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Is the weekend effect really ubiquitous? Retrospective clinical cohort analyses of 30-day mortality by day of week and time of day using linked population data from New South Wales, Australia

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ABSTRACT

Objective

To examine the associations between day of week and time of admission and 30-day mortality for six clinical conditions: ischaemic and haemorrhagic stroke, acute myocardial infarction, pneumonia, chronic obstructive pulmonary disease and congestive heart failure.

Design

Retrospective population-based cohort analyses. Hospitalisation records were linked to emergency department and deaths data. Logistic regression models were used, adjusting for casemix and clustering within hospitals.

Setting

All hospitals in New South Wales, Australia from July 2009 to June 2012.

Participants

Patients admitted to hospital with a primary diagnosis for one of the six clinical conditions examined.

Outcome measures

The adjusted odds ratios for all-cause mortality within 30 days of admission, by day of week and time of day.

Results

A total of 148,722 patients were included in the study, with 17,721 deaths within 30 days of admission. Day of week of admission was not associated with significantly higher adjusted probability of death for five of the six conditions. There was significant variation in mortality for chronic obstructive pulmonary disease by day of week, however, this was not consistent with a weekend effect (Thursday: OR 1.29, 95% CI 1.12–1.48; Friday: OR 1.25, 95%CI 1.08–1.44; Saturday: OR 1.18, 95% CI 1.02–1.37; Sunday OR 1.05, 95% CI 0.90–1.22; compared to Monday). There was evidence for a night effect for patients admitted for stroke (ischaemic: OR 1.30, 95% CI 1.17–1.45; haemorrhagic: OR 1.58, 95% CI 1.40–1.78).

Conclusions

Mortality outcomes for these conditions, adjusted for casemix, do not vary in accordance with the weekend effect hypothesis. Our findings support a growing body of evidence that questions the ubiquity of the weekend effect.

Keywords

Weekend effect, night effect, out-of-hours effect, stroke, AMI, pneumonia, COPD, CHF

Article summary

Strengths and limitations of this study

- The examined conditions encompass a range of time sensitivity, interventions, acuity and prognosis, providing a gradient to assess potential causality of association.
- The use of linked hospital admission and emergency department (ED) data allowed complete coverage of hospital admissions for the state, while minimising misclassification bias from time spent in ED and maximising validity and quality of diagnosis and comorbidity data.
- The use of clinical cohorts of patients allows more precise adjustment for casemix than non-specific admissions.
- Linkage to the Deaths Register allowed the capture of 30-day all-cause mortality.
- Mortality is a standard indicator, but it may be a blunt tool, and other outcomes may be more sensitive to variation in patient outcomes.

INTRODUCTION

In recent years, researchers and policy makers have shown growing interest in the 'weekend effect', examining whether patients admitted to hospital at the weekend experience worse outcomes compared to patients admitted during the week. This effect has been observed in numerous studies of health systems around the world, for a wide range of conditions and procedures.[1-5] Studies have also observed a 'night effect', suggesting that the phenomenon may extend to out-of-hours presentation more broadly.[1-4]

Considerable uncertainty remains as to the cause of the apparent effect of weekend and night-time (hereafter collectively 'out-of-hours') presentation on patient outcomes. Two main hypotheses have been proposed to explain the observed variation: these focus on healthcare service quality and on patient characteristics.[2] The first hypothesis posits that the poorer outcomes seen among patients admitted on the weekend are explained by lower quality of care out-of-hours. More specifically, putative factors include lower staffing levels, fewer senior consultants and specialists, and reduced availability of diagnostic procedures.[3] This hypothesis gained considerable traction with policy makers and has contributed to the recent, controversial push towards seven day hospital services in the UK.[6]

The second hypothesis proposes that the weekend effect is largely attributable to patient characteristics, and at least partly an artefact of the data. There is little clear evidence that higher mortality is a consequence of staffing levels[6], and a number of studies have found no significant correlation between consultant seniority or specialist availability and mortality.[7-10] There is also an increasing body of evidence to suggest that the weekend effect dissipates after adjustment for casemix[11], arrival by ambulance as a proxy for illness severity[12] and a higher severity threshold for admission.[11] This phenomenon may also be influenced by self-selection, whereby patients wait until the weekend to present to hospital

and may therefore present with more advanced disease, and less comprehensive note-taking on the weekend limiting the ability to risk-adjust.[13]

The night effect is less extensively studied than the weekend effect, and reasons for the night effect are usually presumed to be the similar to the weekend effect. The few studies that have examined the effects of out-of-hours presentation on mortality in Australia have had mixed results.[3,4,14,15] Previous studies have been limited by using in-hospital mortality only and therefore not capturing deaths that occurred post-discharge[16], reduced ability to adequately risk adjust by focusing on clinically non-specific admissions.[3,15,17] Further, previous studies have often relied on unlinked emergency department (ED) data[4], which contain limited and largely incomplete and inaccurate information on principle diagnosis and comorbidity, or unlinked hospitalisation data, which may be affected by misclassification bias due to time spent in waiting in ED prior to admission.[14,17]

Overall, previous studies have shown that the out-of-hours effect does not apply to all clinical presentations and procedures.[1-4,7] It is therefore beneficial to investigate conditions for which we can expect that the weekend is more likely to occur, based on theoretical grounds, on clinical plausibility or on previous evidence.[2]

We investigated the existence of the weekend effect and the night effect for acute hospitalisations for various conditions, comprising ischaemic stroke, haemorrhagic stroke, AMI, pneumonia, COPD, and congestive heart failure (CHF), across all hospitals in NSW. These conditions provide insights into a range of aspects of healthcare, including timely delivery of interventions, surgical services, differences in acuity and prognosis, and provide a gradient to assess potential causality of association as they vary in the importance of immediate care. We predicted that if day and time effects exist, they would show strongest effects for the most urgent conditions (stroke and AMI), and be weakest for patients with the

least urgent conditions (pneumonia and COPD). We hypothesized that presentations on Saturdays and Sundays would show higher 30-day mortality for the six conditions than presentations that occurred during the week, and that night-time presentations would show higher mortality than presentations that occurred during the day.

METHODS

Retrospective cohort analyses were performed for the six indicator conditions. Cohorts were identified from all admissions to NSW public and private hospitals for the period of 1 July 2009 to 30 June 2012, extracted from the NSW Admitted Patient Data Collection, which is a census of all hospital admissions in NSW. These data were linked to emergency department (ED) attendances in all NSW public hospitals recorded in the Emergency Department Data Collection, representing approximately 85% of all emergency presentations in NSW.[18,19] Emergency department data were linked to allow the capture of the start day and time of the patients' contact with the hospital system for the episode of illness, minimising any bias imposed by time spent in the emergency department that may affect the day and time of hospitalisation, since patients may spend longer in the ED before admission at night or at weekends. Mortality data were obtained from the NSW Deaths Register. Data were linked by the NSW Centre for Health Record Linkage using probabilistic methods.

The principal diagnosis in the patient record, coded using International Classification of Diseases 10th revision Australian modification, was used to identify each clinical cohort. Only records coded as acute and emergency, which were complete for key fields (age, sex, admission date, separation date) were included. Patients aged less than 15 years (ischaemic stroke, haemorrhagic stroke, AMI), 18 years (pneumonia) or 45 years (COPD, CHF) were excluded, consistent with existing mortality indicator definitions for these conditions.[20,21]

AMI patients with a non-specific infarction were excluded to allow adjustment for STEMI, consistent with the existing indicator definition.[20,21] Transfers and multiple admissions were identified for each patient to avoid double counting. Contiguous episodes of care separated by transfers were combined into single periods of care, the most recent of which was used for analysis.

Mortality was defined as death (in or out of hospital) occurring within 30 days of the start of the period of care. The day of week of presentation was defined as the first day of contact with the hospital system for the period of care (either hospital admission or ED presentation). An ED presentation was considered relevant for the hospital admission if it occurred on the same day, or previous day, as the hospital admission. Same day ED presentations were only included if the time was recorded as before the hospital admission time. Night time presentation was defined as first presentation between 18:00 and 07:59, using hospital admission time or ED presentation time as described.

Mixed effects logistic regression models were used to investigate the associations between day of week and time of presentation with mortality. To account for clustering of patients within hospitals, hospitals were considered as random effects in the regression models. Risk adjustment was performed to account for casemix factors including age (continuous, tested for curvilinearity), sex, financial year and comorbidities. Condition-specific comorbidity sets defined by the Australian Commission for Safety and Quality in Health Care were used as the basis for building risk adjustment models for each condition, where available (ischaemic stroke, haemorrhagic stroke, AMI, pneumonia), while COPD, CHF used Elixhauser comorbidities.[20] Availability of thrombolysis treatment was also considered as a predictive variable for ischaemic stroke, and STEMI status was considered for AMI. Comorbidities were captured across all hospital admissions over a one year period prior to the index admission.

Models were selected using backwards selection.[22] Factors with a *p*-value of less than 0.2 in the univariate analyses were included in the initial full models. Variables with a *p*-value of less than 0.05 were retained in the model. Variables that were not significant at the 20% level in the univariate models were then checked for significance in the backwards-selected model, and retained in the final model where $p < 0.05$. Overall performance of the models was assessed using c-statistics. Statistical analyses were performed using SAS v9.4 (SAS Institute Inc., Cary, NC, USA) and STATA v12.1 (StataCorp LP, Texas, USA).

RESULTS

There were a total of 213,834 acute, emergency hospital admissions for the conditions of interest during the study period. There were 10,658 admissions excluded due to not meeting eligibility criteria for age, and 2161 patients were excluded who had a non-specified AMI. After accounting for transfers and multiple admissions, there were 148,722 patients were included in the study (table 1). There were 17,721 deaths within 30 days of admission (11.9%). A total of 127,268 admissions were linked to an ED presentation (85.6%). The clinical cohorts comprised between 5,740 (haemorrhagic stroke) and 44,508 (pneumonia) patients that were admitted or presented to between 133 and 183 hospitals. Characteristics of patients are provided by day of week and time of day of arrival in table 2.

The most frequent day of admission was Monday, while Saturdays and Sundays had fewer admissions than weekdays for all conditions. More patients were admitted during daytime than at night, regardless of condition.

There were no significant associations in the univariate analyses between mortality and day of week for haemorrhagic stroke, AMI, pneumonia, or CHF (table 3). There was

significant variation in unadjusted 30-day mortality by day of week for ischaemic stroke and COPD, however this did not show a strict 'weekend effect' (ischaemic stroke: Friday, Saturday and Sunday significantly higher than Monday; COPD: Thursday, Friday and Saturday significantly higher than Monday).

There was no significant difference in 30-day mortality by day of week after adjustment for casemix and other factors for five of the six conditions (table 4, figure 1). While Friday and Sunday presentations had significantly higher mortality than Monday for ischaemic stroke, overall day of the week was not significant in the model. Significant variation in mortality by day of week for COPD was not consistent with a weekend effect (with Thursday, Friday and Saturday being associated with higher mortality compared with Monday).

There was evidence for higher mortality among ischaemic and haemorrhagic stroke patients admitted/presented to hospital overnight. This night effect was observed in both the unadjusted and adjusted analyses (table 3, table 4). There was no evidence of increased mortality among night admissions/presentations for the other conditions. There were no significant interactions between day of week and time of day for any of the conditions.

The models performed moderately well, with c-statistics ranging from 0.68 to 0.82 (ischaemic stroke: 0.73, haemorrhagic stroke: 0.68, AMI: 0.81, pneumonia: 0.82, COPD: 0.74, CHF: 0.72).

DISCUSSION

Main findings

Mortality outcomes do not vary in accordance with the weekend effect, after adjusting for casemix, for patients admitted to hospital with stroke, AMI, pneumonia, COPD, or CHF in NSW. We found increased mortality for stroke patients presenting to hospital at night, with no evidence for the night effect for the remaining conditions.

Our findings support a growing body of evidence that disputes the ubiquity of the weekend effect.[6,11,13,14,23,24] Of the six conditions investigated in this study, only ischaemic stroke and COPD showed significant variation in crude mortality risk by day of week of presentation. Significant variation remained after risk adjustment for COPD only, and this was not consistent with predictions for the weekend effect, with the highest odds of death occurring on Thursday and Friday. This is consistent with studies which have shown more complex patterns of temporal variation in that there are some days/times that are different but not specifically 'the weekend'.[24]

While findings from previous studies for stroke[10,13,25,26], AMI[14,27] and COPD[14,28] have been conflicting, our results are consistent with those that found no weekend effect (stroke[1,13,24,29], AMI[1,30], COPD[14]). Few studies have examined the weekend effect for patients with pneumonia, however our findings contrast with those of Suissa *et al.*[31], which showed higher in-hospital mortality for in-patients staying over the weekend with either pneumonia or COPD, regardless of day of admission.

We found a significantly higher adjusted risk of death for ischaemic and haemorrhagic stroke patients admitted at night compared to those admitted during the day. This is consistent with other studies of stroke.[24,25] This finding may reflect factors specific to

stroke, such as that strokes occurring at night may take longer to recognise due to reduced activity, and may result in delayed seeking of treatment and therefore higher mortality. That we only observed the night effect for stroke patients suggests that this variation is probably not attributable to system-wide deficiencies. However, further research to explore reasons for the increase in mortality for stroke patients admitted at night, and the observed variation in mortality for COPD by day of presentation, and will help to understand whether these excess deaths are preventable.

Strengths and limitations

The conditions we have examined are useful indicators that encompass a range of time sensitivity, interventions, acuity and prognosis. The use of clinical cohorts of patients allows more precise adjustment for casemix than considering non-specific admissions or presentations. We found no weekend effect either in conditions expected to be less sensitive to reduced staffing and services, nor among the more severe, acute conditions, which confers confidence in the validity of our findings.

The use of linked data provides complete coverage of hospital admissions for the conditions of interest in NSW, and minimises several potential biases. Linkage to the Deaths Register provided advantages over many previous studies, capturing death outside of hospital to provide a more complete picture of mortality. While most studies use either hospitalisation data or ED data, the use of linked data in this study minimises misclassification bias in day and time of presentation caused by time spent in ED prior to admission. The use of hospitalisation data from the index and historical admissions of the patients allowed us to maximise the detail and quality of diagnoses and comorbidities. Further, that analysis of three years' complete population data for NSW meant that our cohorts ranged from over 5000 to 44,000, which should provide sufficient power to detect statistically significant differences.

However, it would be interesting to consider the results on the level of individual hospitals, as hospitals may vary in quality of care on weekends, which may be masked in this type of global analysis.

Mortality is a useful indicator for health system performance and for evaluating unwarranted variation. However, it is an extreme outcome, and it may be a blunt tool that could mask some variation in patient outcomes. Further research is needed to determine whether the lower staffing levels and resource access on weekends and out-of-hours may exhibit effects on other outcomes or processes, such as adverse events, delays in care, or other quality indicators.

CONCLUSION

We found no evidence for a weekend effect in 30-day mortality for patients admitted with ischaemic or haemorrhagic stroke, AMI, pneumonia, COPD, or CHF. The finding of a night effect for stroke, and variation between days for COPD, highlights that temporal variation in patient outcomes is more complex than the weekend effect, and may have a variety of causes. Our study provides evidence that differences in services provided out-of-hours does not cause temporal variation in mortality outcomes, and suggest that causal links proposed between about hospital staffing and services on weekends and patient mortality may be unwarranted.

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Contributors

HJB, SMP, HYC, JK, KS and JFL contributed to the study design. HJB and SMP cleaned and analysed the data and HJB produced the figure and tables. All authors contributed to the interpretation of the results. HJB drafted the manuscript, and all authors contributed to revising the manuscript. All authors approved the final version of the manuscript.

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Competing interests

We declare no competing interests.

Data sharing statement

Privacy restrictions for the datasets used in this study prohibit free online availability. Access to these data may be sought from the data custodians, the New South Wales Ministry of Health.

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Table 1. Numbers of patients admitted to hospital in NSW between July 2009 and June 2012 for the conditions examined, number and percentage of deaths within 30 days, by day and time of presentation. Only patients who met the study inclusion criteria are counted.

Condition	Day of week							Time of Day		Total
	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	Day	Night	
Ischaemic stroke (145 hospitals)										
Admissions[1]	2240	2168	2082	2070	2010	1868	1916	9858	4496	14354
Deaths	257	281	281	247	291	267	287	1241	670	1911
30-day mortality (%)	11.5	13.0	13.5	11.9	14.5	14.3	15.0	12.6	14.9	13.3
Haemorrhagic stroke (133 hospitals)										
Admissions[1]	905	894	818	830	853	703	737	3676	2064	5740
Deaths	303	296	288	255	286	254	264	1127	819	1946
30-day mortality (%)	33.5	33.1	35.2	30.7	33.5	36.1	35.8	30.7	39.7	33.9
Acute myocardial infarction (172 hospitals)										
Admissions[1]	4493	4332	4248	4241	4388	4004	3869	16309	13266	29575
Deaths	331	321	320	337	347	292	290	1233	1005	2238
30-day mortality (%)	7.4	7.4	7.5	8.0	7.9	7.3	7.5	7.6	7.6	7.6
Pneumonia (183 hospitals)										
Admissions[1]	7097	6354	6419	6366	6489	5754	6029	27382	17126	44508
Deaths	775	627	703	677	679	667	656	2929	1855	4784
30-day mortality (%)	10.9	9.9	11.0	10.6	10.5	11.6	10.9	10.7	10.8	10.8
Chronic obstructive pulmonary disease (177 hospitals)										
Admissions[1]	4794	4272	4193	4114	4116	3664	3786	17674	11265	28939
Deaths	459	436	426	476	479	408	367	1891	1160	3051
30-day mortality (%)	9.6	10.2	10.2	11.6	11.6	11.1	9.7	10.7	10.3	10.5
Congestive heart failure (177 hospitals)										
Admissions[1]	4325	3935	3828	3799	3780	2962	2977	16046	9560	25606
Deaths	628	568	577	549	566	462	441	2369	1422	3791
30-day mortality (%)	14.5	14.4	15.1	14.5	15.0	15.6	14.8	14.8	14.9	14.8

[1]Day of admission or preceding/related emergency department presentation

Table 2. Demographic and clinical characteristics of patients with acute, emergency hospital admissions for the conditions of interest by time of admission, NSW, July 2009 - June 2012. Conditions included are ischaemic stroke, haemorrhagic stroke, acute myocardial infarction, pneumonia, chronic obstructive pulmonary disease, and congestive heart failure.

Characteristic	Day of week		Time of day	
	Weekday	Weekend	Day	Night
	N = 110,453 (%)	N = 38,269 (%)	N = 90,945 (%)	N = 57,777 (%)
Age groups				
15-39	4,361 (4.0)	1,580 (4.1)	3,501 (3.9)	2,440 (4.2)
40-59	16,623 (15.1)	5,804 (15.2)	13,044 (14.3)	9,383 (16.2)
60-79	46,943 (42.5)	16,178 (42.3)	38,593 (42.4)	24,528 (42.5)
80+	42,526 (38.5)	14,707 (38.4)	35,807 (39.4)	21,426 (37.1)
Age (years; median (IQR))	75.8 (63.9-84.1)	75.8 (63.7-84.2)	76.2 (64.5-84.3)	75.1 (62.9-83.9)
Gender				
Female	50,318 (45.6)	17,407 (45.5)	42,300 (46.5)	25,425 (44.0)
Male	60,135 (54.4)	20,862 (54.5)	48,645 (53.5)	32,352 (56.0)
Charlson comorbidity index				
0	74,780 (67.7)	25,954 (67.8)	61,248 (67.4)	39,486 (68.3)
1-2	28,678 (26.0)	9,859 (25.8)	23,930 (26.3)	14,607 (25,3)
3+	6,995 (6.3)	2,456 (6.4)	5,767 (6.3)	3,684 (6.4)
Admitted via ED	93,799 (84.9)	33,469 (87.5)	76,835 (84.5)	50,433 (87.3)

Day = 08:00-17:59, night = 18:00-07:59, ED = emergency department

Table 3. Unadjusted odds ratios for 30-day mortality for day of week and time of day of hospital admission or ED presentation. Hospital is included as a random effect.

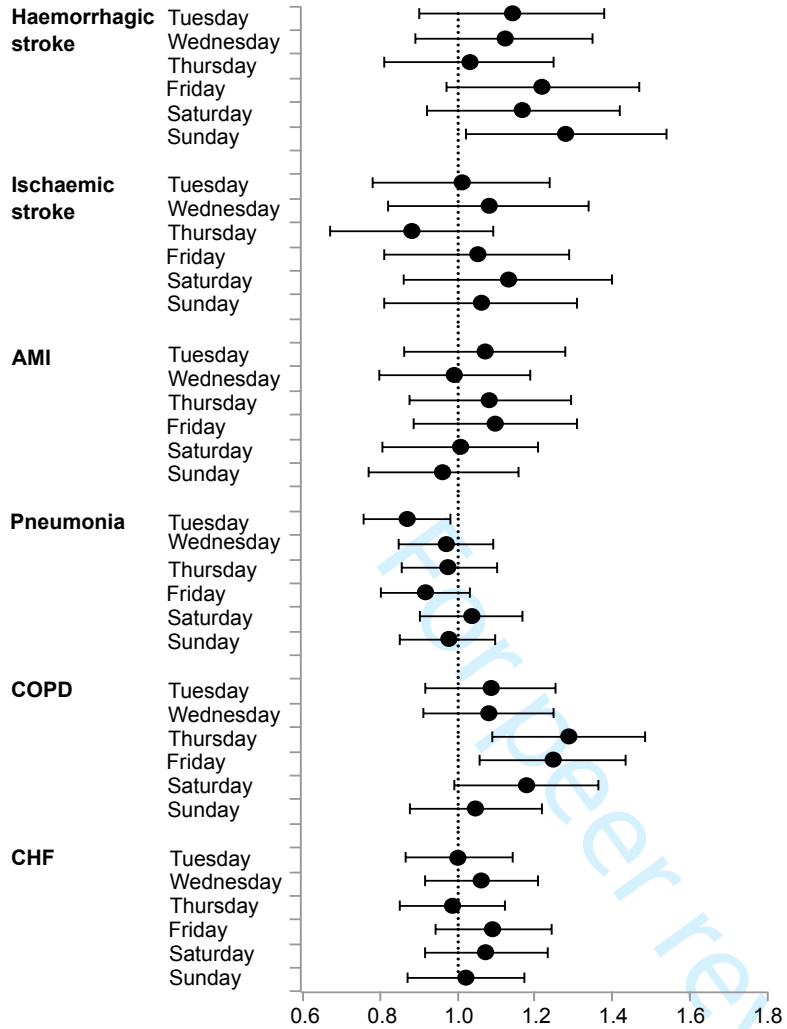
Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value
Day of week		0.006		0.271		0.879		0.092		0.003		0.813
Monday	Reference		Reference		Reference		Reference		Reference		Reference	
Tuesday	1.14 (0.95-1.37)	0.152	0.97 (0.80-1.19)	0.789	1.00 (0.86-1.18)	0.964	0.90 (0.80-1.00)	0.052	1.07 (0.93-1.23)	0.332	0.99 (0.88-1.12)	0.927
Wednesday	1.20 (1.00-1.44)	0.051	1.07 (0.88-1.31)	0.493	1.02 (0.87-1.20)	0.787	1.01 (0.90-1.12)	0.916	1.07 (0.93-1.23)	0.354	1.05 (0.93-1.18)	0.462
Thursday	1.04 (0.86-1.25)	0.668	0.87 (0.71-1.07)	0.194	1.08 (0.92-1.27)	0.321	0.97 (0.87-1.08)	0.600	1.24 (1.08-1.42)	0.002	0.99 (0.88-1.13)	0.929
Friday	1.30 (1.09-1.56)	0.004	1.00 (0.82-1.23)	0.969	1.08 (0.92-1.26)	0.355	0.95 (0.85-1.06)	0.346	1.24 (1.08-1.42)	0.002	1.04 (0.92-1.17)	0.566
Saturday	1.28 (1.07-1.54)	0.008	1.12 (0.91-1.38)	0.288	0.99 (0.84-1.16)	0.887	1.07 (0.96-1.20)	0.211	1.18 (1.02-1.36)	0.023	1.09 (0.96-1.24)	0.195
Sunday	1.35 (1.12-1.61)	0.001	1.10 (0.90-1.36)	0.352	1.02 (0.86-1.20)	0.843	1.00 (0.89-1.12)	0.981	1.01 (0.88-1.17)	0.866	1.03 (0.90-1.17)	0.712
Time of day		0.001		<0.001		0.967		0.750		0.231		0.794
Day	Reference		Reference		Reference		Reference		Reference		Reference	
Night	1.22 (1.10-1.35)		1.49 (1.33-1.67)		1.00 (0.92-1.09)		1.01 (0.95-1.07)		0.95 (0.88-1.03)		1.01 (0.94-1.08)	

Table 4. Adjusted odds-ratios for 30-day mortality by day of week and time of day of hospital admission or ED presentation. Models were adjusted for age, sex, and comorbidities (final model results for all variables are provided in supplementary table S1). Hospital is included as a random effect.

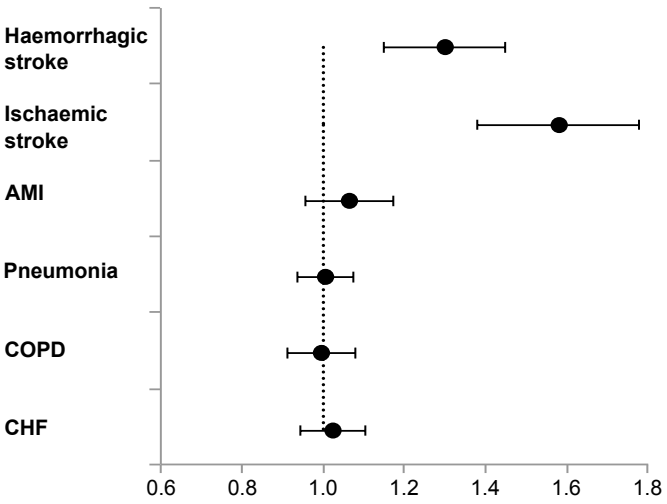
Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value
Day of week		0.136		0.404		0.741		0.136		0.003		0.660
Monday	Reference		Reference		Reference		Reference		Reference		Reference	
Tuesday	1.14 (0.95-1.38)	0.167	1.01 (0.82-1.24)	0.926	1.07 (0.90-1.28)	0.451	0.87 (0.77-0.98)	0.023	1.09 (0.94-1.25)	0.269	1.00 (0.88-1.14)	0.971
Wednesday	1.12 (0.93-1.35)	0.242	1.08 (0.88-1.34)	0.451	0.99 (0.83-1.19)	0.936	0.97 (0.86-1.09)	0.606	1.08 (0.93-1.25)	0.298	1.06 (0.93-1.21)	0.373
Thursday	1.03 (0.84-1.25)	0.803	0.88 (0.71-1.09)	0.228	1.08 (0.91-1.29)	0.371	0.98 (0.87-1.10)	0.720	1.29 (1.12-1.48)	0.001	0.99 (0.87-1.12)	0.829
Friday	1.22 (1.01-1.47)	0.039	1.05 (0.85-1.29)	0.653	1.10 (0.92-1.31)	0.303	0.92 (0.81-1.03)	0.156	1.25 (1.08-1.44)	0.002	1.09 (0.96-1.24)	0.175
Saturday	1.17 (0.96-1.42)	0.112	1.13 (0.91-1.40)	0.275	1.01 (0.84-1.21)	0.941	1.03 (0.92-1.17)	0.578	1.18 (1.02-1.37)	0.030	1.07 (0.94-1.23)	0.315
Sunday	1.28 (1.06-1.54)	0.012	1.06 (0.85-1.31)	0.595	0.96 (0.80-1.16)	0.681	0.97 (0.86-1.10)	0.670	1.05 (0.90-1.22)	0.550	1.02 (0.89-1.17)	0.784
Time of day		<0.001		<0.001		0.200		0.861		0.905		0.525
Day	Reference		Reference		Reference		Reference		Reference		Reference	
Night	1.30 (1.17-1.45)		1.58 (1.40-1.78)		1.07 (0.97-1.17)		1.01 (0.94-1.08)		1.00 (0.92-1.08)		1.02 (0.95-1.10)	

Figure 1. a) Adjusted odds ratios for 30-day mortality for day of week of presentation by clinical condition. Reference group is Monday (dotted line). b) adjusted odds ratios for 30-day mortality for presentation to hospital at night compared to during the day, by clinical condition. AMI = acute myocardial infarction, COPD = chronic obstructive pulmonary disease, CHF = congestive heart failure.

a)



b)



SUPPLEMENTARY MATERIAL

Table S1. Final multivariable model results for 30-day mortality by day of week and time of day of hospital or ED presentation for ischaemic and haemorrhagic stroke, AMI, pneumonia, COPD and CHF.

Condition Variable	Odds Ratio (95% CI)	*p*-value	Condition Variable	Odds Ratio (95% CI)	*p*-value
Ischaemic stroke			**Haemorrhagic stroke**		
Day of week (ref = Mon)		0.136	Day of week (ref = Mon)		0.404
Tuesday	1.14 (0.95-1.38)	0.167	Tuesday	1.01 (0.82-1.24)	0.926
Wednesday	1.12 (0.93-1.35)	0.242	Wednesday	1.08 (0.88-1.34)	0.451
Thursday	1.03 (0.84-1.25)	0.803	Thursday	0.88 (0.71-1.09)	0.228
Friday	1.22 (1.01-1.47)	0.039	Friday	1.05 (0.85-1.29)	0.653
Saturday	1.17 (0.96-1.42)	0.112	Saturday	1.13 (0.91-1.40)	0.275
Sunday	1.28 (1.06-1.54)	0.012	Sunday	1.06 (0.85-1.31)	0.595
Night	1.30 (1.17-1.45)	<0.001	Night	1.58 (1.40-1.78)	<0.001
Sex (ref = male)	1.32 (1.19-1.47)	<0.001	Sex (ref = male)	1.39 (1.24-1.56)	<0.001
Age (centred)	1.06 (1.06-1.07)	<0.001	Age (centred)	1.04 (1.04-1.05)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001	Heart	1.47 (1.16-1.87)	0.001
Kidney	1.70 (1.48-1.97)	<0.001	Malignancy	2.75 (2.20-3.45)	<0.001
Heart	1.95 (1.66-2.28)	<0.001	Previous H-stroke	0.61 (0.48-0.77)	<0.001
Malignancy	2.64 (2.15-3.24)	<0.001			
AMI			**Pneumonia**		
Day of week (ref = Mon)		0.741	Day of week (ref=Mon)		0.136
Tuesday	1.07 (0.90-1.28)	0.451	Tuesday	0.87 (0.77-0.98)	0.023
Wednesday	0.99 (0.83-1.19)	0.936	Wednesday	0.97 (0.86-1.09)	0.606

Thursday	1.08 (0.91-1.29)	0.371
Friday	1.10 (0.92-1.31)	0.303
Saturday	1.01 (0.84-1.21)	0.941
Sunday	0.96 (0.80-1.16)	0.681
Night	1.07 (0.97-1.17)	0.200
Age (centred)	1.06 (1.05-1.06)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
STEMI	2.71 (2.44-3.01)	<0.001
Dementia	2.10 (1.77-2.48)	<0.001
Hypotension	1.29 (1.14-1.46)	<0.001
Shock	9.38 (7.79-11.30)	<0.001
Kidney	2.32 (2.07-2.60)	<0.001
Heart	1.77 (1.58-1.98)	<0.001
Dysrhythmia	1.72 (1.55-1.90)	<0.001
Malignancy	2.38 (1.94-2.92)	<0.001
Hypertension	0.67 (0.61-0.74)	<0.001
Cerebrovascular	2.34 (1.95-2.81)	<0.001

Thursday	0.98 (0.87-1.10)	0.720
Friday	0.92 (0.81-1.03)	0.156
Saturday	1.03 (0.92-1.17)	0.578
Sunday	0.97 (0.86-1.10)	0.670
Night	1.01 (0.94-1.08)	0.861
Financial year (ref = 2009)		<0.001
2010	0.89 (0.82-0.96)	0.004
2011	0.73 (0.67-0.79)	<0.001
Age (centred)	1.05 (1.05-1.05)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
Dementia	2.66 (2.42-2.92)	<0.001
Hypotension	1.19 (1.09-1.30)	<0.001
Shock	4.03 (3.35-4.85)	<0.001
Kidney	1.93 (1.79-2.09)	<0.001
Heart	1.60 (1.48-1.74)	<0.001
Dysrhythmia	1.35 (1.24-1.46)	<0.001
Malignancy	5.53 (5.06-6.05)	<0.001
Hypertension	0.79 (0.73-0.86)	<0.001
Cerebrovascular	1.94 (1.69-2.22)	<0.001
Other COPD	1.17 (1.08-1.28)	<0.001
Liver disease	2.21 (1.78-2.76)	<0.001
Parkinsons	1.70 (1.36-2.12)	<0.001

COPD		
Day of week (ref = Mon)		0.003
Tuesday	1.09 (0.94-1.25)	0.269
Wednesday	1.08 (0.93-1.25)	0.298
Thursday	1.29 (1.12-1.48)	0.001

CHF		
Day of week (ref=Mon)		0.660
Tuesday	1.00 (0.88-1.14)	0.971
Wednesday	1.06 (0.93-1.21)	0.373
Thursday	0.99 (0.87-1.12)	0.829

Friday	1.25 (1.08-1.44)	0.002
Saturday	1.18 (1.02-1.37)	0.030
Sunday	1.05 (0.90-1.22)	0.550
Night	1.00 (0.92-1.08)	0.905
Financial year (ref = 2009)		<0.001
2010	0.77 (0.70-0.85)	<0.001
2011	0.50 (0.45-0.55)	<0.001
Prev acute COPD episode (ref = 0)^		<0.001
1 previous episode	1.67 (1.51-1.85)	<0.001
2 previous episodes	2.13 (1.86-2.43)	<0.001
3+ previous episodes	3.04 (2.69-3.44)	<0.001
Sex (ref=male)	0.82 (0.76-0.89)	<0.001
Age (centred)	1.03 (1.03-1.04)	<0.001
Age (squared)	1.00 (1.00-1.00)	0.013
CHF	1.47 (1.34-1.61)	<0.001
Pulmonary circ. disord.	1.66 (1.46-1.89)	<0.001
Neurological disord.	1.31 (1.05-1.64)	0.016
Diabetes (comp.)	0.83 (0.73-0.95)	0.005
Liver disease	1.98 (1.50-2.61)	<0.001
Metastatic cancer	3.06 (2.38-3.95)	<0.001
Solid tumour w/o metast.	1.42 (1.17-1.72)	<0.001
Weight loss	1.89 (1.68-2.11)	<0.001
Fluid/electrolyte dis.	1.81 (1.66-1.98)	<0.001
Psychoses	2.10 (1.47-3.00)	<0.001

Friday	1.09 (0.96-1.24)	0.175
Saturday	1.07 (0.94-1.23)	0.315
Sunday	1.02 (0.89-1.17)	0.784
Night	1.02 (0.95-1.10)	0.525
Financial year (ref = 2009)		<0.001
2010	0.89 (0.81-0.97)	0.009
2011	0.67 (0.62-0.74)	<0.001
Prev acute CHF episode (ref = 0)^		<0.001
1 previous episode	1.39 (1.26-1.52)	<0.001
2 previous episodes	1.70 (1.48-1.97)	<0.001
3+ previous episodes	2.52 (2.14-2.96)	<0.001
Sex (ref = male)	0.90 (0.84-0.97)	0.008
Age (centred)	1.05 (1.05-1.06)	<0.001
Age (squared)	1.00 (1.00-1.00)	0.003
Pulmonary circ. disord.	1.21 (1.09-1.35)	<0.001
Peripheral vascular disord.	1.19 (1.04-1.37)	0.013
Hypertension (comp/uncomp)	0.83 (0.77-0.90)	<0.001
Paralysis	1.65 (1.34-2.04)	<0.001
Neurological disorders	1.65 (1.39-1.97)	<0.001
Chronic pulmonary disease	1.23 (1.13-1.34)	<0.001
Renal failure	1.88 (1.73-2.03)	<0.001
Liver disease	2.78 (2.29-3.38)	<0.001
Lymphoma	2.24 (1.57-3.19)	<0.001
Metastatic cancer	3.07 (2.44-3.86)	<0.001
Coagulopathy	1.29 (1.15-1.46)	<0.001
Weight loss	1.61 (1.43-1.83)	<0.001
Fluid/electrolyte disorders	1.57 (1.45-1.69)	<0.001
Deficiency anaemia	0.78 (0.68-0.90)	<0.001

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Checked (page #)
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6-7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	8
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8, 19
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	20,21

		which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	considered
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10,11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	11,12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Is the weekend effect really ubiquitous? Retrospective clinical cohort analyses of 30-day mortality by day of week and time of day using linked population data from New South Wales, Australia

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Is the weekend effect really ubiquitous? Retrospective clinical cohort analyses of 30-day mortality by day of week and time of day using linked population data from New South Wales, Australia

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ABSTRACT

Objective

To examine the associations between day of week and time of admission and 30-day mortality for six clinical conditions: ischaemic and haemorrhagic stroke, acute myocardial infarction, pneumonia, chronic obstructive pulmonary disease and congestive heart failure.

Design

Retrospective population-based cohort analyses. Hospitalisation records were linked to emergency department and deaths data. Random effect logistic regression models were used, adjusting for casemix and taking into account clustering within hospitals.

Setting

All hospitals in New South Wales, Australia from July 2009 to June 2012.

Participants

Patients admitted to hospital with a primary diagnosis for one of the six clinical conditions examined.

Outcome measures

Adjusted odds ratios for all-cause mortality within 30 days of admission, by day of week and time of day.

Results

A total of 148,722 patients were included in the study, with 17,721 deaths within 30 days of admission. Day of week of admission was not associated with significantly higher likelihood of death for five of the six conditions after adjusting for casemix. There was significant variation in mortality for chronic obstructive pulmonary disease by day of week, however, this was not consistent with a strict weekend effect (Thursday: OR 1.29, 95% CI 1.12–1.48; Friday: OR 1.25, 95%CI 1.08–1.44; Saturday: OR 1.18, 95% CI 1.02–1.37; Sunday OR 1.05, 95% CI 0.90–1.22; compared to Monday). There was evidence for a night effect for patients admitted for stroke (ischaemic: OR 1.30, 95% CI 1.17–1.45; haemorrhagic: OR 1.58, 95% CI 1.40–1.78).

Conclusions

Mortality outcomes for these conditions, adjusted for casemix, do not vary in accordance with the weekend effect hypothesis. Our findings support a growing body of evidence that questions the ubiquity of the weekend effect.

Keywords

Weekend effect, night effect, out-of-hours effect, stroke, AMI, pneumonia, COPD, CHF

Article summary

Strengths and limitations of this study

- The examined conditions encompass a range of time sensitivity, interventions, acuity and prognosis, providing a gradient to assess potential causality of association.
- The use of linked hospital admission and emergency department (ED) data allowed complete coverage of hospital admissions for the state, while minimising misclassification bias from time spent in ED and maximising validity and quality of diagnosis and comorbidity data.
- The use of clinical cohorts of patients allows more precise adjustment for casemix than non-specific admissions.
- Linkage to the Deaths Register allowed the capture of 30-day all-cause mortality. While mortality is a standard indicator, other outcomes may be more sensitive to variation in patient outcomes.
- We focussed on the NSW health system as a whole and did not explore the possible weekend effect at hospital level.

INTRODUCTION

In recent years, researchers and policy makers have shown growing interest in the 'weekend effect', examining whether patients admitted to hospital at the weekend experience worse outcomes compared to patients admitted during the week. This effect has been observed in numerous studies of health systems around the world, for a wide range of conditions and procedures.[1-6] Studies have also observed a 'night effect', suggesting that the phenomenon may extend to out-of-hours presentation more broadly.[1-4]

Considerable uncertainty remains as to the cause of the apparent effect of weekend and night-time (hereafter collectively 'out-of-hours') presentation on patient outcomes. Two main hypotheses have been proposed to explain the observed variation: these focus on healthcare service quality and on patient characteristics.[2] The first hypothesis posits that the poorer outcomes seen among patients admitted on the weekend are explained by lower quality of care out-of-hours. More specifically, putative factors include lower staffing levels, fewer senior consultants and specialists, and reduced availability of diagnostic procedures.[3] This hypothesis gained considerable traction with policy makers and has contributed to the recent, controversial push towards seven day hospital services in the UK.[7]

The second hypothesis proposes that the weekend effect is largely attributable to patient characteristics, and at least partly an artefact of the data. There is little clear evidence that higher mortality is a consequence of staffing levels[7], and a number of studies have found no significant correlation between consultant seniority or specialist availability and mortality.[8-11] There is also an increasing body of evidence to suggest that the weekend effect dissipates after adjustment for casemix[12], arrival by ambulance as a proxy for illness severity[13] and a higher severity threshold for admission.[12] This phenomenon may also be

influenced by self-selection, whereby patients wait until the weekend to present to hospital and may therefore present with more advanced disease, and less comprehensive note-taking on the weekend limiting the ability to risk-adjust.[14]

The night effect is less extensively studied than the weekend effect, and reasons for the night effect are usually presumed to be similar to the weekend effect. The few studies that have examined the effects of out-of-hours presentation on mortality in Australia have had mixed results.[3,4,15,16] Previous studies have been limited by using in-hospital mortality only and therefore not capturing deaths that occurred post-discharge[17], reduced ability to adequately risk adjust by focusing on clinically non-specific admissions.[3,16,18] Further, previous studies have often relied on unlinked emergency department (ED) data[4], which contain limited and largely incomplete and inaccurate information on principle diagnosis and comorbidity, or unlinked hospitalisation data, which may be affected by misclassification bias due to time spent in waiting in ED prior to admission.[15,18]

Overall, previous studies have shown that the out-of-hours effect does not apply to all clinical presentations and procedures.[1-4,8] It is therefore beneficial to investigate conditions for which we can expect that the weekend is more likely to occur, based on theoretical grounds, on clinical plausibility or on previous evidence.[2]

We investigated the existence of the weekend effect and the night effect for acute hospitalisations for various conditions, comprising ischaemic stroke, haemorrhagic stroke, acute myocardial infarction (AMI), pneumonia, chronic obstructive pulmonary disease (COPD), and congestive heart failure (CHF), across all hospitals in New South Wales (NSW). These conditions provide insights into a range of aspects of healthcare, including timely delivery of interventions, surgical services, differences in acuity and prognosis, and provide a gradient to assess potential causality of association as they vary in the importance

of immediate care. We predicted that if day and time effects exist, they would show strongest effects for the most urgent conditions (stroke and AMI), and be weakest for patients with the least urgent conditions (pneumonia and COPD). We hypothesized that presentations on Saturdays and Sundays would show higher 30-day mortality for the six conditions than presentations that occurred during the week, and that night-time presentations would show higher mortality than presentations that occurred during the day.

METHODS

Retrospective cohort analyses were performed for the six indicator conditions. Cohorts were identified from all admissions to NSW public and private hospitals for the period of 1 July 2009 to 30 June 2012, extracted from the NSW Admitted Patient Data Collection, which is a census of all hospital admissions in NSW. These data were linked to emergency department (ED) attendances in all NSW public hospitals recorded in the Emergency Department Data Collection, representing approximately 85% of all emergency presentations in NSW.[19,20] Emergency department data were linked to allow the capture of the start day and time of the patients' contact with the hospital system for the episode of illness, minimising any bias imposed by time spent in the ED that may affect the day and time of hospitalisation, since patients may spend longer in the ED before admission at night or at weekends. Mortality data were obtained from the NSW Deaths Register. Data were linked by the NSW Centre for Health Record Linkage using probabilistic methods based on personal identifiers. The estimated false positive rate for the current version of the Master Linkage Key is 5 per 1000.[21]

The principal diagnosis in the patient record, coded using International Classification of Diseases 10th revision Australian modification, was used to identify each clinical cohort.

Only complete records of admissions coded as acute and emergency were included. The proportion of records excluded for missing values on key variables such as age, sex, date of admission and separation, type of care and emergency status was less than 0.1%. Patients aged less than 15 years (ischaemic stroke, haemorrhagic stroke, AMI), 18 years (pneumonia) or 45 years (COPD, CHF) were excluded, consistent with existing mortality indicator definitions for these conditions, due to low mortality rates among these groups.[22,23] AMI can be classified as ST-elevated myocardial infarction (STEMI) or non-ST elevated myocardial infarction (non-STEMI) based on the electrocardiogram reading, or unspecified AMI when diagnostic records are unavailable. STEMI is associated with higher mortality at 30 days compared to non-STEMI, and the unspecified group is a heterogeneous mix of critically unwell patients who died before their AMI could be specified and patients for whom diagnostic records were less precise, so AMI patients with a non-specific infarction were excluded to allow adjustment for STEMI.[22,23] Transfers and multiple contiguous hospitalisations were considered as a single period of care. For patients with multiple periods of care during the study period, only the last period of care was included in the analyses.

Mortality was defined as death (in or out of hospital) occurring within 30 days of the start of the period of care. The day of week of presentation was defined as the first day of contact with the hospital system for the period of care (either hospital admission or ED presentation). Patients dead on arrival to ED and not admitted to hospital were excluded. An ED presentation was considered relevant for the hospital admission if it occurred on the same day, or previous day, as the hospital admission. Same day ED presentations were only included if the time was recorded as before the hospital admission time. In this study, the weekend comprises Saturday and Sunday, while weekdays are defined as Monday through Friday. Night time presentation was defined as first presentation between 18:00 and 07:59, using hospital admission time or ED presentation time as described.

Random effects logistic regression models were used to investigate associations between day of week, or time of presentation, with mortality. To account for clustering of patients within hospitals, hospitals were considered as random effects in the regression models. Risk adjustment was performed to account for casemix factors including age (continuous, tested for curvilinearity), sex, year and comorbidities. Condition-specific comorbidity sets defined by the Australian Commission for Safety and Quality in Health Care were used as the basis for building risk adjustment models for each condition, where available (ischaemic stroke, haemorrhagic stroke, AMI, pneumonia), while COPD and CHF used Elixhauser comorbidities.[22] Availability of thrombolysis treatment was also considered as a predictive variable for ischaemic stroke, and STEMI status was considered for AMI. Comorbidities were captured across all hospital admissions over a one year period prior to the index admission. Interactions between day of the week and night time presentations were also explored in the final models using likelihood ratio tests.

Models were selected using backwards selection.[24] Factors with a *p*-value of less than 0.2 in the univariate analyses were included in the initial full models. Variables with a *p*-value of less than 0.05 were retained in the model. Variables that were not significant at the 20% level in the univariate models were then checked for significance in the backwards-selected model, and retained in the final model where $p < 0.05$. Overall performance of the models was assessed using c-statistics. In order to capture daily variation, 30-day mortality risks for each day of the week were compared against a reference weekday (Monday). We define observation of a weekend effect as significantly higher odds of 30-day mortality on weekend days (Saturday and Sunday) compared to Monday. To validate our findings, additional analyses were performed comparing weekend days against weekdays. Statistical analyses were performed using SAS v9.4 (SAS Institute Inc., Cary, NC, USA) and STATA v12.1 (StataCorp LP, Texas, USA).

RESULTS

There were a total of 213,834 acute, emergency hospital admissions for the conditions of interest during the study period. There were 10,658 admissions excluded as they did not meet the eligibility criteria for age, and 2161 patients were excluded who had a non-specified AMI. After accounting for transfers and multiple admissions, there were 148,722 patients were included in the study (table 1). There were 17,721 deaths within 30 days of admission (11.9%). A total of 127,268 admissions were linked to an ED presentation (85.6%). The clinical cohorts comprised between 5,740 (haemorrhagic stroke) and 44,508 (pneumonia) patients that were admitted or presented to between 133 and 183 hospitals. Characteristics of patients are provided by day of week and time of day of arrival in table 2.

The most frequent day of presentation was Monday, while Saturdays and Sundays had fewer presentations than weekdays for all conditions. More patients were admitted during daytime than at night, regardless of condition.

There were no significant associations in the univariate analyses between mortality and day of week, for haemorrhagic stroke, AMI, pneumonia, or CHF (table 3). There was significant variation in unadjusted 30-day mortality by day of week for ischaemic stroke and COPD, however this did not show a strict 'weekend effect' (ischaemic stroke: Friday, Saturday and Sunday significantly higher than Monday; COPD: Thursday, Friday and Saturday significantly higher than Monday).

There was no significant difference in 30-day mortality by day of week after adjustment for casemix and other factors for five of the six conditions (table 4, figure 1). While Friday and Sunday presentations had significantly higher mortality than Monday for

ischaemic stroke, overall day of the week was not significant in the model. Significant variation in mortality by day of week for COPD was not consistent with a weekend effect (with Thursday, Friday and Saturday being associated with higher mortality compared with Monday).

There was evidence for higher mortality among ischaemic and haemorrhagic stroke patients who presented to hospital overnight. This night effect was observed in both the unadjusted and adjusted analyses (table 3, table 4). There was no evidence of increased mortality among night admissions for the other conditions. There were no significant interactions between day of week and time of day, after adjustment for confounding factors, for any of the conditions.

The models performed moderately well, with c-statistics ranging from 0.68 to 0.82 (ischaemic stroke: 0.73, haemorrhagic stroke: 0.68, AMI: 0.81, pneumonia: 0.82, COPD: 0.74, CHF: 0.72).

Results from the analyses comparing 30-day mortality on pooled weekend versus weekdays showed that the weekend was associated with a higher unadjusted likelihood of 30-day mortality compared with weekday for ischaemic stroke and pneumonia (table 5). However, after taking into account other risk factors, no significant differences were observed in 30-day mortality between weekdays and weekend for any of the conditions studied.

DISCUSSION

Main findings

Mortality outcomes do not vary in accordance with the weekend effect, after adjusting for casemix, for patients admitted to hospital with stroke, AMI, pneumonia, COPD, or CHF in NSW. We found increased mortality for stroke patients presenting to hospital at night, with no evidence for the night effect for the remaining conditions.

Our findings support a growing body of evidence that disputes the ubiquity of the weekend effect.[7,12,14,15,25,26] Of the six conditions investigated in this study, only ischaemic stroke and COPD showed significant variation in crude mortality risk by day of week of presentation. Significant variation remained after risk adjustment for COPD only, and this was not consistent with predictions for the weekend effect, with the highest odds of death within 30 days was found for those who presented on Thursday and Friday. When weekend and week days were pooled, there were no significant differences in odds of death after adjusting for other risk factors. This is consistent with studies which have shown more complex patterns of temporal variation in that there are some days/times that are different but not specifically 'the weekend'.[4,17,26,27]

While findings from previous studies for stroke[11,14,28,29], AMI[15,30] and COPD[15,31] have been conflicting, our results are consistent with those that found no weekend effect (stroke[1,14,26,32], AMI[1,33], COPD[15]). A recent meta-analysis found no weekend effect for COPD and pneumonia, although it did find significant effects for intracerebral haemorrhage, ischaemic stroke and myocardial infarction[34]. However, on comparing effects between continents, Oceania was found to have the lowest overall increase in odds of death (OR = 1.04; compared to South America, OR = 1.47), suggesting that the weekend effect may be highly heterogenous and dependent not only on clinical conditions but also on hospital contexts, regional policy and other factors that may vary widely by geographic setting.

We observed that the numbers of admissions were lower at weekends in New South Wales, and that the number of deaths within 30 days are generally proportionate to the number of admissions. This is in contrast to the findings of previous studies.[1,6,12,35] There are a number of differences between our study and some of the previously published work which may explain these differences. The use of 30-day mortality through linkage to the Deaths Register, as opposed to in-hospital death[1,3,6,12,13,35] allows the capture not only of patients who died in hospital, but also those died in community due to variation in care or early discharge. This provides a more complete picture of mortality.

Further, our study has examined six specific clinical conditions, as opposed to all emergency conditions.[3,4,12,35] Not all emergency admissions have the same urgency or acuity for treatment, and the conditions we have examined are useful indicators that encompass a range of time sensitivity, interventions, acuity and prognosis. The use of clinical cohorts of patients allows more precise adjustment for case-mix than considering non-specific admissions. We found no effect on mortality of weekend presentation either in conditions expected to be less sensitive to reduced staffing and services, nor among the more severe, acute conditions, which confers confidence in the validity of our findings. Our analyses comprised three years' complete population data for NSW with cohorts ranging from over 5000 to 44,000, which should provide sufficient power to detect statistically significant differences.

In contrast to other studies, the use of linked hospitalisation and emergency department data provides complete coverage of hospital admissions for the conditions of interest in NSW, and minimises several potential biases. While most studies use either hospital admission data[1,6,35] or ED data[3,4], the use of linked data in this study minimises misclassification bias in day and time of presentation caused by time spent in ED prior to

admission. Additionally, the use of hospitalisation data from the index and historical admissions of the patients allowed us to maximise the detail and quality of diagnoses and comorbidities. This increases our confidence in our finding of no evidence for increased mortality associated with weekend presentation.

We found significantly higher adjusted risk of death for ischaemic and haemorrhagic stroke patients who presented at night compared to those who presented during the day. This is consistent with other studies of stroke.[26,28] This finding may reflect factors specific to stroke, such as that strokes occurring at night may take longer to recognise due to reduced activity, and may result in delayed seeking of treatment and therefore higher mortality. That we only observed the night effect for stroke patients suggests that this variation is probably not attributable to system-wide deficiencies. However, further research to explore reasons for the increase in mortality for stroke patients admitted at night, and the observed variation in mortality for COPD by day of presentation, including potential contributions from poorer community care, will help to understand whether these excess deaths are preventable.

Our study is limited by a lack contextual information in our data about the differences in weekend and weekday or night time and day time practice, such as the availability of clinical or laboratory staff. It would be interesting to consider the results on the level of individual hospitals, as hospital variation in quality of care on weekends may be masked in this type of global analysis.

Mortality is a useful indicator for health system performance and for evaluating unwarranted variation. However, it is an extreme outcome, and it may be a blunt tool that could mask some variation in patient outcomes. Further research is needed to determine whether the lower staffing levels and resource access on weekends and out-of-hours may

exhibit effects on other outcomes or processes, such as adverse events, delays in care, or other quality indicators.

CONCLUSION

We found no evidence for a weekend effect in 30-day mortality for patients admitted with ischaemic or haemorrhagic stroke, AMI, pneumonia, COPD, or CHF. The finding of a night effect for stroke, and variation between days for COPD, highlights that temporal variation in patient outcomes is more complex than the weekend effect, and may have a variety of causes. Our study provides evidence that differences in services provided out-of-hours does not cause temporal variation in mortality outcomes, and suggest that causal links proposed between about hospital staffing and services on weekends and patient mortality may be unwarranted.

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Contributors

HJB, SMP, HYC, JK, KS and JFL contributed to the study design. HJB and SMP cleaned and analysed the data and HJB produced the figure and tables. All authors contributed to the interpretation of the results. HJB drafted the manuscript, and all authors contributed to revising the manuscript. All authors approved the final version of the manuscript.

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Competing interests

We declare no competing interests.

Data sharing statement

Privacy restrictions for the datasets used in this study prohibit free online availability. Access to these data may be sought from the data custodians, the New South Wales Ministry of Health.

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Table 1. Numbers of patients admitted to hospital in NSW between July 2009 and June 2012 for the conditions examined, number and percentage of deaths within 30 days, by day and time of presentation[1].

Condition	Day of week							Time of Day		Total
	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	Day	Night	
Ischaemic stroke (145 hospitals)										
Admissions[1]	2240	2168	2082	2070	2010	1868	1916	9858	4496	14354
Deaths	257	281	281	247	291	267	287	1241	670	1911
30-day mortality (%)	11.5	13.0	13.5	11.9	14.5	14.3	15.0	12.6	14.9	13.3
Haemorrhagic stroke (133 hospitals)										
Admissions[1]	905	894	818	830	853	703	737	3676	2064	5740
Deaths	303	296	288	255	286	254	264	1127	819	1946
30-day mortality (%)	33.5	33.1	35.2	30.7	33.5	36.1	35.8	30.7	39.7	33.9
Acute myocardial infarction (172 hospitals)										
Admissions[1]	4493	4332	4248	4241	4388	4004	3869	16309	13266	29575
Deaths	331	321	320	337	347	292	290	1233	1005	2238
30-day mortality (%)	7.4	7.4	7.5	8.0	7.9	7.3	7.5	7.6	7.6	7.6
Pneumonia (183 hospitals)										
Admissions[1]	7097	6354	6419	6366	6489	5754	6029	27382	17126	44508
Deaths	775	627	703	677	679	667	656	2929	1855	4784
30-day mortality (%)	10.9	9.9	11.0	10.6	10.5	11.6	10.9	10.7	10.8	10.8
Chronic obstructive pulmonary disease (177 hospitals)										
Admissions[1]	4794	4272	4193	4114	4116	3664	3786	17674	11265	28939
Deaths	459	436	426	476	479	408	367	1891	1160	3051
30-day mortality (%)	9.6	10.2	10.2	11.6	11.6	11.1	9.7	10.7	10.3	10.5
Congestive heart failure (177 hospitals)										
Admissions[1]	4325	3935	3828	3799	3780	2962	2977	16046	9560	25606
Deaths	628	568	577	549	566	462	441	2369	1422	3791
30-day mortality (%)	14.5	14.4	15.1	14.5	15.0	15.6	14.8	14.8	14.9	14.8

[1]Day of hospital admission or associated preceding emergency department presentation

Table 2. Demographic and clinical characteristics of patients with acute, emergency hospital admissions for the conditions of interest by day of week and time of day of presentation[1], NSW, July 2009 - June 2012.

Characteristic	Day of week		Time of day	
	Weekday	Weekend	Day	Night
	N = 110,453 (%)	N = 38,269 (%)	N = 90,945 (%)	N = 57,777 (%)
Age groups				
15-39	4,361 (4.0)	1,580 (4.1)	3,501 (3.9)	2,440 (4.2)
40-59	16,623 (15.1)	5,804 (15.2)	13,044 (14.3)	9,383 (16.2)
60-79	46,943 (42.5)	16,178 (42.3)	38,593 (42.4)	24,528 (42.5)
80+	42,526 (38.5)	14,707 (38.4)	35,807 (39.4)	21,426 (37.1)
Age (years; median (IQR))	75.8 (63.9-84.1)	75.8 (63.7-84.2)	76.2 (64.5-84.3)	75.1 (62.9-83.9)
Gender				
Female	50,318 (45.6)	17,407 (45.5)	42,300 (46.5)	25,425 (44.0)
Male	60,135 (54.4)	20,862 (54.5)	48,645 (53.5)	32,352 (56.0)
Charlson comorbidity index				
0	74,780 (67.7)	25,954 (67.8)	61,248 (67.4)	39,486 (68.3)
1-2	28,678 (26.0)	9,859 (25.8)	23,930 (26.3)	14,607 (25,3)
3+	6,995 (6.3)	2,456 (6.4)	5,767 (6.3)	3,684 (6.4)
Admitted via ED	93,799 (84.9)	33,469 (87.5)	76,835 (84.5)	50,433 (87.3)

[1]Day of hospital admission or associated preceding emergency department presentation

Conditions included are ischaemic stroke, haemorrhagic stroke, acute myocardial infarction, pneumonia, chronic obstructive pulmonary disease, and congestive heart failure.

Table 3. Unadjusted odds ratios for 30-day mortality for day of week and time of day of presentation[1].

Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value
Day of week		0.006		0.271		0.879		0.092		0.003		0.813
Monday	Reference		Reference		Reference		Reference		Reference		Reference	
Tuesday	1.14 (0.95-1.37)	0.152	0.97 (0.80-1.19)	0.789	1.00 (0.86-1.18)	0.964	0.90 (0.80-1.00)	0.052	1.07 (0.93-1.23)	0.332	0.99 (0.88-1.12)	0.927
Wednesday	1.20 (1.00-1.44)	0.051	1.07 (0.88-1.31)	0.493	1.02 (0.87-1.20)	0.787	1.01 (0.90-1.12)	0.916	1.07 (0.93-1.23)	0.354	1.05 (0.93-1.18)	0.462
Thursday	1.04 (0.86-1.25)	0.668	0.87 (0.71-1.07)	0.194	1.08 (0.92-1.27)	0.321	0.97 (0.87-1.08)	0.600	1.24 (1.08-1.42)	0.002	0.99 (0.88-1.13)	0.929
Friday	1.30 (1.09-1.56)	0.004	1.00 (0.82-1.23)	0.969	1.08 (0.92-1.26)	0.355	0.95 (0.85-1.06)	0.346	1.24 (1.08-1.42)	0.002	1.04 (0.92-1.17)	0.566
Saturday	1.28 (1.07-1.54)	0.008	1.12 (0.91-1.38)	0.288	0.99 (0.84-1.16)	0.887	1.07 (0.96-1.20)	0.211	1.18 (1.02-1.36)	0.023	1.09 (0.96-1.24)	0.195
Sunday	1.35 (1.12-1.61)	0.001	1.10 (0.90-1.36)	0.352	1.02 (0.86-1.20)	0.843	1.00 (0.89-1.12)	0.981	1.01 (0.88-1.17)	0.866	1.03 (0.90-1.17)	0.712
Time of day		0.001		<0.001		0.967		0.750		0.231		0.794
Day	Reference		Reference		Reference		Reference		Reference		Reference	
Night	1.22 (1.10-1.35)		1.49 (1.33-1.67)		1.00 (0.92-1.09)		1.01 (0.95-1.07)		0.95 (0.88-1.03)		1.01 (0.94-1.08)	

[1]Day of hospital admission or associated preceding emergency department presentation

Hospital is included as a random effect.

Table 4. Adjusted odds-ratios for 30-day mortality by day of week and time of day of presentation[1].

Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value
Day of week		0.136		0.404		0.741		0.136		0.003		0.660
Monday	Reference		Reference		Reference		Reference		Reference		Reference	
Tuesday	1.14 (0.95-1.38)	0.167	1.01 (0.82-1.24)	0.926	1.07 (0.90-1.28)	0.451	0.87 (0.77-0.98)	0.023	1.09 (0.94-1.25)	0.269	1.00 (0.88-1.14)	0.971
Wednesday	1.12 (0.93-1.35)	0.242	1.08 (0.88-1.34)	0.451	0.99 (0.83-1.19)	0.936	0.97 (0.86-1.09)	0.606	1.08 (0.93-1.25)	0.298	1.06 (0.93-1.21)	0.373
Thursday	1.03 (0.84-1.25)	0.803	0.88 (0.71-1.09)	0.228	1.08 (0.91-1.29)	0.371	0.98 (0.87-1.10)	0.720	1.29 (1.12-1.48)	0.001	0.99 (0.87-1.12)	0.829
Friday	1.22 (1.01-1.47)	0.039	1.05 (0.85-1.29)	0.653	1.10 (0.92-1.31)	0.303	0.92 (0.81-1.03)	0.156	1.25 (1.08-1.44)	0.002	1.09 (0.96-1.24)	0.175
Saturday	1.17 (0.96-1.42)	0.112	1.13 (0.91-1.40)	0.275	1.01 (0.84-1.21)	0.941	1.03 (0.92-1.17)	0.578	1.18 (1.02-1.37)	0.030	1.07 (0.94-1.23)	0.315
Sunday	1.28 (1.06-1.54)	0.012	1.06 (0.85-1.31)	0.595	0.96 (0.80-1.16)	0.681	0.97 (0.86-1.10)	0.670	1.05 (0.90-1.22)	0.550	1.02 (0.89-1.17)	0.784
Time of day		<0.001		<0.001		0.200		0.861		0.905		0.525
Day	Reference		Reference		Reference		Reference		Reference		Reference	
Night	1.30 (1.17-1.45)		1.58 (1.40-1.78)		1.07 (0.97-1.17)		1.01 (0.94-1.08)		1.00 (0.92-1.08)		1.02 (0.95-1.10)	

[1]Day of hospital admission or associated preceding emergency department presentation

Models were adjusted for age, sex, and comorbidities (final model results for all variables are provided in supplementary table S1). Hospital is included as a random effect.

Table 5. Unadjusted and adjusted odds ratios for 30-day mortality for day of week, categorized as weekend versus weekday, of hospital presentation[1] using random effect logistic regression models

Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value
Unadjusted												
Day of week		0.006		0.057		0.498		0.042		0.617		0.310
Weekday	Reference		Reference		Reference		Reference		Reference		Reference	
Weekend	1.16 (1.04-1.29)		1.13 (1.00-1.28)		0.97 (0.88-1.07)		1.07 (1.00-1.15)		0.98 (0.90-1.07)		1.04 (0.96-1.13)	
Adjusted												
Day of week												
Weekday	Reference	0.067	Reference	0.197	Reference	0.261	Reference	0.135	Reference	0.686	Reference	0.686
Weekend	1.11 (0.99-1.24)		1.09 (0.96-1.24)		0.94 (0.84-1.05)		1.06 (0.98-1.14)		0.98 (0.90-1.07)		1.02 (0.93-1.11)	
Time of day												
Day	Reference	<0.001	Reference	<0.001	Reference	0.210	Reference	0.939	Reference	0.930	Reference	
Night	1.30 (1.17-1.45)		1.57 (1.40-1.77)		1.06 (0.97-1.17)		1.00 (0.94-1.07)		1.00 (0.92-1.08)		1.02 (0.95-1.10)	0.930

[1]Day of hospital admission or associated preceding emergency department presentation

Adjusted models included age, sex and comorbidities. All models included hospital as a random effect.

Figure 1. a) Adjusted odds ratios for 30-day mortality for day of week of presentation by clinical condition. Reference group is Monday (dotted line). b) adjusted odds ratios for 30-day mortality for presentation to hospital at night compared to during the day, by clinical condition. AMI = acute myocardial infarction, COPD = chronic obstructive pulmonary disease, CHF = congestive heart failure.

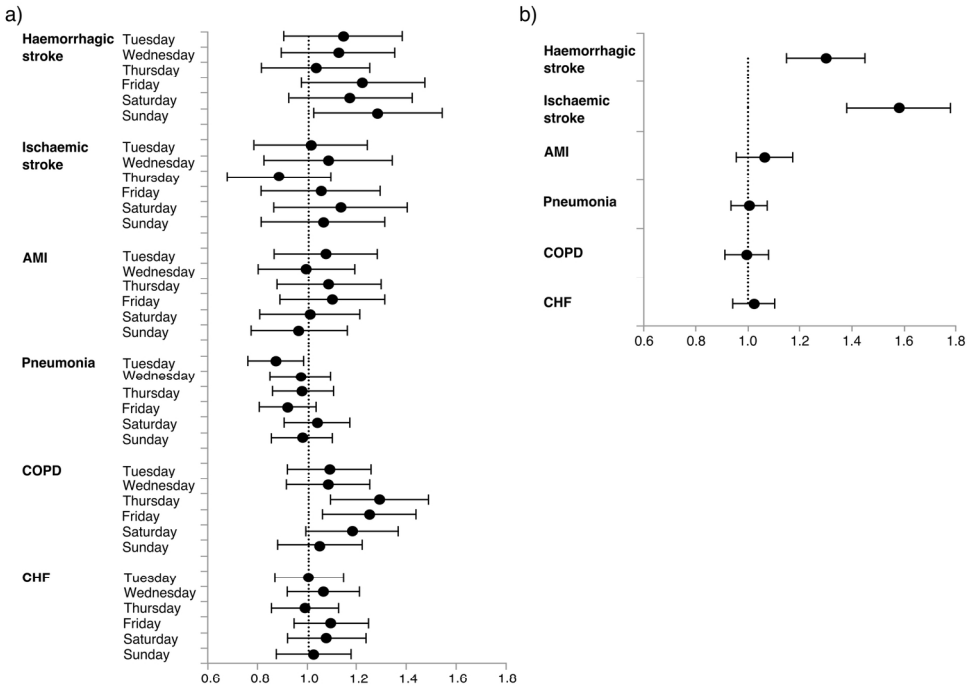

Figure 1. a) Adjusted odds ratios for 30-day mortality for day of week of admission by clinical condition. Reference group is Monday (dotted line). b) adjusted odds ratios for 30-day mortality for admission to hospital at night compared to during the day, by clinical condition. AMI = acute myocardial infarction, COPD = chronic obstructive pulmonary disease, CHF = congestive heart failure.

165x131mm (300 x 300 DPI)

SUPPLEMENTARY MATERIAL

Table S1. Final multivariable model results for 30-day mortality by day of week and time of day of hospital admission or related, preceding ED presentation for ischaemic and haemorrhagic stroke, AMI, pneumonia, COPD and CHF.

Condition Variable	Odds Ratio (95% CI)	*p*-value
Ischaemic stroke		
Day of week (ref = Mon)		0.136
Tuesday	1.14 (0.95-1.38)	0.167
Wednesday	1.12 (0.93-1.35)	0.242
Thursday	1.03 (0.84-1.25)	0.803
Friday	1.22 (1.01-1.47)	0.039
Saturday	1.17 (0.96-1.42)	0.112
Sunday	1.28 (1.06-1.54)	0.012
Night	1.30 (1.17-1.45)	<0.001
Sex (ref = male)	1.32 (1.19-1.47)	<0.001
Age (centred)	1.06 (1.06-1.07)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
Renal failure	1.70 (1.48-1.97)	<0.001
Heart failure	1.95 (1.66-2.28)	<0.001
Malignancy	2.64 (2.15-3.24)	<0.001
AMI		
Day of week (ref = Mon)		0.741
Tuesday	1.07 (0.90-1.28)	0.451
Wednesday	0.99 (0.83-1.19)	0.936
Thursday	1.08 (0.91-1.29)	0.371
Friday	1.10 (0.92-1.31)	0.303
Saturday	1.01 (0.84-1.21)	0.941
Sunday	0.96 (0.80-1.16)	0.681
Night	1.07 (0.97-1.17)	0.200
Age (centred)	1.06 (1.05-1.06)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
STEMI	2.71 (2.44-3.01)	<0.001
Dementia	2.10 (1.77-2.48)	<0.001
Hypotension	1.29 (1.14-1.46)	<0.001
Shock	9.38 (7.79-11.30)	<0.001
Renal failure	2.32 (2.07-2.60)	<0.001
Heart failure	1.77 (1.58-1.98)	<0.001
Dysrhythmia	1.72 (1.55-1.90)	<0.001
Malignancy	2.38 (1.94-2.92)	<0.001
Hypertension	0.67 (0.61-0.74)	<0.001
Cerebrovascular disease	2.34 (1.95-2.81)	<0.001

Condition Variable	Odds Ratio (95% CI)	*p*-value
Haemorrhagic stroke		
Day of week (ref = Mon)		0.404
Tuesday	1.01 (0.82-1.24)	0.926
Wednesday	1.08 (0.88-1.34)	0.451
Thursday	0.88 (0.71-1.09)	0.228
Friday	1.05 (0.85-1.29)	0.653
Saturday	1.13 (0.91-1.40)	0.275
Sunday	1.06 (0.85-1.31)	0.595
Night	1.58 (1.40-1.78)	<0.001
Sex (ref = male)	1.39 (1.24-1.56)	<0.001
Age (centred)	1.04 (1.04-1.05)	<0.001
Heart failure	1.47 (1.16-1.87)	0.001
Malignancy	2.75 (2.20-3.45)	<0.001
Previous H-stroke	0.61 (0.48-0.77)	<0.001
Pneumonia		
Day of week (ref=Mon)		0.136
Tuesday	0.87 (0.77-0.98)	0.023
Wednesday	0.97 (0.86-1.09)	0.606
Thursday	0.98 (0.87-1.10)	0.720
Friday	0.92 (0.81-1.03)	0.156
Saturday	1.03 (0.91-1.16)	0.578
Sunday	0.97 (0.86-1.10)	0.670
Night	1.00 (0.94-1.07)	0.861
Financial year (ref = 2009)		<0.001
2010	0.90 (0.83-0.97)	0.004
2011	0.74 (0.68-0.80)	<0.001
Age (centred)	1.05 (1.05-1.05)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
Dementia	2.66 (2.42-2.92)	<0.001
Hypotension	1.18 (1.08-1.28)	<0.001
Shock	4.02 (3.34-4.84)	<0.001
Renal failure	1.84 (1.70-1.99)	<0.001
Heart failure	1.55 (1.43-1.68)	<0.001
Dysrhythmia	1.32 (1.22-1.42)	<0.001
Malignancy	5.54 (5.07-6.05)	<0.001
Cerebrovascular disease	1.82 (1.59-2.08)	<0.001
Other COPD	1.17 (1.08-1.27)	<0.001
Liver disease	2.81 (1.75-2.71)	<0.001
Parkinsons	1.69 (1.35-2.11)	<0.001

COPD		
Day of week (ref = Mon)		0.003
Tuesday	1.09 (0.94-1.25)	0.269
Wednesday	1.08 (0.93-1.25)	0.298
Thursday	1.29 (1.12-1.48)	0.001
Friday	1.25 (1.08-1.44)	0.002
Saturday	1.18 (1.02-1.37)	0.030
Sunday	1.05 (0.90-1.22)	0.550
Night	1.00 (0.92-1.08)	0.905
Financial year (ref = 2009)		<0.001
2010	0.77 (0.70-0.85)	<0.001
2011	0.50 (0.45-0.55)	<0.001
Prev acute COPD episode (ref = 0)[1]		<0.001
1 previous episode	1.67 (1.51-1.85)	<0.001
2 previous episodes	2.13 (1.86-2.43)	<0.001
3+ previous episodes	3.04 (2.69-3.44)	<0.001
Sex (ref=male)	0.82 (0.76-0.89)	<0.001
Age (centred)	1.03 (1.03-1.04)	<0.001
Age (squared)	1.00 (1.00-1.00)	0.013
CHF	1.47 (1.34-1.61)	<0.001
Pulmonary circ. disord.	1.66 (1.46-1.89)	<0.001
Neurological disord.	1.31 (1.05-1.64)	0.016
Diabetes (comp.)	0.83 (0.73-0.95)	0.005
Liver disease	1.98 (1.50-2.61)	<0.001
Metastatic cancer	3.06 (2.38-3.95)	<0.001
Solid tumour w/o metast.	1.42 (1.17-1.72)	<0.001
Weight loss	1.89 (1.68-2.11)	<0.001
Fluid/electrolyte dis.	1.81 (1.66-1.98)	<0.001
Psychoses	2.10 (1.47-3.00)	<0.001

CHF		
Day of week (ref=Mon)		0.660
Tuesday	1.00 (0.88-1.14)	0.971
Wednesday	1.06 (0.93-1.21)	0.373
Thursday	0.99 (0.87-1.12)	0.829
Friday	1.09 (0.96-1.24)	0.175
Saturday	1.07 (0.94-1.23)	0.315
Sunday	1.02 (0.89-1.17)	0.784
Night	1.02 (0.95-1.10)	0.525
Financial year (ref = 2009)		<0.001
2010	0.89 (0.81-0.97)	0.009
2011	0.67 (0.62-0.74)	<0.001
Prev acute CHF episode (ref = 0)[1]		<0.001
1 previous episode	1.39 (1.26-1.52)	<0.001
2 previous episodes	1.70 (1.48-1.97)	<0.001
3+ previous episodes	2.52 (2.14-2.96)	<0.001
Sex (ref = male)	0.90 (0.84-0.97)	0.008
Age (centred)	1.05 (1.05-1.06)	<0.001
Age (squared)	1.00 (1.00-1.00)	0.003
Pulmonary circ. disord.	1.21 (1.09-1.35)	<0.001
Peripheral vascular disord.	1.19 (1.04-1.37)	0.013
Hypertension (comp/uncomp)	0.83 (0.77-0.90)	<0.001
Paralysis	1.65 (1.34-2.04)	<0.001
Neurological disorders	1.65 (1.39-1.97)	<0.001
Chronic pulmonary disease	1.23 (1.13-1.34)	<0.001
Renal failure	1.88 (1.73-2.03)	<0.001
Liver disease	2.78 (2.29-3.38)	<0.001
Lymphoma	2.24 (1.57-3.19)	<0.001
Metastatic cancer	3.07 (2.44-3.86)	<0.001
Coagulopathy	1.29 (1.15-1.46)	<0.001
Weight loss	1.61 (1.43-1.83)	<0.001
Fluid/electrolyte disorders	1.57 (1.45-1.69)	<0.001
Deficiency anaemia	0.78 (0.68-0.90)	<0.001

[1] lookback to 2004

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Checked (page #)
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6-7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	8
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8, 19
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	20,21

		which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	considered
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10,11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	11,12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Is the weekend effect really ubiquitous? Retrospective clinical cohort analyses of 30-day mortality by day of week and time of day using linked population data from New South Wales, Australia

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Is the weekend effect really ubiquitous? Retrospective clinical cohort analyses of 30-day mortality by day of week and time of day using linked population data from New South Wales, Australia

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Word count (abstract + body): 3401

ABSTRACT

Objective

To examine the associations between day of week and time of admission and 30-day mortality for six clinical conditions: ischaemic and haemorrhagic stroke, acute myocardial infarction, pneumonia, chronic obstructive pulmonary disease and congestive heart failure.

Design

Retrospective population-based cohort analyses. Hospitalisation records were linked to emergency department and deaths data. Random effect logistic regression models were used, adjusting for casemix and taking into account clustering within hospitals.

Setting

All hospitals in New South Wales, Australia from July 2009 to June 2012.

Participants

Patients admitted to hospital with a primary diagnosis for one of the six clinical conditions examined.

Outcome measures

Adjusted odds ratios for all-cause mortality within 30 days of admission, by day of week and time of day.

Results

A total of 148,722 patients were included in the study, with 17,721 deaths within 30 days of admission. Day of week of admission was not associated with significantly higher likelihood of death for five of the six conditions after adjusting for casemix. There was significant variation in mortality for chronic obstructive pulmonary disease by day of week, however, this was not consistent with a strict weekend effect (Thursday: OR 1.29, 95% CI 1.12–1.48; Friday: OR 1.25, 95%CI 1.08–1.44; Saturday: OR 1.18, 95% CI 1.02–1.37; Sunday OR 1.05, 95% CI 0.90–1.22; compared to Monday). There was evidence for a night effect for patients admitted for stroke (ischaemic: OR 1.30, 95% CI 1.17–1.45; haemorrhagic: OR 1.58, 95% CI 1.40–1.78).

Conclusions

Mortality outcomes for these conditions, adjusted for casemix, do not vary in accordance with the weekend effect hypothesis. Our findings support a growing body of evidence that questions the ubiquity of the weekend effect.

Keywords

Weekend effect, night effect, out-of-hours effect, stroke, AMI, pneumonia, COPD, CHF

Article summary

Strengths and limitations of this study

- The examined conditions encompass a range of time sensitivity, interventions, acuity and prognosis, providing a gradient to assess potential causality of association.
- The use of linked hospital admission and emergency department (ED) data allowed complete coverage of hospital admissions for the state, while minimising misclassification bias from time spent in ED and maximising validity and quality of diagnosis and comorbidity data.
- The use of clinical cohorts of patients allows more precise adjustment for casemix than non-specific admissions.
- Linkage to the Deaths Register allowed the capture of 30-day all-cause mortality. While mortality is a standard indicator, other outcomes may be more sensitive to variation in patient outcomes.
- We focussed on the NSW health system as a whole and did not explore the possible weekend effect at hospital level.

INTRODUCTION

In recent years, researchers and policy makers have shown growing interest in the 'weekend effect', examining whether patients admitted to hospital at the weekend experience worse outcomes compared to patients admitted during the week. This effect has been observed in numerous studies of health systems around the world, for a wide range of conditions and procedures.[1-6] Studies have also observed a 'night effect', suggesting that the phenomenon may extend to out-of-hours presentation more broadly.[1-4]

Considerable uncertainty remains as to the cause of the apparent effect of weekend and night-time (hereafter collectively 'out-of-hours') presentation on patient outcomes. Two main hypotheses have been proposed to explain the observed variation: these focus on healthcare service quality and on patient characteristics.[2] The first hypothesis posits that the poorer outcomes seen among patients admitted on the weekend are explained by lower quality of care out-of-hours. More specifically, putative factors include lower staffing levels, fewer senior consultants and specialists, and reduced availability of diagnostic procedures.[3] This hypothesis gained considerable traction with policy makers and has contributed to the recent, controversial push towards seven day hospital services in the UK.[7]

The second hypothesis proposes that the weekend effect is largely attributable to patient characteristics, and at least partly a data artefact resulting from insufficient information on patient characteristics in administrative datasets. There is little clear evidence that higher mortality is a consequence of staffing levels[7], and a number of studies have found no significant correlation between consultant seniority or specialist availability and mortality.[8-11] There is also an increasing body of evidence to suggest that the weekend effect dissipates after adjustment for casemix[12], arrival by ambulance as a proxy for illness

severity[13] and a higher severity threshold for admission.[12] This phenomenon may be influenced by self-selection, whereby patients wait until the weekend to present to hospital and may therefore present with more advanced disease, and less comprehensive note-taking on the weekend limiting the ability to risk-adjust.[14]

The night effect is less extensively studied than the weekend effect, and reasons for the night effect are usually presumed to be similar to the weekend effect. The few studies that have examined the effects of out-of-hours presentation on mortality in Australia have had mixed results.[3,4,15,16] Previous studies have been limited by using in-hospital mortality only and therefore not capturing deaths that occurred post-discharge[17], reduced ability to adequately risk adjust by focusing on clinically non-specific admissions.[3,16,18] Further, previous studies have often relied on unlinked emergency department (ED) data[4], which contain limited and largely incomplete and inaccurate information on principle diagnosis and comorbidity, or unlinked hospitalisation data, which may be affected by misclassification bias due to time spent in waiting in ED prior to admission.[15,18]

Overall, previous studies have shown that the out-of-hours effect does not apply to all clinical presentations and procedures.[1-4,8] It is therefore beneficial to investigate conditions for which we can expect that the weekend is more likely to occur, based on theoretical grounds, on clinical plausibility or on previous evidence.[2]

We investigated the existence of the weekend effect and the night effect for acute hospitalisations for various conditions, comprising ischaemic stroke, haemorrhagic stroke, acute myocardial infarction (AMI), pneumonia, chronic obstructive pulmonary disease (COPD), and congestive heart failure (CHF), across all hospitals in New South Wales (NSW). These conditions provide insights into a range of aspects of healthcare, including timely delivery of interventions, surgical services, differences in acuity and prognosis, and

provide a gradient to assess potential causality of association as they vary in the importance of immediate care. We predicted that if day and time effects exist, they would show strongest effects for the most urgent conditions (stroke and AMI), and be weakest for patients with the least urgent conditions (pneumonia and COPD). We hypothesized that presentations on Saturdays and Sundays would show higher 30-day mortality for the six conditions than presentations that occurred during the week, and that night-time presentations would show higher mortality than presentations that occurred during the day.

METHODS

Retrospective cohort analyses were performed for the six indicator conditions. Cohorts were identified from all admissions to NSW public and private hospitals for the period of 1 July 2009 to 30 June 2012, extracted from the NSW Admitted Patient Data Collection, which is a census of all hospital admissions in NSW. These data were linked to emergency department (ED) attendances in all NSW public hospitals recorded in the Emergency Department Data Collection, representing approximately 85% of all emergency presentations in NSW.[19,20] Emergency department data were linked to allow the capture of the start day and time of the patients' contact with the hospital system for the episode of illness, minimising any bias imposed by time spent in the ED that may affect the day and time of hospitalisation, since patients may spend longer in the ED before admission at night or at weekends. Mortality data were obtained from the NSW Deaths Register. Data were linked by the NSW Centre for Health Record Linkage using probabilistic methods based on personal identifiers. The estimated false positive rate for the current version of the Master Linkage Key is 5 per 1000.[21]

The principal diagnosis in the patient record, coded using International Classification of Diseases 10th revision Australian modification, was used to identify each clinical cohort. Only complete records of admissions coded as acute and emergency were included. The proportion of records excluded for missing values on key variables such as age, sex, date of admission and separation, type of care and emergency status was less than 0.1%. Patients aged less than 15 years (ischaemic stroke, haemorrhagic stroke, AMI), 18 years (pneumonia) or 45 years (COPD, CHF) were excluded, consistent with existing mortality indicator definitions for these conditions, due to low mortality rates among these groups.[22,23] AMI can be classified as ST-elevated myocardial infarction (STEMI) or non-ST elevated myocardial infarction (non-STEMI) based on the electrocardiogram reading, or unspecified AMI when diagnostic records are unavailable. STEMI is associated with higher mortality at 30 days compared to non-STEMI, and the unspecified group is a heterogeneous mix of critically unwell patients who died before their AMI could be specified and patients for whom diagnostic records were less precise, so AMI patients with a non-specific infarction were excluded to allow adjustment for STEMI.[22,23] Transfers and multiple contiguous hospitalisations were considered as a single period of care. For patients with multiple periods of care during the study period, only the last period of care was included in the analyses.

Mortality was defined as death (in or out of hospital) occurring within 30 days of the start of the period of care. The day of week of presentation was defined as the first day of contact with the hospital system for the period of care (either hospital admission or ED presentation). Patients dead on arrival to ED and not admitted to hospital were excluded. An ED presentation was considered relevant for the hospital admission if it occurred on the same day, or previous day, as the hospital admission. Same day ED presentations were only included if the time was recorded as before the hospital admission time. In this study, the weekend comprises Saturday and Sunday, while weekdays are defined as Monday through

Friday. Night time presentation was defined as first presentation between 18:00 and 07:59, using hospital admission time or ED presentation time as described.

Random effects logistic regression models were used to investigate associations between day of week, or time of presentation, with mortality. To account for clustering of patients within hospitals, hospitals were considered as random effects in the regression models. Risk adjustment was performed to account for casemix factors including age (continuous, tested for curvilinearity), sex, year and comorbidities. Condition-specific comorbidity sets defined by the Australian Commission for Safety and Quality in Health Care were used as the basis for building risk adjustment models for each condition, where available (ischaemic stroke, haemorrhagic stroke, AMI, pneumonia), while COPD and CHF used Elixhauser comorbidities.[22] Availability of thrombolysis treatment was also considered as a predictive variable for ischaemic stroke, and STEMI status was considered for AMI. Comorbidities were captured across all hospital admissions over a one year period prior to the index admission. Interactions between day of the week and night time presentations were also explored in the final models using likelihood ratio tests.

Models were selected using backwards selection.[24] Factors with a *p*-value of less than 0.2 in the univariate analyses were included in the initial full models. Variables with a *p*-value of less than 0.05 were retained in the model. Variables that were not significant at the 20% level in the univariate models were then checked for significance in the backwards-selected model, and retained in the final model where $p < 0.05$. Overall performance of the models was assessed using c-statistics. In order to capture daily variation, 30-day mortality risks for each day of the week were compared against a reference weekday (Monday). We define observation of a weekend effect as significantly higher odds of 30-day mortality on weekend days (Saturday and Sunday) compared to Monday. To validate our findings, additional analyses were performed comparing weekend days against weekdays. Statistical

analyses were performed using SAS v9.4 (SAS Institute Inc., Cary, NC, USA) and STATA v12.1 (StataCorp LP, Texas, USA).

RESULTS

There were a total of 213,834 acute, emergency hospital admissions for the conditions of interest during the study period. There were 10,658 admissions excluded as they did not meet the eligibility criteria for age, and 2161 patients were excluded who had a non-specified AMI. After accounting for transfers and multiple admissions, there were 148,722 patients were included in the study (table 1). There were 17,721 deaths within 30 days of admission (11.9%). A total of 127,268 admissions were linked to an ED presentation (85.6%). The clinical cohorts comprised between 5,740 (haemorrhagic stroke) and 44,508 (pneumonia) patients that were admitted or presented to between 133 and 183 hospitals. Characteristics of patients are provided by day of week and time of day of arrival in table 2.

The most frequent day of presentation was Monday, while Saturdays and Sundays had fewer presentations than weekdays for all conditions. More patients were admitted during daytime than at night, regardless of condition.

There were no significant associations in the univariate analyses between mortality and day of week, for haemorrhagic stroke, AMI, pneumonia, or CHF (table 3). There was significant variation in unadjusted 30-day mortality by day of week for ischaemic stroke and COPD, however this did not show a strict 'weekend effect' (ischaemic stroke: Friday, Saturday and Sunday significantly higher than Monday; COPD: Thursday, Friday and Saturday significantly higher than Monday).

There was no significant difference in 30-day mortality by day of week after adjustment for casemix and other factors for five of the six conditions (table 4, figure 1). While Friday and Sunday presentations had significantly higher mortality than Monday for ischaemic stroke, overall day of the week was not significant in the model. Significant variation in mortality by day of week for COPD was not consistent with a weekend effect (with Thursday, Friday and Saturday being associated with higher mortality compared with Monday).

There was evidence for higher mortality among ischaemic and haemorrhagic stroke patients who presented to hospital overnight. This night effect was observed in both the unadjusted and adjusted analyses (table 3, table 4). There was no evidence of increased mortality among night admissions for the other conditions. There were no significant interactions between day of week and time of day, after adjustment for confounding factors, for any of the conditions.

The models performed moderately well, with c-statistics ranging from 0.68 to 0.82 (ischaemic stroke: 0.73, haemorrhagic stroke: 0.68, AMI: 0.81, pneumonia: 0.82, COPD: 0.74, CHF: 0.72).

Results from the analyses comparing 30-day mortality on pooled weekend versus weekdays showed that the weekend was associated with a higher unadjusted likelihood of 30-day mortality compared with weekday for ischaemic stroke and pneumonia (table 5). However, after taking into account other risk factors, no significant differences were observed in 30-day mortality between weekdays and weekend for any of the conditions studied.

DISCUSSION

Main findings

Mortality outcomes do not vary in accordance with the weekend effect, after adjusting for casemix, for patients admitted to hospital with stroke, AMI, pneumonia, COPD, or CHF in NSW. We found increased mortality for stroke patients presenting to hospital at night, with no evidence for the night effect for the remaining conditions.

Our findings support a growing body of evidence that disputes the ubiquity of the weekend effect.[7,12,14,15,25,26] Of the six conditions investigated in this study, only ischaemic stroke and COPD showed significant variation in crude mortality risk by day of week of presentation. Significant variation remained after risk adjustment for COPD only, and this was not consistent with predictions for the weekend effect, with the highest odds of death within 30 days was found for those who presented on Thursday and Friday. When weekend and week days were pooled, there were no significant differences in odds of death after adjusting for other risk factors. This is consistent with studies which have shown more complex patterns of temporal variation in that there are some days/times that are different but not specifically 'the weekend'.[4,17,26,27]

While findings from previous studies for stroke[11,14,28,29], AMI[15,30] and COPD[15,31] have been conflicting, our results are consistent with those that found no weekend effect (stroke[1,14,26,32], AMI[1,33], COPD[15]). A recent meta-analysis found no weekend effect for COPD and pneumonia, although it did find significant effects for intracerebral haemorrhage, ischaemic stroke and myocardial infarction[34]. However, on comparing effects between continents, Oceania was found to have the lowest overall increase in odds of death (OR = 1.04; compared to South America, OR = 1.47), suggesting that the weekend effect may be

highly heterogenous and dependent not only on clinical conditions but also on hospital contexts, regional policy and other factors that may vary widely by geographic setting.

We observed that the numbers of admissions were lower at weekends in New South Wales, and that the number of deaths within 30 days are generally proportionate to the number of admissions. This is in contrast to the findings of previous studies.[1,6,12,35] There are a number of differences between our study and some of the previously published work which may explain these differences. The use of 30-day mortality through linkage to the Deaths Register as opposed to in-hospital death[1,3,6,12,13,35] allows the capture not only of patients who died in hospital, but also those died in community due to variation in care or early discharge. This provides a more complete picture of mortality.

Further, our study has examined six specific clinical conditions, as opposed to all emergency conditions.[3,4,12,35] Not all emergency admissions have the same urgency or acuity for treatment, and the conditions we have examined are useful indicators that encompass a range of time sensitivity, interventions, acuity and prognosis. The use of clinical cohorts of patients allows more precise adjustment for case-mix than considering non-specific admissions. We found no effect on mortality of weekend presentation either in conditions expected to be less sensitive to reduced staffing and services, nor among the more severe, acute conditions, which confers confidence in the validity of our findings. Our analyses comprised three years' complete population data for NSW with cohorts ranging from over 5000 to 44,000, which should provide sufficient power to detect statistically significant differences.

In contrast to other studies, the use of linked hospitalisation and emergency department data provides complete coverage of hospital admissions for the conditions of interest in NSW, and minimises several potential biases. While most studies use either

hospital admission data[1,6,35] or ED data[3,4], the use of linked data in this study minimises misclassification bias in day and time of presentation caused by time spent in ED prior to admission. Additionally, the use of hospitalisation data from the index and historical admissions of the patients allowed us to maximise the detail and quality of diagnoses and comorbidities. This increases our confidence in our finding of no evidence for increased mortality associated with weekend presentation.

We found significantly higher adjusted risk of death for ischaemic and haemorrhagic stroke patients who presented at night compared to those who presented during the day. This is consistent with other studies of stroke.[26,28] This finding may reflect factors specific to stroke, such as that strokes occurring at night may take longer to recognise due to reduced activity, and may result in delayed seeking of treatment and therefore higher mortality. That we only observed the night effect for stroke patients suggests that this variation is probably not attributable to system-wide deficiencies. However, further research to explore reasons for the increase in mortality for stroke patients admitted at night, and the observed variation in mortality for COPD by day of presentation, including potential contributions from poorer community care, will help to understand whether these excess deaths are preventable.

Our study is limited by a lack contextual information in our data about the differences in weekend and weekday or night time and day time practice, such as the availability of clinical or laboratory staff. It would be interesting to consider the results on the level of individual hospitals, as hospital variation in quality of care on weekends may be masked in this type of global analysis.

Mortality is a useful indicator for health system performance and for evaluating unwarranted variation. However, it is an extreme outcome, and it may be a blunt tool that could mask some variation in patient outcomes. Further research is needed to determine

whether the lower staffing levels and resource access on weekends and out-of-hours may exhibit effects on other outcomes or processes, such as adverse events, delays in care, or other quality indicators.

CONCLUSION

By identifying patients admitted through ED, and taking out-of-hospital deaths into account, this study was able to investigate the weekend effect by following the patient journey from prior to admission to after discharge. We found no evidence for a strict weekend effect in 30-day mortality for patients admitted with ischaemic or haemorrhagic stroke, AMI, pneumonia, COPD, or CHF. The finding of a night effect for stroke, and some variation between days for COPD, highlights that temporal variation in patient outcomes is complex and may have a variety of causes. Our findings increase the weight of evidence challenging the existence of the weekend effect.

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Contributors

HJB, SMP, HYC, JK, KS and JFL contributed to the study design. HJB and SMP cleaned and analysed the data and HJB produced the figure and tables. All authors contributed to the interpretation of the results. HJB drafted the manuscript, and all authors contributed to revising the manuscript. All authors approved the final version of the manuscript.

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Competing interests

We declare no competing interests.

Data sharing statement

Privacy restrictions for the datasets used in this study prohibit free online availability. Access to these data may be sought from the data custodians, the New South Wales Ministry of Health.

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Table 1. Numbers of patients admitted to hospital in NSW between July 2009 and June 2012 for the conditions examined, number and percentage of deaths within 30 days, by day and time of presentation[1].

Condition	Day of week							Time of Day		Total
	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	Day	Night	
Ischaemic stroke (145 hospitals)										
Admissions[1]	2240	2168	2082	2070	2010	1868	1916	9858	4496	14354
Deaths	257	281	281	247	291	267	287	1241	670	1911
30-day mortality (%)	11.5	13.0	13.5	11.9	14.5	14.3	15.0	12.6	14.9	13.3
Haemorrhagic stroke (133 hospitals)										
Admissions[1]	905	894	818	830	853	703	737	3676	2064	5740
Deaths	303	296	288	255	286	254	264	1127	819	1946
30-day mortality (%)	33.5	33.1	35.2	30.7	33.5	36.1	35.8	30.7	39.7	33.9
Acute myocardial infarction (172 hospitals)										
Admissions[1]	4493	4332	4248	4241	4388	4004	3869	16309	13266	29575
Deaths	331	321	320	337	347	292	290	1233	1005	2238
30-day mortality (%)	7.4	7.4	7.5	8.0	7.9	7.3	7.5	7.6	7.6	7.6
Pneumonia (183 hospitals)										
Admissions[1]	7097	6354	6419	6366	6489	5754	6029	27382	17126	44508
Deaths	775	627	703	677	679	667	656	2929	1855	4784
30-day mortality (%)	10.9	9.9	11.0	10.6	10.5	11.6	10.9	10.7	10.8	10.8
Chronic obstructive pulmonary disease (177 hospitals)										
Admissions[1]	4794	4272	4193	4114	4116	3664	3786	17674	11265	28939
Deaths	459	436	426	476	479	408	367	1891	1160	3051
30-day mortality (%)	9.6	10.2	10.2	11.6	11.6	11.1	9.7	10.7	10.3	10.5
Congestive heart failure (177 hospitals)										
Admissions[1]	4325	3935	3828	3799	3780	2962	2977	16046	9560	25606
Deaths	628	568	577	549	566	462	441	2369	1422	3791
30-day mortality (%)	14.5	14.4	15.1	14.5	15.0	15.6	14.8	14.8	14.9	14.8

[1]Day of hospital admission or associated preceding emergency department presentation

Table 2. Demographic and clinical characteristics of patients with acute, emergency hospital admissions for the conditions of interest by day of week and time of day of presentation[1], NSW, July 2009 - June 2012.

Characteristic	Day of week		Time of day	
	Weekday	Weekend	Day	Night
	N = 110,453 (%)	N = 38,269 (%)	N = 90,945 (%)	N = 57,777 (%)
Age groups				
15-39	4,361 (4.0)	1,580 (4.1)	3,501 (3.9)	2,440 (4.2)
40-59	16,623 (15.1)	5,804 (15.2)	13,044 (14.3)	9,383 (16.2)
60-79	46,943 (42.5)	16,178 (42.3)	38,593 (42.4)	24,528 (42.5)
80+	42,526 (38.5)	14,707 (38.4)	35,807 (39.4)	21,426 (37.1)
Age (years; median (IQR))	75.8 (63.9-84.1)	75.8 (63.7-84.2)	76.2 (64.5-84.3)	75.1 (62.9-83.9)
Gender				
Female	50,318 (45.6)	17,407 (45.5)	42,300 (46.5)	25,425 (44.0)
Male	60,135 (54.4)	20,862 (54.5)	48,645 (53.5)	32,352 (56.0)
Charlson comorbidity index				
0	74,780 (67.7)	25,954 (67.8)	61,248 (67.4)	39,486 (68.3)
1-2	28,678 (26.0)	9,859 (25.8)	23,930 (26.3)	14,607 (25,3)
3+	6,995 (6.3)	2,456 (6.4)	5,767 (6.3)	3,684 (6.4)
Admitted via ED	93,799 (84.9)	33,469 (87.5)	76,835 (84.5)	50,433 (87.3)

[1]Day of hospital admission or associated preceding emergency department presentation

Conditions included are ischaemic stroke, haemorrhagic stroke, acute myocardial infarction, pneumonia, chronic obstructive pulmonary disease, and congestive heart failure.

Table 3. Unadjusted odds ratios for 30-day mortality for day of week and time of day of presentation[1].

Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value
Day of week		0.006		0.271		0.879		0.092		0.003		0.813
Monday	Reference		Reference		Reference		Reference		Reference		Reference	
Tuesday	1.14 (0.95-1.37)	0.152	0.97 (0.80-1.19)	0.789	1.00 (0.86-1.18)	0.964	0.90 (0.80-1.00)	0.052	1.07 (0.93-1.23)	0.332	0.99 (0.88-1.12)	0.927
Wednesday	1.20 (1.00-1.44)	0.051	1.07 (0.88-1.31)	0.493	1.02 (0.87-1.20)	0.787	1.01 (0.90-1.12)	0.916	1.07 (0.93-1.23)	0.354	1.05 (0.93-1.18)	0.462
Thursday	1.04 (0.86-1.25)	0.668	0.87 (0.71-1.07)	0.194	1.08 (0.92-1.27)	0.321	0.97 (0.87-1.08)	0.600	1.24 (1.08-1.42)	0.002	0.99 (0.88-1.13)	0.929
Friday	1.30 (1.09-1.56)	0.004	1.00 (0.82-1.23)	0.969	1.08 (0.92-1.26)	0.355	0.95 (0.85-1.06)	0.346	1.24 (1.08-1.42)	0.002	1.04 (0.92-1.17)	0.566
Saturday	1.28 (1.07-1.54)	0.008	1.12 (0.91-1.38)	0.288	0.99 (0.84-1.16)	0.887	1.07 (0.96-1.20)	0.211	1.18 (1.02-1.36)	0.023	1.09 (0.96-1.24)	0.195
Sunday	1.35 (1.12-1.61)	0.001	1.10 (0.90-1.36)	0.352	1.02 (0.86-1.20)	0.843	1.00 (0.89-1.12)	0.981	1.01 (0.88-1.17)	0.866	1.03 (0.90-1.17)	0.712
Time of day		0.001		<0.001		0.967		0.750		0.231		0.794
Day	Reference		Reference		Reference		Reference		Reference		Reference	
Night	1.22 (1.10-1.35)		1.49 (1.33-1.67)		1.00 (0.92-1.09)		1.01 (0.95-1.07)		0.95 (0.88-1.03)		1.01 (0.94-1.08)	

[1]Day of hospital admission or associated preceding emergency department presentation

Hospital is included as a random effect.

Table 4. Adjusted odds-ratios for 30-day mortality by day of week and time of day of presentation[1].

Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value
Day of week		0.136		0.404		0.741		0.136		0.003		0.660
Monday	Reference		Reference		Reference		Reference		Reference		Reference	
Tuesday	1.14 (0.95-1.38)	0.167	1.01 (0.82-1.24)	0.926	1.07 (0.90-1.28)	0.451	0.87 (0.77-0.98)	0.023	1.09 (0.94-1.25)	0.269	1.00 (0.88-1.14)	0.971
Wednesday	1.12 (0.93-1.35)	0.242	1.08 (0.88-1.34)	0.451	0.99 (0.83-1.19)	0.936	0.97 (0.86-1.09)	0.606	1.08 (0.93-1.25)	0.298	1.06 (0.93-1.21)	0.373
Thursday	1.03 (0.84-1.25)	0.803	0.88 (0.71-1.09)	0.228	1.08 (0.91-1.29)	0.371	0.98 (0.87-1.10)	0.720	1.29 (1.12-1.48)	0.001	0.99 (0.87-1.12)	0.829
Friday	1.22 (1.01-1.47)	0.039	1.05 (0.85-1.29)	0.653	1.10 (0.92-1.31)	0.303	0.92 (0.81-1.03)	0.156	1.25 (1.08-1.44)	0.002	1.09 (0.96-1.24)	0.175
Saturday	1.17 (0.96-1.42)	0.112	1.13 (0.91-1.40)	0.275	1.01 (0.84-1.21)	0.941	1.03 (0.92-1.17)	0.578	1.18 (1.02-1.37)	0.030	1.07 (0.94-1.23)	0.315
Sunday	1.28 (1.06-1.54)	0.012	1.06 (0.85-1.31)	0.595	0.96 (0.80-1.16)	0.681	0.97 (0.86-1.10)	0.670	1.05 (0.90-1.22)	0.550	1.02 (0.89-1.17)	0.784
Time of day		<0.001		<0.001		0.200		0.861		0.905		0.525
Day	Reference		Reference		Reference		Reference		Reference		Reference	
Night	1.30 (1.17-1.45)		1.58 (1.40-1.78)		1.07 (0.97-1.17)		1.01 (0.94-1.08)		1.00 (0.92-1.08)		1.02 (0.95-1.10)	

[1]Day of hospital admission or associated preceding emergency department presentation

Models were adjusted for age, sex, and comorbidities (final model results for all variables are provided in supplementary table S1). Hospital is included as a random effect.

Table 5. Unadjusted and adjusted odds ratios for 30-day mortality for day of week, categorized as weekend versus weekday, of hospital presentation[1] using random effect logistic regression models

Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value
Unadjusted												
Day of week		0.006		0.057		0.498		0.042		0.617		0.310
Weekday	Reference		Reference		Reference		Reference		Reference		Reference	
Weekend	1.16 (1.04-1.29)		1.13 (1.00-1.28)		0.97 (0.88-1.07)		1.07 (1.00-1.15)		0.98 (0.90-1.07)		1.04 (0.96-1.13)	
Adjusted												
Day of week												
Weekday	Reference	0.067	Reference	0.197	Reference	0.261	Reference	0.135	Reference	0.686	Reference	0.686
Weekend	1.11 (0.99-1.24)		1.09 (0.96-1.24)		0.94 (0.84-1.05)		1.06 (0.98-1.14)		0.98 (0.90-1.07)		1.02 (0.93-1.11)	
Time of day												
Day	Reference	<0.001	Reference	<0.001	Reference	0.210	Reference	0.939	Reference	0.930	Reference	
Night	1.30 (1.17-1.45)		1.57 (1.40-1.77)		1.06 (0.97-1.17)		1.00 (0.94-1.07)		1.00 (0.92-1.08)		1.02 (0.95-1.10)	0.930

[1]Day of hospital admission or associated preceding emergency department presentation

Adjusted models included age, sex and comorbidities. All models included hospital as a random effect.

Figure 1. a) Adjusted odds ratios for 30-day mortality for day of week of presentation by clinical condition. Reference group is Monday (dotted line). b) adjusted odds ratios for 30-day mortality for presentation to hospital at night compared to during the day, by clinical condition. AMI = acute myocardial infarction, COPD = chronic obstructive pulmonary disease, CHF = congestive heart failure.

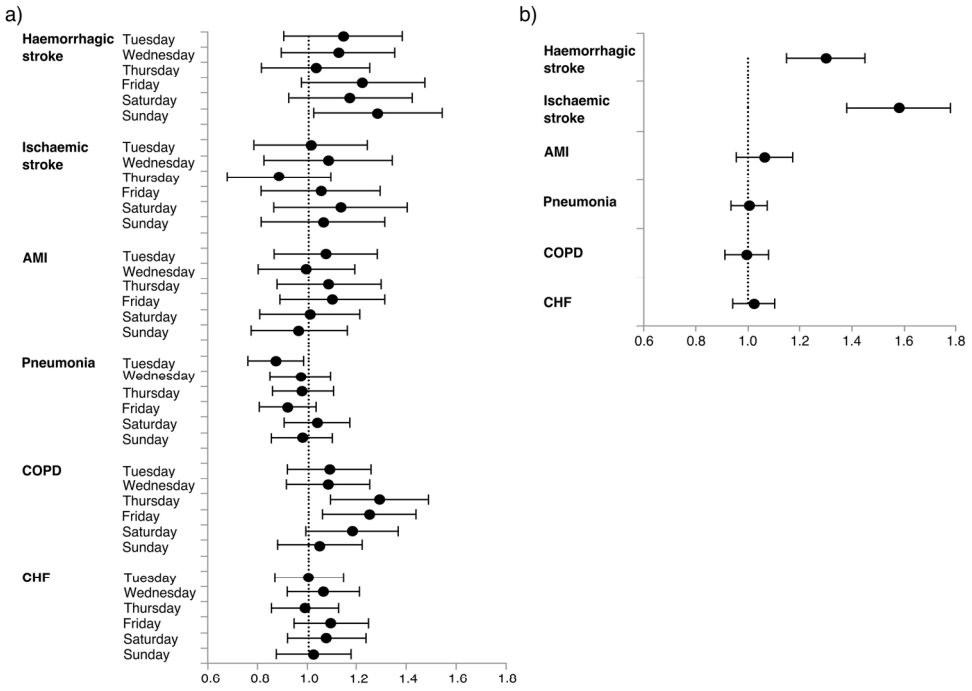

Figure 1. a) Adjusted odds ratios for 30-day mortality for day of week of admission by clinical condition. Reference group is Monday (dotted line). b) adjusted odds ratios for 30-day mortality for admission to hospital at night compared to during the day, by clinical condition. AMI = acute myocardial infarction, COPD = chronic obstructive pulmonary disease, CHF = congestive heart failure.

165x131mm (300 x 300 DPI)

SUPPLEMENTARY MATERIAL

Table S1. Final multivariable model results for 30-day mortality by day of week and time of day of hospital admission or related, preceding ED presentation for ischaemic and haemorrhagic stroke, AMI, pneumonia, COPD and CHF.

Condition Variable	Odds Ratio (95% CI)	*p*-value
Ischaemic stroke		
Day of week (ref = Mon)		0.136
Tuesday	1.14 (0.95-1.38)	0.167
Wednesday	1.12 (0.93-1.35)	0.242
Thursday	1.03 (0.84-1.25)	0.803
Friday	1.22 (1.01-1.47)	0.039
Saturday	1.17 (0.96-1.42)	0.112
Sunday	1.28 (1.06-1.54)	0.012
Night	1.30 (1.17-1.45)	<0.001
Sex (ref = male)	1.32 (1.19-1.47)	<0.001
Age (centred)	1.06 (1.06-1.07)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
Renal failure	1.70 (1.48-1.97)	<0.001
Heart failure	1.95 (1.66-2.28)	<0.001
Malignancy	2.64 (2.15-3.24)	<0.001
AMI		
Day of week (ref = Mon)		0.741
Tuesday	1.07 (0.90-1.28)	0.451
Wednesday	0.99 (0.83-1.19)	0.936
Thursday	1.08 (0.91-1.29)	0.371
Friday	1.10 (0.92-1.31)	0.303
Saturday	1.01 (0.84-1.21)	0.941
Sunday	0.96 (0.80-1.16)	0.681
Night	1.07 (0.97-1.17)	0.200
Age (centred)	1.06 (1.05-1.06)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
STEMI	2.71 (2.44-3.01)	<0.001
Dementia	2.10 (1.77-2.48)	<0.001
Hypotension	1.29 (1.14-1.46)	<0.001
Shock	9.38 (7.79-11.30)	<0.001
Renal failure	2.32 (2.07-2.60)	<0.001
Heart failure	1.77 (1.58-1.98)	<0.001
Dysrhythmia	1.72 (1.55-1.90)	<0.001
Malignancy	2.38 (1.94-2.92)	<0.001
Hypertension	0.67 (0.61-0.74)	<0.001
Cerebrovascular disease	2.34 (1.95-2.81)	<0.001

Condition Variable	Odds Ratio (95% CI)	*p*-value
Haemorrhagic stroke		
Day of week (ref = Mon)		0.404
Tuesday	1.01 (0.82-1.24)	0.926
Wednesday	1.08 (0.88-1.34)	0.451
Thursday	0.88 (0.71-1.09)	0.228
Friday	1.05 (0.85-1.29)	0.653
Saturday	1.13 (0.91-1.40)	0.275
Sunday	1.06 (0.85-1.31)	0.595
Night	1.58 (1.40-1.78)	<0.001
Sex (ref = male)	1.39 (1.24-1.56)	<0.001
Age (centred)	1.04 (1.04-1.05)	<0.001
Heart failure	1.47 (1.16-1.87)	0.001
Malignancy	2.75 (2.20-3.45)	<0.001
Previous H-stroke	0.61 (0.48-0.77)	<0.001
Pneumonia		
Day of week (ref=Mon)		0.136
Tuesday	0.87 (0.77-0.98)	0.023
Wednesday	0.97 (0.86-1.09)	0.606
Thursday	0.98 (0.87-1.10)	0.720
Friday	0.92 (0.81-1.03)	0.156
Saturday	1.03 (0.91-1.16)	0.578
Sunday	0.97 (0.86-1.10)	0.670
Night	1.00 (0.94-1.07)	0.861
Financial year (ref = 2009)		<0.001
2010	0.90 (0.83-0.97)	0.004
2011	0.74 (0.68-0.80)	<0.001
Age (centred)	1.05 (1.05-1.05)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
Dementia	2.66 (2.42-2.92)	<0.001
Hypotension	1.18 (1.08-1.28)	<0.001
Shock	4.02 (3.34-4.84)	<0.001
Renal failure	1.84 (1.70-1.99)	<0.001
Heart failure	1.55 (1.43-1.68)	<0.001
Dysrhythmia	1.32 (1.22-1.42)	<0.001
Malignancy	5.54 (5.07-6.05)	<0.001
Cerebrovascular disease	1.82 (1.59-2.08)	<0.001
Other COPD	1.17 (1.08-1.27)	<0.001
Liver disease	2.81 (1.75-2.71)	<0.001
Parkinsons	1.69 (1.35-2.11)	<0.001

COPD		
Day of week (ref = Mon)		0.003
Tuesday	1.09 (0.94-1.25)	0.269
Wednesday	1.08 (0.93-1.25)	0.298
Thursday	1.29 (1.12-1.48)	0.001
Friday	1.25 (1.08-1.44)	0.002
Saturday	1.18 (1.02-1.37)	0.030
Sunday	1.05 (0.90-1.22)	0.550
Night	1.00 (0.92-1.08)	0.905
Financial year (ref = 2009)		<0.001
2010	0.77 (0.70-0.85)	<0.001
2011	0.50 (0.45-0.55)	<0.001
Prev acute COPD episode (ref = 0)[1]		<0.001
1 previous episode	1.67 (1.51-1.85)	<0.001
2 previous episodes	2.13 (1.86-2.43)	<0.001
3+ previous episodes	3.04 (2.69-3.44)	<0.001
Sex (ref=male)	0.82 (0.76-0.89)	<0.001
Age (centred)	1.03 (1.03-1.04)	<0.001
Age (squared)	1.00 (1.00-1.00)	0.013
CHF	1.47 (1.34-1.61)	<0.001
Pulmonary circ. disord.	1.66 (1.46-1.89)	<0.001
Neurological disord.	1.31 (1.05-1.64)	0.016
Diabetes (comp.)	0.83 (0.73-0.95)	0.005
Liver disease	1.98 (1.50-2.61)	<0.001
Metastatic cancer	3.06 (2.38-3.95)	<0.001
Solid tumour w/o metast.	1.42 (1.17-1.72)	<0.001
Weight loss	1.89 (1.68-2.11)	<0.001
Fluid/electrolyte dis.	1.81 (1.66-1.98)	<0.001
Psychoses	2.10 (1.47-3.00)	<0.001

CHF		
Day of week (ref=Mon)		0.660
Tuesday	1.00 (0.88-1.14)	0.971
Wednesday	1.06 (0.93-1.21)	0.373
Thursday	0.99 (0.87-1.12)	0.829
Friday	1.09 (0.96-1.24)	0.175
Saturday	1.07 (0.94-1.23)	0.315
Sunday	1.02 (0.89-1.17)	0.784
Night	1.02 (0.95-1.10)	0.525
Financial year (ref = 2009)		<0.001
2010	0.89 (0.81-0.97)	0.009
2011	0.67 (0.62-0.74)	<0.001
Prev acute CHF episode (ref = 0)[1]		<0.001
1 previous episode	1.39 (1.26-1.52)	<0.001
2 previous episodes	1.70 (1.48-1.97)	<0.001
3+ previous episodes	2.52 (2.14-2.96)	<0.001
Sex (ref = male)	0.90 (0.84-0.97)	0.008
Age (centred)	1.05 (1.05-1.06)	<0.001
Age (squared)	1.00 (1.00-1.00)	0.003
Pulmonary circ. disord.	1.21 (1.09-1.35)	<0.001
Peripheral vascular disord.	1.19 (1.04-1.37)	0.013
Hypertension (comp/uncomp)	0.83 (0.77-0.90)	<0.001
Paralysis	1.65 (1.34-2.04)	<0.001
Neurological disorders	1.65 (1.39-1.97)	<0.001
Chronic pulmonary disease	1.23 (1.13-1.34)	<0.001
Renal failure	1.88 (1.73-2.03)	<0.001
Liver disease	2.78 (2.29-3.38)	<0.001
Lymphoma	2.24 (1.57-3.19)	<0.001
Metastatic cancer	3.07 (2.44-3.86)	<0.001
Coagulopathy	1.29 (1.15-1.46)	<0.001
Weight loss	1.61 (1.43-1.83)	<0.001
Fluid/electrolyte disorders	1.57 (1.45-1.69)	<0.001
Deficiency anaemia	0.78 (0.68-0.90)	<0.001

[1] lookback to 2004

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Checked (page #)
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6-7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	8
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8, 19
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	20,21

		which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	considered
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10,11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	11,12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Is the weekend effect really ubiquitous? Retrospective clinical cohort analyses of 30-day mortality by day of week and time of day using linked population data from New South Wales, Australia

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Is the weekend effect really ubiquitous? Retrospective clinical cohort analyses of 30-day mortality by day of week and time of day using linked population data from New South Wales, Australia

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ABSTRACT

Objective

To examine the associations between day of week and time of admission and 30-day mortality for six clinical conditions: ischaemic and haemorrhagic stroke, acute myocardial infarction, pneumonia, chronic obstructive pulmonary disease and congestive heart failure.

Design

Retrospective population-based cohort analyses. Hospitalisation records were linked to emergency department and deaths data. Random effect logistic regression models were used, adjusting for casemix and taking into account clustering within hospitals.

Setting

All hospitals in New South Wales, Australia from July 2009 to June 2012.

Participants

Patients admitted to hospital with a primary diagnosis for one of the six clinical conditions examined.

Outcome measures

Adjusted odds ratios for all-cause mortality within 30 days of admission, by day of week and time of day.

Results

A total of 148,722 patients were included in the study, with 17,721 deaths within 30 days of admission. Day of week of admission was not associated with significantly higher likelihood of death for five of the six conditions after adjusting for casemix. There was significant variation in mortality for chronic obstructive pulmonary disease by day of week, however, this was not consistent with a strict weekend effect (Thursday: OR 1.29, 95% CI 1.12–1.48; Friday: OR 1.25, 95%CI 1.08–1.44; Saturday: OR 1.18, 95% CI 1.02–1.37; Sunday OR 1.05, 95% CI 0.90–1.22; compared to Monday). There was evidence for a night effect for patients admitted for stroke (ischaemic: OR 1.30, 95% CI 1.17–1.45; haemorrhagic: OR 1.58, 95% CI 1.40–1.78).

Conclusions

Mortality outcomes for these conditions, adjusted for casemix, do not vary in accordance with the weekend effect hypothesis. Our findings support a growing body of evidence that questions the ubiquity of the weekend effect.

Keywords

Weekend effect, night effect, out-of-hours effect, stroke, AMI, pneumonia, COPD, CHF

Article summary

Strengths and limitations of this study

- The examined conditions encompass a range of time sensitivity, interventions, acuity and prognosis, providing a gradient to assess potential causality of association.
- The use of linked hospital admission and emergency department (ED) data allowed complete coverage of hospital admissions for the state, while minimising misclassification bias from time spent in ED and maximising validity and quality of diagnosis and comorbidity data.
- The use of clinical cohorts of patients allows more precise adjustment for casemix than non-specific admissions.
- Linkage to the Deaths Register allowed the capture of 30-day all-cause mortality. While mortality is a standard indicator, other outcomes may be more sensitive to variation in patient outcomes.
- We focussed on the NSW health system as a whole and did not explore the possible weekend effect at hospital level.

INTRODUCTION

In recent years, researchers and policy makers have shown growing interest in the 'weekend effect', examining whether patients admitted to hospital at the weekend experience worse outcomes compared to patients admitted during the week. This effect has been observed in numerous studies of health systems around the world, for a wide range of conditions and procedures.[1-6] Studies have also observed a 'night effect', suggesting that the phenomenon may extend to out-of-hours presentation more broadly.[1-4]

Considerable uncertainty remains as to the cause of the apparent effect of weekend and night-time (hereafter collectively 'out-of-hours') presentation on patient outcomes. Two main hypotheses have been proposed to explain the observed variation: these focus on healthcare service quality and on patient characteristics.[2] The first hypothesis posits that the poorer outcomes seen among patients admitted on the weekend are explained by lower quality of care out-of-hours. More specifically, putative factors include lower staffing levels, fewer senior consultants and specialists, and reduced availability of diagnostic procedures.[3] This hypothesis gained considerable traction with policy makers and has contributed to the recent, controversial push towards seven day hospital services in the UK.[7]

The second hypothesis proposes that the weekend effect is largely attributable to patient characteristics, and at least partly a data artefact resulting from insufficient information on patient characteristics in administrative datasets. There is little clear evidence that higher mortality is a consequence of staffing levels[7], and a number of studies have found no significant correlation between consultant seniority or specialist availability and mortality.[8-11] There is also an increasing body of evidence to suggest that the weekend effect dissipates after adjustment for casemix[12], arrival by ambulance as a proxy for illness

severity[13] and a higher severity threshold for admission.[12] This phenomenon may be influenced by self-selection, whereby patients wait until the weekend to present to hospital and may therefore present with more advanced disease, and less comprehensive note-taking on the weekend limiting the ability to risk-adjust.[14]

The night effect is less extensively studied than the weekend effect, and reasons for the night effect are usually presumed to be similar to the weekend effect. The few studies that have examined the effects of out-of-hours presentation on mortality in Australia have had mixed results.[3,4,15,16] Previous studies have been limited by using in-hospital mortality only and therefore not capturing deaths that occurred post-discharge[17], reduced ability to adequately risk adjust by focusing on clinically non-specific admissions.[3,16,18] Further, previous studies have often relied on unlinked emergency department (ED) data[4], which contain limited or largely incomplete and inaccurate information on principal diagnosis and comorbidity, or unlinked hospitalisation data, which may be affected by misclassification bias due to time spent in waiting in ED prior to admission.[15,18]

Overall, previous studies have shown that the out-of-hours effect does not apply to all clinical presentations and procedures.[1-4,8] It is therefore beneficial to investigate conditions for which we can expect that the weekend is more likely to occur, based on theoretical grounds, on clinical plausibility or on previous evidence.[2]

We investigated the existence of the weekend effect and the night effect for acute hospitalisations for various conditions, comprising ischaemic stroke, haemorrhagic stroke, acute myocardial infarction (AMI), pneumonia, chronic obstructive pulmonary disease (COPD), and congestive heart failure (CHF), across all hospitals in New South Wales (NSW). These conditions provide insights into a range of aspects of healthcare, including timely delivery of interventions, surgical services, differences in acuity and prognosis, and

provide a gradient to assess potential causality of association as they vary in the importance of immediate care. We predicted that if day and time effects exist, they would show strongest effects for the most urgent conditions (stroke and AMI), and be weakest for patients with the least urgent conditions (pneumonia and COPD). We hypothesized that presentations on Saturdays and Sundays would show higher 30-day mortality for the six conditions than presentations that occurred during the week, and that night-time presentations would show higher mortality than presentations that occurred during the day.

METHODS

Retrospective cohort analyses were performed for the six indicator conditions. Cohorts were identified from all admissions to NSW public and private hospitals for the period of 1 July 2009 to 30 June 2012, extracted from the NSW Admitted Patient Data Collection, which is a census of all hospital admissions in NSW. These data were linked to emergency department (ED) attendances in all NSW public hospitals recorded in the Emergency Department Data Collection, representing approximately 85% of all emergency presentations in NSW.[19,20] Emergency department data were linked to allow the capture of the start day and time of the patients' contact with the hospital system for the episode of illness, minimising any bias imposed by time spent in the ED that may affect the day and time of hospitalisation, since patients may spend longer in the ED before admission at night or at weekends. Mortality data were obtained from the NSW Deaths Register. Data were linked by the NSW Centre for Health Record Linkage using probabilistic methods based on personal identifiers. The estimated false positive rate for the current version of the Master Linkage Key is 5 per 1000.[21]

The principal diagnosis in the patient record, coded using International Classification of Diseases 10th revision Australian modification, was used to identify each clinical cohort. Only complete records of admissions coded as acute and emergency were included. The proportion of records excluded for missing values on key variables such as age, sex, date of admission and separation, type of care and emergency status was less than 0.1%. Patients aged less than 15 years (ischaemic stroke, haemorrhagic stroke, AMI), 18 years (pneumonia) or 45 years (COPD, CHF) were excluded, consistent with existing mortality indicator definitions for these conditions, due to low mortality rates among these groups.[22,23] AMI can be classified as ST-elevated myocardial infarction (STEMI) or non-ST elevated myocardial infarction (non-STEMI) based on the electrocardiogram reading, or unspecified AMI when diagnostic records are unavailable. STEMI is associated with higher mortality at 30 days compared to non-STEMI, and the unspecified group is a heterogeneous mix of critically unwell patients who died before their AMI could be specified and patients for whom diagnostic records were less precise, so AMI patients with a non-specific infarction were excluded to allow adjustment for STEMI.[22,23] Transfers and multiple contiguous hospitalisations were considered as a single period of care. For patients with multiple periods of care during the study period, only the last period of care was included in the analyses.

Mortality was defined as death (in or out of hospital) occurring within 30 days of the start of the period of care. The day of week of presentation was defined as the first day of contact with the hospital system for the period of care (either hospital admission or ED presentation). Patients dead on arrival to ED and not admitted to hospital were excluded. An ED presentation was considered relevant for the hospital admission if it occurred on the same day, or previous day, as the hospital admission. Same day ED presentations were only included if the time was recorded as before the hospital admission time. In this study, the weekend comprises Saturday and Sunday, while weekdays are defined as Monday through

Friday. Night time presentation was defined as first presentation between 18:00 and 07:59, using hospital admission time or ED presentation time as described.

Random effects logistic regression models were used to investigate associations between day of week, or time of presentation, with mortality. To account for clustering of patients within hospitals, hospitals were considered as random effects in the regression models. Risk adjustment was performed to account for casemix factors including age (continuous, tested for curvilinearity), sex, year and comorbidities. Condition-specific comorbidity sets defined by the Australian Commission for Safety and Quality in Health Care were used as the basis for building risk adjustment models for each condition, where available (ischaemic stroke, haemorrhagic stroke, AMI, pneumonia), while COPD and CHF used Elixhauser comorbidities.[22] Availability of thrombolysis treatment was also considered as a predictive variable for ischaemic stroke, and STEMI status was considered for AMI. Comorbidities were captured across all hospital admissions over a one year period prior to the index admission. Interactions between day of the week and night time presentations were also explored in the final models using likelihood ratio tests.

Models were selected using backwards selection.[24] Factors with a *p*-value of less than 0.2 in the univariate analyses were included in the initial full models. Variables with a *p*-value of less than 0.05 were retained in the model. Variables that were not significant at the 20% level in the univariate models were then checked for significance in the backwards-selected model, and retained in the final model where $p < 0.05$. Overall performance of the models was assessed using c-statistics. In order to capture daily variation, 30-day mortality risks for each day of the week were compared against a reference weekday (Monday). We define observation of a weekend effect as significantly higher odds of 30-day mortality on weekend days (Saturday and Sunday) compared to Monday. To validate our findings, additional analyses were performed comparing weekend days against weekdays. Statistical

analyses were performed using SAS v9.4 (SAS Institute Inc., Cary, NC, USA) and STATA v12.1 (StataCorp LP, Texas, USA).

RESULTS

There were a total of 213,834 acute, emergency hospital admissions for the conditions of interest during the study period. There were 10,658 admissions excluded as they did not meet the eligibility criteria for age, and 2161 patients were excluded who had a non-specified AMI. After accounting for transfers and multiple admissions, there were 148,722 patients were included in the study (table 1). There were 17,721 deaths within 30 days of admission (11.9%). A total of 127,268 admissions were linked to an ED presentation (85.6%). The clinical cohorts comprised between 5,740 (haemorrhagic stroke) and 44,508 (pneumonia) patients that were admitted or presented to between 133 and 183 hospitals. Characteristics of patients are provided by day of week and time of day of arrival in table 2.

The most frequent day of presentation was Monday, while Saturdays and Sundays had fewer presentations than weekdays for all conditions. More patients were admitted during daytime than at night, regardless of condition.

There were no significant associations in the univariate analyses between mortality and day of week, for haemorrhagic stroke, AMI, pneumonia, or CHF (table 3). There was significant variation in unadjusted 30-day mortality by day of week for ischaemic stroke and COPD, however this did not show a strict 'weekend effect' (ischaemic stroke: Friday, Saturday and Sunday significantly higher than Monday; COPD: Thursday, Friday and Saturday significantly higher than Monday).

There was no significant difference in 30-day mortality by day of week after adjustment for casemix and other factors for five of the six conditions (table 4, figure 1). While Friday and Sunday presentations had significantly higher mortality than Monday for ischaemic stroke, overall day of the week was not significant in the model. Significant variation in mortality by day of week for COPD was not consistent with a weekend effect (with Thursday, Friday and Saturday being associated with higher mortality compared with Monday).

There was evidence for higher mortality among ischaemic and haemorrhagic stroke patients who presented to hospital overnight. This night effect was observed in both the unadjusted and adjusted analyses (table 3, table 4). There was no evidence of increased mortality among night admissions for the other conditions. There were no significant interactions between day of week and time of day, after adjustment for confounding factors, for any of the conditions.

The models performed moderately well, with c-statistics ranging from 0.68 to 0.82 (ischaemic stroke: 0.73, haemorrhagic stroke: 0.68, AMI: 0.81, pneumonia: 0.82, COPD: 0.74, CHF: 0.72).

Results from the analyses comparing 30-day mortality on pooled weekend versus weekdays showed that the weekend was associated with a higher unadjusted likelihood of 30-day mortality compared with weekday for ischaemic stroke and pneumonia (table 5). However, after taking into account other risk factors, no significant differences were observed in 30-day mortality between weekdays and weekend for any of the conditions studied.

DISCUSSION

Main findings

Mortality outcomes do not vary in accordance with the weekend effect, after adjusting for casemix, for patients admitted to hospital with stroke, AMI, pneumonia, COPD, or CHF in NSW. We found increased mortality for stroke patients presenting to hospital at night, with no evidence for the night effect for the remaining conditions.

Our findings support a growing body of evidence that disputes the ubiquity of the weekend effect.[7,12,14,15,25,26] Of the six conditions investigated in this study, only ischaemic stroke and COPD showed significant variation in crude mortality risk by day of week of presentation. Significant variation remained after risk adjustment for COPD only, and this was not consistent with predictions for the weekend effect, with the highest odds of death within 30 days was found for those who presented on Thursday and Friday. When weekend and week days were pooled, there were no significant differences in odds of death after adjusting for other risk factors. This is consistent with studies which have shown more complex patterns of temporal variation in that there are some days/times that are different but not specifically 'the weekend'.[4,17,26,27]

While findings from previous studies for stroke[11,14,28,29], AMI[15,30] and COPD[15,31] have been conflicting, our results are consistent with those that found no weekend effect (stroke[1,14,26,32], AMI[1,33], COPD[15]). A recent meta-analysis found no weekend effect for COPD and pneumonia, although it did find significant effects for intracerebral haemorrhage, ischaemic stroke and myocardial infarction[34]. However, on comparing effects between continents, Oceania was found to have the lowest overall increase in odds of death (OR = 1.04; compared to South America, OR = 1.47), suggesting that the weekend effect may be

highly heterogenous and dependent not only on clinical conditions but also on hospital contexts, regional policy and other factors that may vary widely by geographic setting.

We observed that the numbers of admissions were lower at weekends in New South Wales, and that the number of deaths within 30 days are generally proportionate to the number of admissions. This is in contrast to the findings of previous studies.[1,6,12,35] There are a number of differences between our study and some of the previously published work which may explain these differences. The use of 30-day mortality through linkage to the Deaths Register as opposed to in-hospital death[1,3,6,12,13,35] allows the capture not only of patients who died in hospital, but also those died in community due to variation in care or early discharge. This provides a more complete picture of mortality.

Further, our study has examined six specific clinical conditions, as opposed to all emergency conditions.[3,4,12,35] Not all emergency admissions have the same urgency or acuity for treatment, and the conditions we have examined are useful indicators that encompass a range of time sensitivity, interventions, acuity and prognosis. The use of clinical cohorts of patients allows more precise adjustment for case-mix than considering non-specific admissions. We found no effect on mortality of weekend presentation either in conditions expected to be less sensitive to reduced staffing and services, nor among the more severe, acute conditions, which confers confidence in the validity of our findings. Our analyses comprised three years' complete population data for NSW with cohorts ranging from over 5000 to 44,000, which should provide sufficient power to detect statistically significant differences.

In contrast to other studies, the use of linked hospitalisation and emergency department data provides complete coverage of hospital admissions for the conditions of interest in NSW, and minimises several potential biases. While most studies use either

hospital admission data[1,6,35] or ED data[3,4], the use of linked data in this study minimises misclassification bias in day and time of presentation caused by time spent in ED prior to admission. Additionally, the use of hospitalisation data from the index and historical admissions of the patients allowed us to maximise the detail and quality of diagnoses and comorbidities. This increases our confidence in our finding of no evidence for increased mortality associated with weekend presentation.

We found significantly higher adjusted risk of death for ischaemic and haemorrhagic stroke patients who presented at night compared to those who presented during the day. This is consistent with other studies of stroke.[26,28] This finding may reflect factors specific to stroke, such as that strokes occurring at night may take longer to recognise due to reduced activity, and may result in delayed seeking of treatment and therefore higher mortality. That we only observed the night effect for stroke patients suggests that this variation is probably not attributable to system-wide deficiencies. However, further research to explore reasons for the increase in mortality for stroke patients admitted at night, and the observed variation in mortality for COPD by day of presentation, including potential contributions from poorer community care, will help to understand whether these excess deaths are preventable.

Our study is limited by a lack contextual information in our data about the differences in weekend and weekday or night time and day time practice, such as the availability of clinical or laboratory staff. It would be interesting to consider the results on the level of individual hospitals, as hospital variation in quality of care on weekends may be masked in this type of global analysis.

Mortality is a useful indicator for health system performance and for evaluating unwarranted variation. However, it is an extreme outcome, and it may be a blunt tool that could mask some variation in patient outcomes. Further research is needed to determine

whether lower staffing levels and resource access on weekends and out-of-hours may exhibit effects on other outcomes or processes, such as adverse events, delays in test results or care, or other quality indicators. Across healthcare systems, different models of care or availability of out-of-hours specialist services may affect any weekend effect seen locally.

Unlike many other studies, our findings do not suggest a threshold effect or differing propensity to admit patients across days of the week. This may be a reflection of the particular conditions that our study focused upon or it may be the case that there is no weekend effect in NSW public hospitals. While our study does address both weekend effect and night time effect, it is possible that more complex patterns of temporal variation exist that could not be observed using our models."

CONCLUSION

By identifying patients admitted through ED, and taking out-of-hospital deaths into account, this study was able to investigate the weekend effect by following the patient journey from prior to admission to after discharge. We found no evidence for a strict weekend effect in 30-day mortality for patients admitted with ischaemic or haemorrhagic stroke, AMI, pneumonia, COPD, or CHF. The finding of a night effect for stroke, and some variation between days for COPD, highlights that temporal variation in patient outcomes is complex and may have a variety of causes. Our findings increase the weight of evidence challenging the existence of the weekend effect.

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Contributors

HJB, SMP, HYC, JK, KS and JFL contributed to the study design. HJB and SMP cleaned and analysed the data and HJB produced the figure and tables. All authors contributed to the interpretation of the results. HJB drafted the manuscript, and all authors contributed to revising the manuscript. All authors approved the final version of the manuscript.

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Competing interests

We declare no competing interests.

Data sharing statement

Privacy restrictions for the datasets used in this study prohibit free online availability. Access to these data may be sought from the data custodians, the New South Wales Ministry of Health.

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Table 1. Numbers of patients admitted to hospital in NSW between July 2009 and June 2012 for the conditions examined, number and percentage of deaths within 30 days, by day and time of presentation[1].

Condition	Day of week							Time of Day		Total
	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	Day	Night	
Ischaemic stroke (145 hospitals)										
Admissions[1]	2240	2168	2082	2070	2010	1868	1916	9858	4496	14354
Deaths	257	281	281	247	291	267	287	1241	670	1911
30-day mortality (%)	11.5	13.0	13.5	11.9	14.5	14.3	15.0	12.6	14.9	13.3
Haemorrhagic stroke (133 hospitals)										
Admissions[1]	905	894	818	830	853	703	737	3676	2064	5740
Deaths	303	296	288	255	286	254	264	1127	819	1946
30-day mortality (%)	33.5	33.1	35.2	30.7	33.5	36.1	35.8	30.7	39.7	33.9
Acute myocardial infarction (172 hospitals)										
Admissions[1]	4493	4332	4248	4241	4388	4004	3869	16309	13266	29575
Deaths	331	321	320	337	347	292	290	1233	1005	2238
30-day mortality (%)	7.4	7.4	7.5	8.0	7.9	7.3	7.5	7.6	7.6	7.6
Pneumonia (183 hospitals)										
Admissions[1]	7097	6354	6419	6366	6489	5754	6029	27382	17126	44508
Deaths	775	627	703	677	679	667	656	2929	1855	4784
30-day mortality (%)	10.9	9.9	11.0	10.6	10.5	11.6	10.9	10.7	10.8	10.8
Chronic obstructive pulmonary disease (177 hospitals)										
Admissions[1]	4794	4272	4193	4114	4116	3664	3786	17674	11265	28939
Deaths	459	436	426	476	479	408	367	1891	1160	3051
30-day mortality (%)	9.6	10.2	10.2	11.6	11.6	11.1	9.7	10.7	10.3	10.5
Congestive heart failure (177 hospitals)										
Admissions[1]	4325	3935	3828	3799	3780	2962	2977	16046	9560	25606
Deaths	628	568	577	549	566	462	441	2369	1422	3791
30-day mortality (%)	14.5	14.4	15.1	14.5	15.0	15.6	14.8	14.8	14.9	14.8

[1]Day of hospital admission or associated preceding emergency department presentation

Table 2. Demographic and clinical characteristics of patients with acute, emergency hospital admissions for the conditions of interest by day of week and time of day of presentation[1], NSW, July 2009 - June 2012.

Characteristic	Day of week		Time of day	
	Weekday	Weekend	Day	Night
	N = 110,453 (%)	N = 38,269 (%)	N = 90,945 (%)	N = 57,777 (%)
Age groups				
15-39	4,361 (4.0)	1,580 (4.1)	3,501 (3.9)	2,440 (4.2)
40-59	16,623 (15.1)	5,804 (15.2)	13,044 (14.3)	9,383 (16.2)
60-79	46,943 (42.5)	16,178 (42.3)	38,593 (42.4)	24,528 (42.5)
80+	42,526 (38.5)	14,707 (38.4)	35,807 (39.4)	21,426 (37.1)
Age (years; median (IQR))	75.8 (63.9-84.1)	75.8 (63.7-84.2)	76.2 (64.5-84.3)	75.1 (62.9-83.9)
Gender				
Female	50,318 (45.6)	17,407 (45.5)	42,300 (46.5)	25,425 (44.0)
Male	60,135 (54.4)	20,862 (54.5)	48,645 (53.5)	32,352 (56.0)
Charlson comorbidity index				
0	74,780 (67.7)	25,954 (67.8)	61,248 (67.4)	39,486 (68.3)
1-2	28,678 (26.0)	9,859 (25.8)	23,930 (26.3)	14,607 (25,3)
3+	6,995 (6.3)	2,456 (6.4)	5,767 (6.3)	3,684 (6.4)
Admitted via ED	93,799 (84.9)	33,469 (87.5)	76,835 (84.5)	50,433 (87.3)

[1]Day of hospital admission or associated preceding emergency department presentation

Conditions included are ischaemic stroke, haemorrhagic stroke, acute myocardial infarction, pneumonia, chronic obstructive pulmonary disease, and congestive heart failure.

Table 3. Unadjusted odds ratios for 30-day mortality for day of week and time of day of presentation[1].

Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value	Unadjusted Odds Ratio	*P*-value
Day of week		0.006		0.271		0.879		0.092		0.003		0.813
Monday	Reference		Reference		Reference		Reference		Reference		Reference	
Tuesday	1.14 (0.95-1.37)	0.152	0.97 (0.80-1.19)	0.789	1.00 (0.86-1.18)	0.964	0.90 (0.80-1.00)	0.052	1.07 (0.93-1.23)	0.332	0.99 (0.88-1.12)	0.927
Wednesday	1.20 (1.00-1.44)	0.051	1.07 (0.88-1.31)	0.493	1.02 (0.87-1.20)	0.787	1.01 (0.90-1.12)	0.916	1.07 (0.93-1.23)	0.354	1.05 (0.93-1.18)	0.462
Thursday	1.04 (0.86-1.25)	0.668	0.87 (0.71-1.07)	0.194	1.08 (0.92-1.27)	0.321	0.97 (0.87-1.08)	0.600	1.24 (1.08-1.42)	0.002	0.99 (0.88-1.13)	0.929
Friday	1.30 (1.09-1.56)	0.004	1.00 (0.82-1.23)	0.969	1.08 (0.92-1.26)	0.355	0.95 (0.85-1.06)	0.346	1.24 (1.08-1.42)	0.002	1.04 (0.92-1.17)	0.566
Saturday	1.28 (1.07-1.54)	0.008	1.12 (0.91-1.38)	0.288	0.99 (0.84-1.16)	0.887	1.07 (0.96-1.20)	0.211	1.18 (1.02-1.36)	0.023	1.09 (0.96-1.24)	0.195
Sunday	1.35 (1.12-1.61)	0.001	1.10 (0.90-1.36)	0.352	1.02 (0.86-1.20)	0.843	1.00 (0.89-1.12)	0.981	1.01 (0.88-1.17)	0.866	1.03 (0.90-1.17)	0.712
Time of day		0.001		<0.001		0.967		0.750		0.231		0.794
Day	Reference		Reference		Reference		Reference		Reference		Reference	
Night	1.22 (1.10-1.35)		1.49 (1.33-1.67)		1.00 (0.92-1.09)		1.01 (0.95-1.07)		0.95 (0.88-1.03)		1.01 (0.94-1.08)	

[1]Day of hospital admission or associated preceding emergency department presentation

Hospital is included as a random effect.

Table 4. Adjusted odds-ratios for 30-day mortality by day of week and time of day of presentation[1].

Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value	Adjusted Odds Ratio	*P*-value
Day of week		0.136		0.404		0.741		0.136		0.003		0.660
Monday	Reference		Reference		Reference		Reference		Reference		Reference	
Tuesday	1.14 (0.95-1.38)	0.167	1.01 (0.82-1.24)	0.926	1.07 (0.90-1.28)	0.451	0.87 (0.77-0.98)	0.023	1.09 (0.94-1.25)	0.269	1.00 (0.88-1.14)	0.971
Wednesday	1.12 (0.93-1.35)	0.242	1.08 (0.88-1.34)	0.451	0.99 (0.83-1.19)	0.936	0.97 (0.86-1.09)	0.606	1.08 (0.93-1.25)	0.298	1.06 (0.93-1.21)	0.373
Thursday	1.03 (0.84-1.25)	0.803	0.88 (0.71-1.09)	0.228	1.08 (0.91-1.29)	0.371	0.98 (0.87-1.10)	0.720	1.29 (1.12-1.48)	0.001	0.99 (0.87-1.12)	0.829
Friday	1.22 (1.01-1.47)	0.039	1.05 (0.85-1.29)	0.653	1.10 (0.92-1.31)	0.303	0.92 (0.81-1.03)	0.156	1.25 (1.08-1.44)	0.002	1.09 (0.96-1.24)	0.175
Saturday	1.17 (0.96-1.42)	0.112	1.13 (0.91-1.40)	0.275	1.01 (0.84-1.21)	0.941	1.03 (0.92-1.17)	0.578	1.18 (1.02-1.37)	0.030	1.07 (0.94-1.23)	0.315
Sunday	1.28 (1.06-1.54)	0.012	1.06 (0.85-1.31)	0.595	0.96 (0.80-1.16)	0.681	0.97 (0.86-1.10)	0.670	1.05 (0.90-1.22)	0.550	1.02 (0.89-1.17)	0.784
Time of day		<0.001		<0.001		0.200		0.861		0.905		0.525
Day	Reference		Reference		Reference		Reference		Reference		Reference	
Night	1.30 (1.17-1.45)		1.58 (1.40-1.78)		1.07 (0.97-1.17)		1.01 (0.94-1.08)		1.00 (0.92-1.08)		1.02 (0.95-1.10)	

[1]Day of hospital admission or associated preceding emergency department presentation

Models were adjusted for age, sex, and comorbidities (final model results for all variables are provided in supplementary table S1). Hospital is included as a random effect.

Table 5. Unadjusted and adjusted odds ratios for 30-day mortality for day of week, categorized as weekend versus weekday, of hospital presentation[1] using random effect logistic regression models

Variable	Ischaemic stroke		Haemorrhagic stroke		AMI		Pneumonia		COPD		CHF	
	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value	Odds ratio	*P*-value
Unadjusted												
Day of week		0.006		0.057		0.498		0.042		0.617		0.310
Weekday	Reference		Reference		Reference		Reference		Reference		Reference	
Weekend	1.16 (1.04-1.29)		1.13 (1.00-1.28)		0.97 (0.88-1.07)		1.07 (1.00-1.15)		0.98 (0.90-1.07)		1.04 (0.96-1.13)	
Adjusted												
Day of week												
Weekday	Reference	0.067	Reference	0.197	Reference	0.261	Reference	0.135	Reference	0.686	Reference	0.686
Weekend	1.11 (0.99-1.24)		1.09 (0.96-1.24)		0.94 (0.84-1.05)		1.06 (0.98-1.14)		0.98 (0.90-1.07)		1.02 (0.93-1.11)	
Time of day												
Day	Reference	<0.001	Reference	<0.001	Reference	0.210	Reference	0.939	Reference	0.930	Reference	
Night	1.30 (1.17-1.45)		1.57 (1.40-1.77)		1.06 (0.97-1.17)		1.00 (0.94-1.07)		1.00 (0.92-1.08)		1.02 (0.95-1.10)	0.930

[1]Day of hospital admission or associated preceding emergency department presentation

Adjusted models included age, sex and comorbidities. All models included hospital as a random effect.

Figure 1. a) Adjusted odds ratios for 30-day mortality for day of week of presentation by clinical condition. Reference group is Monday (dotted line). b) adjusted odds ratios for 30-day mortality for presentation to hospital at night compared to during the day, by clinical condition. AMI = acute myocardial infarction, COPD = chronic obstructive pulmonary disease, CHF = congestive heart failure.

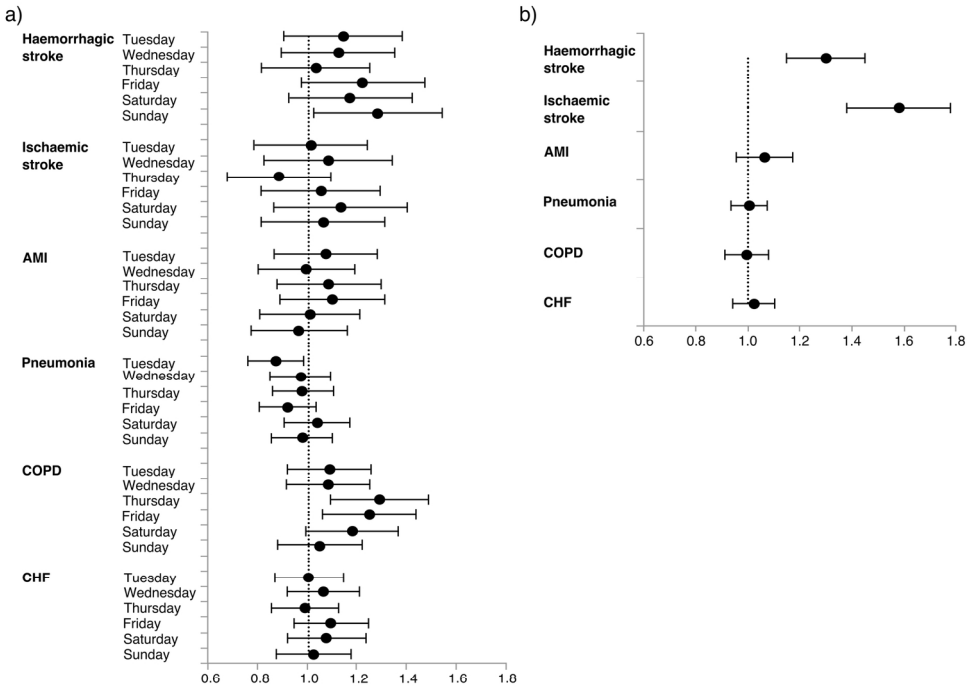

Figure 1. a) Adjusted odds ratios for 30-day mortality for day of week of admission by clinical condition. Reference group is Monday (dotted line). b) adjusted odds ratios for 30-day mortality for admission to hospital at night compared to during the day, by clinical condition. AMI = acute myocardial infarction, COPD = chronic obstructive pulmonary disease, CHF = congestive heart failure.

165x131mm (300 x 300 DPI)

SUPPLEMENTARY MATERIAL

Table S1. Final multivariable model results for 30-day mortality by day of week and time of day of hospital admission or related, preceding ED presentation for ischaemic and haemorrhagic stroke, AMI, pneumonia, COPD and CHF.

Condition Variable	Odds Ratio (95% CI)	*p*-value
Ischaemic stroke		
Day of week (ref = Mon)		0.136
Tuesday	1.14 (0.95-1.38)	0.167
Wednesday	1.12 (0.93-1.35)	0.242
Thursday	1.03 (0.84-1.25)	0.803
Friday	1.22 (1.01-1.47)	0.039
Saturday	1.17 (0.96-1.42)	0.112
Sunday	1.28 (1.06-1.54)	0.012
Night	1.30 (1.17-1.45)	<0.001
Sex (ref = male)	1.32 (1.19-1.47)	<0.001
Age (centred)	1.06 (1.06-1.07)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
Renal failure	1.70 (1.48-1.97)	<0.001
Heart failure	1.95 (1.66-2.28)	<0.001
Malignancy	2.64 (2.15-3.24)	<0.001
AMI		
Day of week (ref = Mon)		0.741
Tuesday	1.07 (0.90-1.28)	0.451
Wednesday	0.99 (0.83-1.19)	0.936
Thursday	1.08 (0.91-1.29)	0.371
Friday	1.10 (0.92-1.31)	0.303
Saturday	1.01 (0.84-1.21)	0.941
Sunday	0.96 (0.80-1.16)	0.681
Night	1.07 (0.97-1.17)	0.200
Age (centred)	1.06 (1.05-1.06)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
STEMI	2.71 (2.44-3.01)	<0.001
Dementia	2.10 (1.77-2.48)	<0.001
Hypotension	1.29 (1.14-1.46)	<0.001
Shock	9.38 (7.79-11.30)	<0.001
Renal failure	2.32 (2.07-2.60)	<0.001
Heart failure	1.77 (1.58-1.98)	<0.001
Dysrhythmia	1.72 (1.55-1.90)	<0.001
Malignancy	2.38 (1.94-2.92)	<0.001
Hypertension	0.67 (0.61-0.74)	<0.001
Cerebrovascular disease	2.34 (1.95-2.81)	<0.001

Condition Variable	Odds Ratio (95% CI)	*p*-value
Haemorrhagic stroke		
Day of week (ref = Mon)		0.404
Tuesday	1.01 (0.82-1.24)	0.926
Wednesday	1.08 (0.88-1.34)	0.451
Thursday	0.88 (0.71-1.09)	0.228
Friday	1.05 (0.85-1.29)	0.653
Saturday	1.13 (0.91-1.40)	0.275
Sunday	1.06 (0.85-1.31)	0.595
Night	1.58 (1.40-1.78)	<0.001
Sex (ref = male)	1.39 (1.24-1.56)	<0.001
Age (centred)	1.04 (1.04-1.05)	<0.001
Heart failure	1.47 (1.16-1.87)	0.001
Malignancy	2.75 (2.20-3.45)	<0.001
Previous H-stroke	0.61 (0.48-0.77)	<0.001
Pneumonia		
Day of week (ref=Mon)		0.136
Tuesday	0.87 (0.77-0.98)	0.023
Wednesday	0.97 (0.86-1.09)	0.606
Thursday	0.98 (0.87-1.10)	0.720
Friday	0.92 (0.81-1.03)	0.156
Saturday	1.03 (0.91-1.16)	0.578
Sunday	0.97 (0.86-1.10)	0.670
Night	1.00 (0.94-1.07)	0.861
Financial year (ref = 2009)		<0.001
2010	0.90 (0.83-0.97)	0.004
2011	0.74 (0.68-0.80)	<0.001
Age (centred)	1.05 (1.05-1.05)	<0.001
Age (squared)	1.00 (1.00-1.00)	<0.001
Dementia	2.66 (2.42-2.92)	<0.001
Hypotension	1.18 (1.08-1.28)	<0.001
Shock	4.02 (3.34-4.84)	<0.001
Renal failure	1.84 (1.70-1.99)	<0.001
Heart failure	1.55 (1.43-1.68)	<0.001
Dysrhythmia	1.32 (1.22-1.42)	<0.001
Malignancy	5.54 (5.07-6.05)	<0.001
Cerebrovascular disease	1.82 (1.59-2.08)	<0.001
Other COPD	1.17 (1.08-1.27)	<0.001
Liver disease	2.81 (1.75-2.71)	<0.001
Parkinsons	1.69 (1.35-2.11)	<0.001

COPD		
Day of week (ref = Mon)		0.003
Tuesday	1.09 (0.94-1.25)	0.269
Wednesday	1.08 (0.93-1.25)	0.298
Thursday	1.29 (1.12-1.48)	0.001
Friday	1.25 (1.08-1.44)	0.002
Saturday	1.18 (1.02-1.37)	0.030
Sunday	1.05 (0.90-1.22)	0.550
Night	1.00 (0.92-1.08)	0.905
Financial year (ref = 2009)		<0.001
2010	0.77 (0.70-0.85)	<0.001
2011	0.50 (0.45-0.55)	<0.001
Prev acute COPD episode (ref = 0)[1]		<0.001
1 previous episode	1.67 (1.51-1.85)	<0.001
2 previous episodes	2.13 (1.86-2.43)	<0.001
3+ previous episodes	3.04 (2.69-3.44)	<0.001
Sex (ref=male)	0.82 (0.76-0.89)	<0.001
Age (centred)	1.03 (1.03-1.04)	<0.001
Age (squared)	1.00 (1.00-1.00)	0.013
CHF	1.47 (1.34-1.61)	<0.001
Pulmonary circ. disord.	1.66 (1.46-1.89)	<0.001
Neurological disord.	1.31 (1.05-1.64)	0.016
Diabetes (comp.)	0.83 (0.73-0.95)	0.005
Liver disease	1.98 (1.50-2.61)	<0.001
Metastatic cancer	3.06 (2.38-3.95)	<0.001
Solid tumour w/o metast.	1.42 (1.17-1.72)	<0.001
Weight loss	1.89 (1.68-2.11)	<0.001
Fluid/electrolyte dis.	1.81 (1.66-1.98)	<0.001
Psychoses	2.10 (1.47-3.00)	<0.001

CHF		
Day of week (ref=Mon)		0.660
Tuesday	1.00 (0.88-1.14)	0.971
Wednesday	1.06 (0.93-1.21)	0.373
Thursday	0.99 (0.87-1.12)	0.829
Friday	1.09 (0.96-1.24)	0.175
Saturday	1.07 (0.94-1.23)	0.315
Sunday	1.02 (0.89-1.17)	0.784
Night	1.02 (0.95-1.10)	0.525
Financial year (ref = 2009)		<0.001
2010	0.89 (0.81-0.97)	0.009
2011	0.67 (0.62-0.74)	<0.001
Prev acute CHF episode (ref = 0)[1]		<0.001
1 previous episode	1.39 (1.26-1.52)	<0.001
2 previous episodes	1.70 (1.48-1.97)	<0.001
3+ previous episodes	2.52 (2.14-2.96)	<0.001
Sex (ref = male)	0.90 (0.84-0.97)	0.008
Age (centred)	1.05 (1.05-1.06)	<0.001
Age (squared)	1.00 (1.00-1.00)	0.003
Pulmonary circ. disord.	1.21 (1.09-1.35)	<0.001
Peripheral vascular disord.	1.19 (1.04-1.37)	0.013
Hypertension (comp/uncomp)	0.83 (0.77-0.90)	<0.001
Paralysis	1.65 (1.34-2.04)	<0.001
Neurological disorders	1.65 (1.39-1.97)	<0.001
Chronic pulmonary disease	1.23 (1.13-1.34)	<0.001
Renal failure	1.88 (1.73-2.03)	<0.001
Liver disease	2.78 (2.29-3.38)	<0.001
Lymphoma	2.24 (1.57-3.19)	<0.001
Metastatic cancer	3.07 (2.44-3.86)	<0.001
Coagulopathy	1.29 (1.15-1.46)	<0.001
Weight loss	1.61 (1.43-1.83)	<0.001
Fluid/electrolyte disorders	1.57 (1.45-1.69)	<0.001
Deficiency anaemia	0.78 (0.68-0.90)	<0.001

[1] lookback to 2004

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Checked (page #)
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5-6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6-7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	7
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	8
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8, 19
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	20,21

		which confounders were adjusted for and why they were included	
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	considered
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10,11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	11,12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Correction: *Is the weekend effect really ubiquitous? A retrospective clinical cohort analysis of 30-day mortality by day of week and time of day using linked population data from New South Wales, Australia*

Baldwin HJ, Marashi-Pour S, Chen H, *et al*. Is the weekend effect really ubiquitous? A retrospective clinical cohort analysis of 30-day mortality by day of week and time of day using linked population data from New South Wales, Australia. *BMJ Open* 2018;8:e016943. doi: 10.1136/bmjopen-2017-016943

This article has been corrected since it first published. In the article title 'A retrospective clinical analyses' was corrected to 'A retrospective clinical analysis'.

BMJ Open 2018;**8**:e016943corr1. doi:10.1136/bmjopen-2017-016943corr1