associated with staff resources and workload in the ICU: a multicenter observational study. *Crit Care Med* 2015; **43**: 1587–94

27. Arabi Y, Alshimemeri A, Taher S. Weekend and weeknight admissions have the same outcome of weekday admissions to an intensive care unit with onsite intensivist coverage. *Crit Care Med* 2006; **34**: 605–11

28. Sprung CL, Geber D, Eidelman LA, *et al*. Evaluation of triage decisions for intensive care admission. *Crit Care Med* 1999; **27**: 1073–9

29. Harris S, Singer M, Rowan K, Sanderson C. Delay to admission to critical care and mortality among deteriorating ward patients in UK hospitals: a multicentre, prospective, observational cohort study. *Lancet* 2015; **385 (Suppl 1)**: S40

Handling editor: P. S. Myles