Increased mortality associated with after-hours and weekend admission to the intensive care unit: a retrospective analysis

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ABSTRACT

Objective: To study variation in mortality associated with time and day of admission to the intensive care unit (ICU).

Design: Retrospective cohort analysis using the Australian and New Zealand Intensive Care Society Adult Patient Database.

Setting and participants: 245 057 admissions to 41 Australian ICUs from January 2000 to December 2008.

Main outcome measures: Observed mortality and standardised mortality ratio (SMR) based on Acute Physiology and Chronic Health Evaluation III, 10th iteration (APACHE III-j) scores. Subgroup analysis was performed on the basis of elective surgical or emergency admission to ICU.

Results: 48% of patients were admitted after hours (18:00–05:59) and 20% of patients were admitted on weekends (Saturday and Sunday). Patients admitted after hours had a 17% hospital mortality rate compared with 14% of patients admitted in hours ($P < 0.001$); and SMRs of 0.92 (95% CI, 0.91–0.93) and 0.83 (95% CI, 0.83–0.84), respectively. Weekend admissions had a 20% hospital mortality rate compared with 14% on weekdays ($P < 0.001$), with SMRs of 0.95 (95% CI, 0.94–0.97) and 0.92 (95% CI, 0.92–0.93), respectively. Variation in outcome with time of admission to ICU was accounted for predominantly by elective surgical patients.

Conclusions: Patients admitted to ICUs in Australia after hours and on weekends have a higher observed and risk-adjusted mortality than patients admitted at other times. Further research is required to determine the causes and relationship to resource availability and staffing.

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Studies examining hospital mortality of patients admitted to intensive care units (ICUs) have revealed increased mortality after (or “off”) hours and on weekends.[1-10] In most studies, however, this effect disappeared after controlling for illness severity.[1,3-8,10] A systematic review and meta-analysis of the association between time of admission to the ICU and mortality found that patients admitted to the ICU during weekends had an 8% higher risk of death compared with patients admitted during weekdays, but found no such effect for after-hours admission.[11]

The Australian and New Zealand Intensive Care Society (ANZICS) Centre for Outcome and Resource Evaluation (CORE) manages the ANZICS Adult Patient Database (APD),[12] which collects data on ICU admissions in Australian, New Zealand and, more recently, Hong Kong hospitals, and now holds over a million records. The minimum dataset and data definitions used are available on the ANZICS CORE website (http://anzics.com.au/core).

In 2008, 128 ICUs in Australia and New Zealand (about 65 000 ICU admissions), including 34 of the 35 tertiary hospitals, contributed toward the APD. This was estimated to capture over 80% of all Australian ICU admissions that year.[13] Thus, the APD is an ideal tool for examining the relationship between time of admission to ICU and hospital mortality.

Previous studies have focused on whether the absence of on-site specialist intensivists after hours significantly increases the mortality of ICU patients admitted after hours.[1-10] However, there was considerable heterogeneity in the patient population, definitions of after hours and results of these studies.[1-10] The resources, rosters and work practices within ICUs specifically and hospitals in general vary considerably across Australia.[13]

In the absence of consistent messages from past research, and any Australian publications on the subject, we aimed to investigate whether there was a relationship between time of admission to ICU and mortality. If present, our aim was to identify subgroups at particular risk.

METHODS

We performed a retrospective cohort analysis of admissions to Australian adult ICUs between 1 January 2000 and 31 December 2008 recorded in the ANZICS APD. Data from hospitals that submitted fewer than 200 submissions a year, or that did not submit data throughout the study period, were excluded. Also excluded were records of readmissions to ICU, patients with no time of admission recorded, patients with no hospital outcome listed, and admissions in countries other than Australia.

Rural, metropolitan, tertiary and private hospitals were represented in the dataset, and all Australian jurisdictions were represented. Investigators did not know the identities or locations of individual hospitals. No information about staffing or resource availability was recorded in the database.

Data retrieved included Acute Physiology and Chronic Health Evaluation III, 10th iteration (APACHE III-j) predicted risk of death (the version used by ANZICS CORE), hospital mortality, date and time of admission to ICU, elective surgical status and diagnosis on admission to ICU. All individual data were de-identified.

Ethics approval for the study was granted by the Liverpool Hospital Human Research Ethics Committee.

Outcomes examined included observed mortality and risk-adjusted mortality, represented by APACHE III-j standardised mortality ratio (SMR). Patients with a length of ICU stay under 4 hours and those with no APACHE III-j predicted risk of death were excluded from analysis of the SMR.

There is no standard definition of “after hours” for intensive care practice in Australia, and previous publications have not used a consistent definition. A study of the ANZICS APD on the effect on patient outcome of discharge timing from Australian and New Zealand ICUs defined after hours as 18:00 to 05:59,[14] so we used the same definition in our study. In hours, after hours, weekdays and weekends are defined in Box 1.

Outcomes at different admission times were examined in four ways:

1 Definitions used for this study

Term	Definition
After hours	18:00 to 05:59*
In hours	06:00 to 17:59*
Weekend	Saturday 00:00 to Sunday 23:59
Weekdays	Monday 00:00 to Friday 23:59
Daily admissions	00:00 to 23:59 on the same calendar day
Elective surgical admission to ICU	Planned admission to ICU following elective surgery
Emergency admission to ICU	Any admission that was not an elective surgical admission (ie, including emergency surgical and medical admissions)
Mortality	Hospital mortality

ICU = intensive care unit. * On all 7 days of the week. ◆

2 Characteristics and outcomes of 245 057 patients admitted to Australian ICUs in hours and after hours, January 2000 – December 2008

	In hours	After hours*	*P*
No. of admissions (%)	127 984 (52.2%)	117 073 (47.8%)	
Age in years, mean (SD)	60.7 (18.5)	57.8 (20.0)	< 0.001
APACHE III-j score, mean (SD)	54.6 (28.4)	57.1 (29.9)	< 0.001
APACHE III-j risk of death, median (IQR)	0.04 (0.01–0.17)	0.06 (0.01–0.23)	< 0.001
Ventilated in first 24 hours in ICU, % (no.)	47.0% (60 189)	46.5% (54 380)	0.004
Diagnostic subgroups, % (no.)			
All postoperative diagnoses	55.4% (70 938)	38.9% (45 552)	< 0.001
Elective surgery only	46.1% (59 032)	23.4% (27 400)	< 0.001
Cardiac surgery only	23.1% (29 554)	9.0% (10 554)	< 0.001
Chronic health status, % (no.)			
Chronic cardiovascular disease	12.4% (15 839)	10.5% (12 276)	< 0.001
Chronic liver disease	2.0% (2509)	2.5% (2923)	< 0.001
Chronic renal failure	3.5% (4533)	3.9% (4513)	< 0.001
Chronic respiratory disease	7.6% (9730)	7.6% (8866)	0.78
Immunosuppressed	3.3% (4227)	3.4% (3968)	0.23
Outcomes			
ICU mortality, % (no.)	9.1% (11 682)	10.8% (12 596)	< 0.001
Hospital mortality, % (no.)	14.0% (17 877)	16.5% (19 364)	< 0.001
Standardised mortality ratio (95% CI)	0.83 (0.83–0.84)	0.92 (0.91–0.93)	< 0.001
Length of ICU stay in hours, median (IQR)	43.5 (22.9–82.3)	42.5 (19.0–97.4)	0.14
Length of hospital stay in hours, median (IQR)	240 (142–457)	255 (122–506)	0.04

APACHE III-j = Acute Physiology and Chronic Health Evaluation III, 10th iteration. ICU = intensive care unit. IQR = interquartile range. * Defined as 18:00 to 05:59. ◆

- Hourly cohorts, to give a continuous representation of outcomes over 24 hours.
- Two-group comparison of after-hours and in-hours admission to ICU.
- Daily cohorts, to give a continuous representation of outcomes over 1 week.
- Two-group comparison of weekend and weekday admission to ICU.

Statistical analysis

Data were analysed using SAS version 9.1 (SAS Institute Inc, Cary, NC, USA). Univariate analyses were performed using the Student *t* test, analysis of variance (ANOVA), the Wilcoxon rank-sum test, the Kruskal–Wallis test and the Wald χ^2 test of equal proportion, according to the type of data. $P < 0.05$ was considered significant.

Multivariate logistic regression analysis was undertaken to quantify factors independently associated with mortality and to identify significant interactions between independent variables.

RESULTS

The study included 245 057 ICU patient episodes in 41 ICUs; of these, 47.8% of patients were admitted after hours (Box 2) and 20.1% of patients were admitted on weekends (Box 3). Patients admitted after hours and on weekends were younger than those admitted in hours but had higher APACHE III-j scores and predicted risk of death. Box 4 shows the diurnal variation in number of admissions and observed and APACHE III-j predicted risk of death, and Box 5 shows the diurnal variation in SMR.

ICU mortality, hospital mortality and SMRs were significantly increased among patients admitted after hours and on weekends compared with patients admitted in hours and on weekdays, respectively (Box 2 and Box 3). ICU and hospital lengths of stay were significantly increased among patients admitted on weekends (Box 3), but no such effect was seen after hours (Box 2).

Multivariate logistic regression demonstrated that APACHE III-j risk of death, after-hours admission, weekend admission, a medical diagnosis on admission (as opposed to postoperative admission) and emergency (as opposed to elective surgical) admission were all independently associated with increased mortality (Box 6 and Box 7). Although most variables were highly significant ($P < 0.001$), elective surgical patients had a Wald χ^2 statistic that was over 17 times larger than that of postoperative patients as a whole (847 v 48). Time-of-day and day-of-week SMRs varied considerably between elective surgical patients and emergency medical and surgical patients (Box 8).

Subgroup analysis

Box 9 and Box 10 show the 15 most prevalent elective surgical diagnostic groups, and their observed mortalities and SMRs. Observed mortality was higher among patients who were admitted to the ICU after hours following cardiothoracic surgery, abdominal aortic aneurysm surgery and other gastrointestinal surgery. SMRs were higher among patients who were admitted to the ICU after hours following valvular heart surgery and abdominal aortic aneurysm repair. Many other diagnostic groups showed trends towards increased observed mortality and SMRs among after-hours and weekend admissions, but individually did not reach statistical significance. As seen in Box 9 and Box 10, the SMRs of some elective surgical diagnostic groups, such as "other respiratory surgery" and "laminectomy or spinal cord surgery" were higher in hours compared with after hours and weekdays compared with weekends.

DISCUSSION

The main finding of our retrospective cohort analysis is that patients admitted to the ICU after hours and on weekends have increased mortality and SMRs. The increased mortality with after-hours and weekend admission to the ICU is predominantly accounted for by patients with planned admissions following elective surgery. This is the largest reported cohort study on this topic, and our findings are important from clinical and operational planning perspectives.

A retrospective cohort study in the Paris metropolitan region showed that off-hours admission to the ICU is common, and may be associated with a slightly lower death rate.[5] The researchers attributed this to a delay in assessment of individual patients admitted in hours, higher workloads and more invasive diagnostic and therapeutic interventions in hours. Day shifts are defined by law in France and the definition of off hours used in that study[5] was different from our definition of after hours.

A systematic review found that weekend admission was associated with an 8% (95% CI, 4%–13%) higher risk of death than weekday admission. The meta-analysis was dominated by one study that included admission only during mid week (Tuesdays, Wednesdays and Thursdays) as the control group. It found significant heterogeneity among the studies. Moreover, it excluded studies that compared SMRs of the control and study groups.[11] Our study population is bigger than that included in the meta-analysis. The definitions of SMRs in the meta-analysis were not uniform. We compared SMRs and did not correlate mortality to ICU physician staffing.

The difference in mortality for patients admitted to the ICU after hours and on weekends in our study was predominantly due to an effect seen in planned admissions to the ICU after elective surgery. This has not been reported before, although Dutch[6] and Saudi Arabian[1] researchers found similar trends in their studies. However, the Dutch study[6] defined "elective surgery" differently from the ANZICS — they included all patients admitted to the ICU within 7 days of elective surgery, whereas the ANZICS defines elective surgical admissions as those admitted directly from the operating theatre or recovery room.

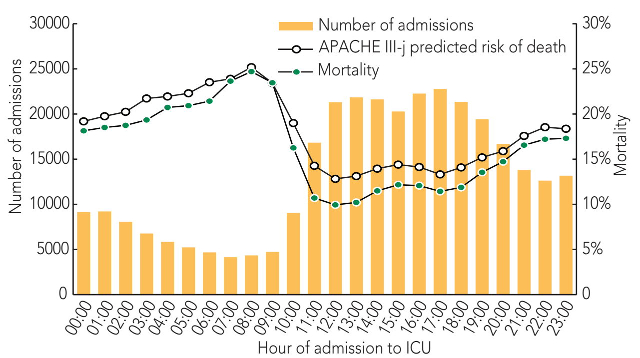
We found significant differences in the observed mortality for some of the 15 most prevalent elective surgery diagnostic groups, but the 95% confidence intervals for the SMR for the in–after hours and weekday–

3 Characteristics and outcomes of 245 057 patients admitted to Australian ICUs on weekdays and weekends, January 2000 – December 2008

	Weekdays	Weekends*	*P*
No. of admissions (%)	195 725 (79.9%)	49 332 (20.1%)	
Age in years, mean (SD)	60.3 (18.7)	55.7 (20.9)	< 0.001
APACHE III-j score, mean (SD)	54.8 (28.4)	59.9 (31.7)	< 0.001
APACHE III-j risk of death, median (IQR)	0.04 (0.01–0.17)	0.09 (0.02–0.30)	< 0.001
Ventilated in first 24 hours in ICU, % (no.)	46.0% (90 090)	49.6% (24 479)	< 0.001
Diagnostic subgroups, % (no.)			
All postoperative diagnoses	52.9% (103 543)	26.2% (12 947)	< 0.001
Elective surgery only	41.3% (80 793)	11.4% (5639)	< 0.001
Cardiac surgery only	19.5% (38 220)	3.8% (1888)	< 0.001
Chronic health status, % (no.)			
Chronic cardiovascular disease	11.9% (23 210)	9.9% (4905)	< 0.001
Chronic liver disease	2.0% (4019)	2.9% (1413)	< 0.001
Chronic renal failure	3.6% (7109)	3.9% (1937)	0.002
Chronic respiratory disease	7.4% (14 474)	8.4% (4122)	< 0.001
Immunosuppressed	3.2% (6307)	3.8% (1888)	< 0.001
Outcomes			
ICU mortality, % (no.)	9.0% (17 607)	13.5% (6671)	< 0.001
Hospital mortality, % (no.)	14.0% (27 434)	19.9% (9807)	< 0.001
Standardised mortality ratio (95% CI)	0.92 (0.92–0.93)	0.95 (0.94–0.97)	< 0.001
Length of ICU stay in hours, median (IQR)	41.0 (21.4–87.6)	52.3 (25.2–114.7)	< 0.001
Length of hospital stay in hours, median (IQR)	242 (141–476)	256 (111–524)	< 0.001

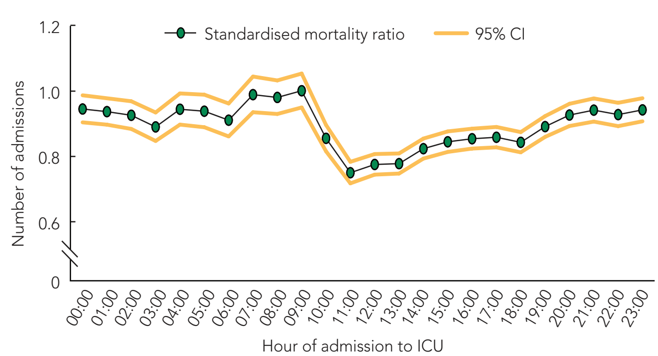
APACHE III-j = Acute Physiology and Chronic Health Evaluation III, 10th iteration. ICU = intensive care unit. IQR = interquartile range. * Defined as Saturday 00:00 to Sunday 23:59. ◆

4 Admissions to ICUs per hour of the day, with hospital mortality and APACHE III-j predicted risk of death



APACHE III-j = Acute Physiology and Chronic Health Evaluation III, 10th iteration. ICU = intensive care unit. ◆

5 APACHE III-j standardised mortality ratios per hour of the day for all admissions to the ICU



APACHE III-j = Acute Physiology and Chronic Health Evaluation III, 10th iteration. ICU = intensive care unit. ◆

weekend comparisons were not statistically significant. These findings may be influenced by the differences in the sample sizes between the cohorts compared. There were significantly fewer patients in the after-hours and weekend groups compared with the in-hours and weekday groups.

After-hours and weekend planned admission to the ICU following elective surgery was associated with increased mortality, and there are several possible reasons for this. After-hours return to the ICU following elective surgery may imply prolonged surgery started in hours, where intraoperative complications have delayed ICU admission, but the resulting physiological derangement is not reflected in the APACHE III-j risk of death. Alternatively, these admissions may be of patients whose elective surgical procedures were started at times when a lack of normal facilities, resources and staff have put the patients at increased risk of death. It may equally be related to patient selection for elective surgery, patient workup for elective surgery, surgical team skill mix or hospital resources. Finally, a lack of early assessment and formation of a management plan by intensivists may be the reason for this difference.

However, none of these factors are likely to uniquely affect patients admitted after hours and on weekends. We did not have information on the time surgery started, staffing levels or skill mix within the operating theatre or ICU, or incidence of unrecognised and unanticipated complications of surgery.

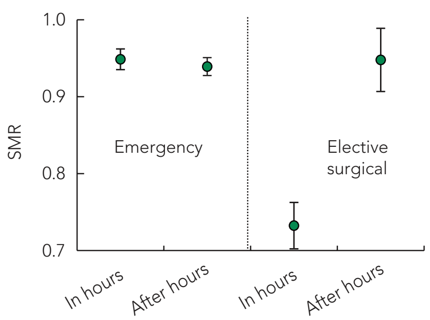
The use of SMRs to compare the mortality in cohorts of ICU patients is valid.[15] APACHE III-j has been validated as a risk adjustor for calculation of the SMR among an Australasian ICU population.[16]

Our study has several limitations. The differences seen may be related to data entry, data synthesis or data integrity. However, as such data errors and inaccuracies are likely to be random, they are unlikely to significantly affect the findings in a study of this size. In addition, regular education and accreditation of data managers, and data verification are conducted by the ANZICS CORE, and the APD is recognised as a high-quality database.[12] Elective surgical status is generally well recorded. The ANZICS APD audit of 1102 randomly selected admissions to 44 hospitals demonstrated elective surgical status was coded correctly in 94% of cases.[17]

Despite the possibly contradictory finding that a small group of elective surgical patients admitted in hours (between 06:00 and 10:00) have high SMRs, because they constitute a relatively small proportion of the overall numbers admitted between 06:00 and 18:00, the difference in overall after-hours and in-hours SMRs remained significant. Without knowing the time at which surgery began, it is not known whether this finding is due to surgery having been inappropriately started out of hours that led to ICU admission during the early part of the working day.

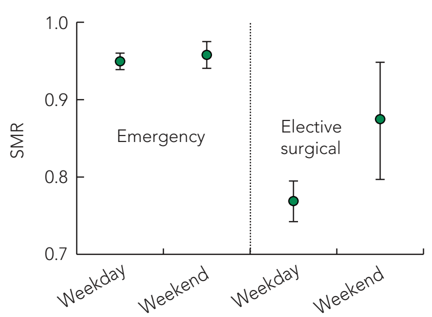
We defined after hours as 18:00 to 05:59; other studies[1,2,5-7] defined after hours as weeknights and all weekend. The most appropriate definition is unknown. We did not include Friday evenings and Monday mornings as weekends in our audit. This may have influenced our results, although we speculate that broadening the definition would further strengthen our findings.

6 APACHE III-j SMRs for elective surgical and emergency patients admitted to intensive care units in hours and after hours



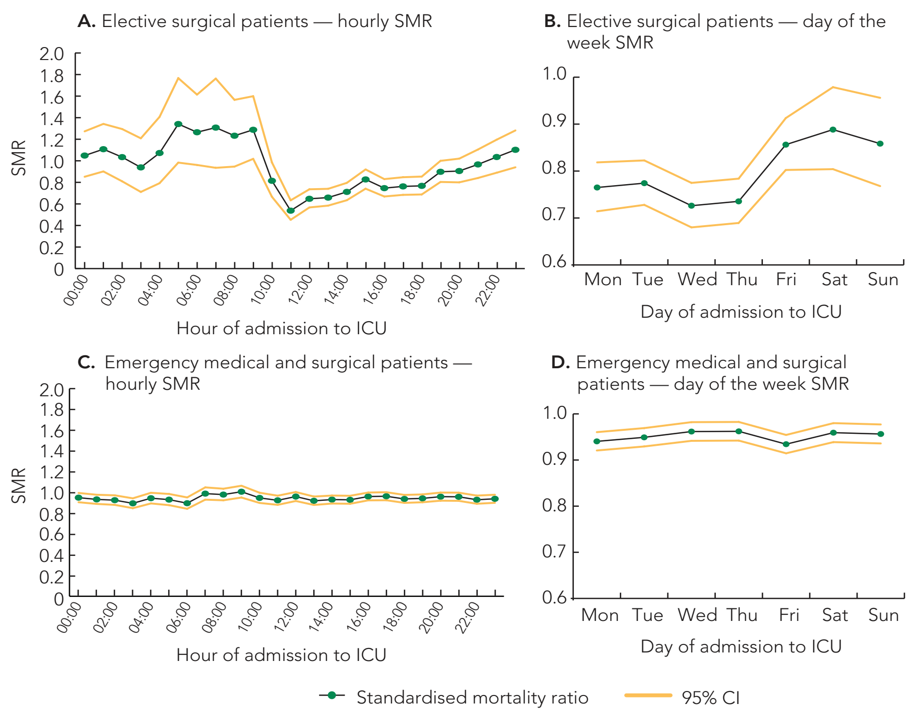
APACHE III-j = Acute Physiology and Chronic Health Evaluation III, 10th iteration. SMR = standardised mortality ratio. ◆

7 APACHE III-j SMRs for elective surgical and emergency patients admitted to intensive care units on weekdays and weekends



APACHE III-j = Acute Physiology and Chronic Health Evaluation III, 10th iteration. SMR = standardised mortality ratio. ◆

8 APACHE III-j SMRs for elective surgical and emergency patients admitted to ICUs by time of day and day of the week



APACHE III-j = Acute Physiology and Chronic Health Evaluation III, 10th iteration. ICU = intensive care unit. SMR = standardised mortality ratio. ◆

9 Observed mortality and APACHE III-j standardised mortality ratios (SMRs) in hours and after hours for the 15 most prevalent elective surgical diagnoses

Elective surgical procedure	In hours, no. (% observed mortality)	After hours, no. (% observed mortality)	*P* for observed mortality comparison	In hours SMR (95% CI)	After hours SMR (95% CI)
Coronary artery bypass grafting	7732 (1.0%)	2080 (2.0%)	< 0.001	0.74 (0.59–0.93)	1.13 (0.81–1.52)
Valvular heart surgery	8067 (1.4%)	1677 (3.8%)	< 0.001	0.34 (0.28–0.40)	0.67 (0.52–0.85)
Gastrointestinal neoplasm surgery	6057 (5.0%)	3399 (5.5%)	0.29	0.88 (0.78–0.98)	0.90 (0.78–1.04)
Craniotomy for neoplasm	3679 (2.0%)	1149 (3.0%)	0.07	0.80 (0.63–1.00)	0.96 (0.67–1.34)
Elective abdominal aortic aneurysm surgery	3048 (3.6%)	929 (6.5%)	0.003	0.81 (0.67–0.97)	1.36 (1.05–1.74)
Other respiratory surgery	2518 (2.7%)	1165 (2.8%)	0.91	0.58 (0.46–0.74)	0.53(0.37–0.74)
Other gastrointestinal surgery	2413 (3.2%)	1216 (5.7%)	< 0.001	0.82 (0.65–1.02)	1.08 (0.85–1.36)
Other cardiovascular surgery	2094 (2.5%)	781 (4.5%)	0.01	0.53 (0.40–0.69)	0.74 (0.52–1.02)
Carotid endarterectomy	2298 (0.9%)	491 (1.4%)	0.32	0.59 (0.36–0.90)	0.76 (0.31–1.56)
Respiratory neoplasm surgery	1724 (3.3%)	793 (4.9%)	0.06	0.74 (0.56–0.95)	1.17 (0.84–1.59)
Coronary artery bypass grafting with valve surgery	1541 (3.3%)	486 (3.7%)	0.67	0.53 (0.39–0.69)	0.47 (0.28–0.74)
Orthopaedic surgery	1248 (3.1%)	700 (4.7%)	0.34	0.49 (0.35–0.66)	0.66 (0.46–0.92)
Other neurosurgery	1343 (1.6%)	446 (1.8%)	0.83	0.46 (0.29–0.70)	0.47 (0.21–0.93)
Laminectomy or spinal cord surgery	1215 (1.6%)	559 (1.4%)	1.00	0.52 (0.31–0.81)	0.38 (0.16–0.74)
Renal neoplasm surgery	1072 (1.9%)	579 (2.8%)	0.29	0.51 (0.31–0.79)	0.73 (0.42–1.17)

APACHE III-j = Acute Physiology and Chronic Health Evaluation III, 10th iteration. ◆

10 Observed mortality and APACHE III-j standardised mortality ratios (SMRs) on weekdays and weekends for the 15 most prevalent elective surgical diagnoses

Elective surgical procedure	Weekdays, no. (% observed mortality)	Weekends, no. (% observed mortality)	*P* for observed mortality comparison	Weekdays SMR (95% CI)	Weekends SMR (95% CI)
Coronary artery bypass grafting	9630 (1.2%)	182 (2.2%)	< 0.001	0.83 (0.69–1.00)	1.05 (0.28–2.60)
Coronary artery bypass grafting with valve surgery	2007 (3.4%)	20 (0.0%)	0.005	0.51 (0.40–0.65)	0.00 (0.00–2.00)
Carotid endarterectomy	2753 (1.0%)	36 (2.8%)	0.05	0.61 (0.40–0.89)	0.88 (0.22–4.60)
Craniotomy for neoplasm	4750 (2.2%)	78 (5.1%)	0.14	0.82 (0.67–1.00)	1.83 (0.50–4.50)
Elective abdominal aortic aneurysm surgery	3918 (4.2%)	59 (5.1%)	1.00	0.94 (0.80–1.00)	0.97 (0.20–2.70)
Gastrointestinal neoplasm surgery	8873 (5.2%)	583 (4.6%)	0.39	0.89 (0.81– 0.97)	0.79 (0.52–1.10)
Laminectomy or spinal cord surgery	1702 (1.5%)	72 (1.4%)	0.14	0.48 (0.31–0.70)	0.27 (0.07–1.50)
Orthopaedic surgery	1788 (3.6%)	160 (5.0%)	0.18	0.54 (0.42–0.69)	0.60 (0.26–1.15)
Other cardiovascular surgery	2698 (2.6%)	177 (10.2%)	1.00	0.53 (0.41–0.66)	1.16 (0.70–1.79)
Other gastrointestinal surgery	3328 (3.7%)	301 (7.3%)	0.31	0.86 (0.72–1.00)	1.50 (0.95–2.20)
Other neurosurgery	1737 (1.6%)	52 (5.8%)	0.10	0.44 (0.29–0.64)	0.79 (0.16–2.18)
Other respiratory surgery	3517 (2.7%)	166 (4.8%)	0.74	0.56 (0.46–0.69)	0.54 (0.23–1.05)
Renal neoplasm surgery	1629 (2.2%)	22 (0.0%)	0.63	0.60 (0.42–0.83)	0.00 (0.00–1.90)
Respiratory neoplasm surgery	2482 (3.8%)	35 (5.7%)	1.00	0.86 (0.70–1.00)	0.83 (0.10–2.70)
Valvular heart surgery	9636 (1.8%)	108 (3.7%)	0.38	0.40 (0.34–0.46)	0.50 (0.13–1.20)

APACHE III-j = Acute Physiology and Chronic Health Evaluation III, 10th iteration. ◆

It is not known whether our findings can be generalised to all hospitals. The ANZICS APD currently collates data from 193 ICUs in three countries and we expect that work practices in these ICUs and hospitals are heterogeneous. However, our study used data from 41 Australian hospitals, and all hospital types and all regions of Australia were represented.

Finally, it is possible that practices have changed over the 9-year study period examined and it is unknown whether our findings are relevant to contemporary intensive care practice.

Elective surgical patients admitted to the ICU after hours and on weekends were more likely to die than similar patients admitted in hours and on weekdays.

Whether this is due to surgery occurring after hours and on weekends that could have been conducted more safely during routine working hours will require further investigation. Individual regions, hospitals or ICUs should investigate whether these findings are relevant to their own practice. We recommend a prospective study to determine how our findings relate to resource availability and staffing.

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COMPETING INTERESTS

None identified.

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