Original article

Retrospective analysis of 30-day mortality for emergency general surgery admissions evaluating the weekend effect

I. J. D. McCallum, R. C. McLean, S. Dixon and P. O'Loughlin

Department of Colorectal Surgery, Queen Elizabeth Hospital, Gateshead NE9 6SX, UK
Correspondence to: Mr P. O'Loughlin (e-mail: paul.oloughlin@ghnt.nhs.uk)

Background: The weekend effect describes excess mortality associated with hospital admission on Saturday or Sunday. This study assessed whether a weekend effect exists for patients admitted for emergency general surgery.

Methods: Data for emergency general surgical admissions to National Health Service hospitals in the Northern Deanery in England between 2000 and 2014 were collected, including demographics, co-morbidities, diagnoses, operations undertaken and outcomes. The primary outcome of interest was in-hospital death within 30 days of admission. Cox regression analysis was undertaken with adjustment for co-variables.

Results: There were 12 100 in-hospital deaths within 30 days of admission (3·3 per cent). The overall 30-day mortality rate reduced significantly during the 15-year interval studied, from 5·4 per cent (2000–2004) to 4·0 per cent (2005–2009) and 2·9 per cent during 2010–2014 ($P < 0·001$). There was no significant mortality difference for patients admitted at the weekend in adjusted Cox models (hazard ratio (HR) 1·00 for Saturday and 0·90 for Sunday, *versus* Wednesday). There was a significantly higher mortality for operations undertaken at the weekend (HR 1·15 for Saturday and 1·40 for Sunday; $P = 0·021$ and $P < 0·001$ respectively). The significantly increased mortality that was evident for emergency surgery at the weekend compared with weekdays in 2000–2004 (HR 1·46 for Saturday and 1·55 for Sunday; both $P < 0·001$); had reduced by 2010–2014, when the adjusted mortality risk was not significant (HR 1·18 for Saturday and 1·12 for Sunday).

Conclusion: During the past 15 years there has been a weekend effect in patients undergoing emergency general surgery based on day of operation, but not day of admission. Overall mortality for emergency general surgery has improved significantly, and in the past 5 years the increased mortality risk of weekend surgery has reduced.

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Introduction

There has been considerable recent clinical and political interest regarding variable mortality of patients depending on the day of the week that they are admitted to hospital. However, this is yet to be investigated in the emergency general surgical population. Analysis of large national administrative data sets has shown a persistent excess mortality associated with admission on a weekend (Saturday or Sunday) compared with a weekday[1,2]. Such an effect appears to be replicated internationally[1,3,4]. Possible explanations for this effect are that there is a different case mix in weekend admissions accounting for excess mortality, or that it is owing to reduced service provision at weekends. The critical unanswered question is to what extent the excess mortality is preventable by change in service model.

Models of care between specialties differ; in general surgery the emergency workload usually has consistent coverage throughout the week and weekend. This difference between specialties was highlighted by Aylin and colleagues[5], who demonstrated an increase in mortality at the weekend, for just one of seven surgical diagnoses compared with eight of 32 medical diagnoses. At weekends for medical patients in hospital, there is decreased consultant input for acute medical admissions[6], and large numbers of never-events[7] and errors[8]. Excess weekend mortality may be reduced in emergency general surgery as weekend on-call surgical teams are often similar to the weekday emergency team. This is potentially due to a longer

awareness of the dangers of out-of-hours work since the publication of the 1995–1996 National Confidential Enquiry into Patient Outcome and Death report *Who Operates When?*, particularly by non-consultants[9].

The largest North American study[4] of the weekend effect on non-elective surgical admissions over 5 years found a 10·5 per cent increased mortality rate for weekend admissions (absolute 2·7 *versus* 2·3 per cent). This finding is striking owing to the consistency of its effect estimate compared with other data from the USA and UK published at a similar time[1,3,10,11]. Other surgical data have identified that this effect may vary by patient group. When English data were analysed separately for emergency and elective surgery, the excess weekend mortality was threefold greater for elective compared with emergency admissions (odds ratio 1·32 for elective *versus* 1·09 for emergency surgery)[12].

The aims of this study were to describe changes in emergency general surgical admissions, and to assess whether weekend admission and/or operation was associated with any additional mortality risk in all admissions to National Health Service (NHS) hospitals in the North East of England during a 15-year interval.

Methods

Patient data in NHS hospitals are collected routinely for submission to the Health and Social Care Information Centre to provide Hospital Episode Statistics (HES), which contain details of all admissions[13]. These data were sought from all acute NHS Foundation Trusts in the North of England after Caldicott approval in the Trust. Data were requested for all emergency admissions under a general surgeon between 1 January 2000 and 31 December 2014. This start date was decided as the most recent version of the International Classification of Diseases (ICD-10)[14] was released at that time. Data fields that were requested are listed in *Table 1*. Data were anonymized irreversibly before leaving each hospital.

Table 1 Data fields requested from the National Health Service Foundation Trusts' Caldicott Guardian

Demographic fields	Age, sex, postcode
Co-morbidity fields	ICD-10 diagnosis 2 onwards
Diagnosis/operation fields	Primary diagnosis (ICD-10 diagnosis 1), operation date, operation type (OPCS codes for operation 1 onwards)
Outcome fields	Admission date and source, discharge date and location, readmission within 30 days of discharge, mortality (time to death)

Data definitions

The cohort comprised all patients aged 16 years or more who were admitted under a general surgeon as an emergency to all acute hospitals in the North of England between 2000 and 2014. Historically, surgical working patterns have defined weekends as Saturday and Sunday, with weekdays Monday to Friday. Postal codes were converted to Index of Multiple Deprivation (IMD) scores using the online postcode conversion tool[15] and then converted to deprivation quintiles[16]. The IMD is derived from 37 indicators across seven domains (income, employment, health and disability, education, skills and training, crime, barriers to housing and services, and living environment) and is used to rank data zones at Lower Super Output Area level, of which there are 32 482 (mean population of 1500). Co-morbidity data (secondary ICD-10 diagnostic codes) were converted to Charlson scores[17,18] using weightings employed by the hospital standardized mortality ratio[19,20]. To account partially for patients' illness severity, a clinical risk grouping was generated by ranking ICD-10 diagnoses into four equally sized groups based on the 30-day crude in-hospital mortality rate for the primary diagnoses. Primary procedure data, provided by hospital Trusts, were used to identify which patients underwent general surgical operations after admission (excluding endoscopic or radiological procedures); see *Appendix S1* (supporting information) for OPCS codes. The data provided enabled calculation of age at admission, day of admission, duration of hospital stay, time to procedure from admission, day of procedure, and day of in-hospital death. The mortality outcome of interest was in-hospital death within 30 days of admission. Admissions with missing patient characteristics or 30-day in-hospital mortality (1·5 per cent of 376 234 cases) were excluded from the analysis.

Statistical analysis

These retrospective observational data were analysed according to three time periods: 1 January 2000 to 31 December 2004; 1 January 2005 to 31 December 2009; and 1 January 2010 to 31 December 2014. Categorical data were summarized using frequencies and percentages, and continuous data using the mean with its 95 per cent confidence interval. Changes in case mix over time were tested using Pearson's χ^2 test for trend for categorical variables, and differences between continuous variables were analysed using ANOVA with *post hoc* testing.

The factors associated with 30-day in-hospital death were determined using a Cox regression model with a

time-dependent co-variable to describe the hazards associated with each day of the week[1]. Factors with $P < 0{\cdot}200$ in the univariable models were entered into multivariable models. The multivariable models were built by inclusion of variables that achieved $P < 0{\cdot}050$ and significant improvement of model fit (reduction in Akaike's information criterion of at least 4)[1,21]. The case mix factors included in the models were: age (continuous); sex; deprivation quintile; Charlson co-morbidity score; year of admission; day of the week of admission; day of the week of procedure; day of the week of death; admission source, for example from the accident and emergency department (A&E) or general practitioner (GP); and clinical risk grouping (all categorical). When analysing the risks associated with days of the week, Wednesday was used as the referent day[1,2,21]. Data were collected in Excel® 2010 (Microsoft, Redmond, Washington, USA) and analyses were undertaken using Stata® 13.1 software (StataCorp, College Station, Texas, USA). Statistical significance was defined as $P < 0{\cdot}050$.

Results

Patient characteristics by day of the week of admission

During the 15-year study there were 376 234 emergency general surgical admissions to NHS hospitals in the North of England. In 370 671 cases, information on 30-day in-hospital mortality and patient characteristics was available and included in the principal analyses (1·5 per cent missing). There were 12 100 in-hospital deaths within 30 days of admission (3·3 per cent). General surgical operations were undertaken in 63 994 patients, of whom 2661 died (5·2 per cent of 51 724 patients with available mortality data).

The number of admissions was greatest on Monday (17·3 per cent of all admissions) and lowest at the weekend (10·8 per cent each on Saturday or Sunday) (*Fig. 1*, *Table 2*).

There were differences in the stratified baseline characteristics of patients admitted as an emergency to general surgery (*Table 2*). Patients admitted at the weekend were significantly younger, had lower Charlson co-morbidity scores, had less severe aetiology judged by clinical risk grouping, were more likely to be admitted from A&E, and there were significantly more men (all $P < 0{\cdot}001$). There were significant differences in deprivation score and operations by day of the week, although these were not associated with a weekend effect.

The pattern for admission method reversed at the weekend, with more patients admitted via A&E compared with the majority being referred by their GP during the week

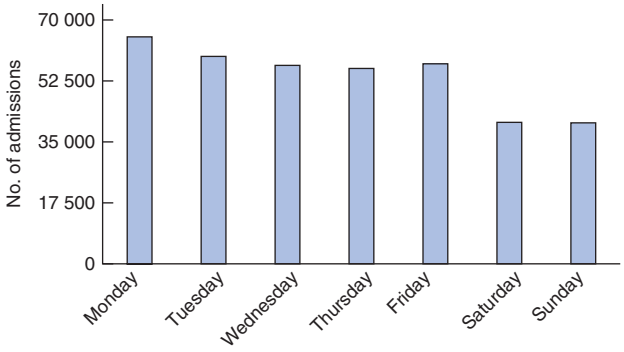

Fig. 1 Total number of general surgical admissions, by day of the week

(*Table 2*). At the weekend, 34 251 admissions came through A&E, 74·2 per cent greater than the number referred for admission via GPs at the weekend. During the week, 22·5 per cent more patients were admitted following GP referral rather than by presenting through A&E (103 312 *versus* 84 310 respectively). Patients admitted via A&E, compared with GP admissions, were significantly younger, and had significantly fewer co-morbidities and less severe aetiology (all $P < 0{\cdot}001$).

Overall, 17·0 per cent of patients admitted as an emergency under general surgery required an operation during their hospital stay (*Table 2*). The proportion of patients admitted on any given day of the week who went on to require a surgical intervention remained fairly consistent, although a significantly higher proportion of patients admitted on a Monday required surgery during their admission (17·9 per cent) compared with other days ($P < 0{\cdot}001$). The number of operations performed on any given day of the week remained stable; however, fewer operations were undertaken at the weekend. (*Table 3*, *Fig. 2*).

Effect of day of the week of admission on mortality

Table 3 shows the crude 30-day in-hospital mortality for emergency general surgical admissions by day of the week of admission and operation. Some 3699 deaths (30·6 per cent) occurred within 3 days of admission. There was a significantly higher crude mortality rate and unadjusted hazard ratio (HR) for patients admitted at the weekend (HR 1·11 (95 per cent c.i. 1·03 to 1·19) for Saturday and 1·13 (1·05 to 1·22) for Sunday *versus* Wednesday) (*Table 4*). However, following adjustment for co-variables there was no significant difference in mortality by day of admission (HR 1·00 (0·84 to 1·19) for Saturday and 0·90 (0·76 to 1·08) for Sunday *versus* Wednesday) (*Table 4*, *Fig. 3*).

Table 2 Baseline characteristics of patients admitted as an emergency under a general surgeon, by day of admission

	Day of the week								
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Overall	*P*†
Admissions	65 141 (17·3)	59 548 (15·8)	56 955 (15·1)	56 077 (14·9)	57 422 (15·3)	40 617 (10·8)	40 474 (10·8)	376 234	
Age (years)*	53·3 (53·1, 53·5)	52·8 (52·7, 53·0)	53·1 (52·9, 53·3)	53·3 (53·2, 53·5)	53·6 (53·4, 53·8)	52·6 (52·4, 52·8)	52·5 (52·3, 52·7)	53·1 (53·0, 53·2)	<0·001‡
Sex									0·001
M	30 083 (46·2)	27 497 (46·2)	26 143 (45·9)	25 905 (46·2)	26 349 (45·9)	19 075 (47·0)	19 003 (47·0)	174 055 (46·3)	
F	35 054 (53·8)	32 047 (53·8)	30 809 (54·1)	30 171 (53·8)	31 071 (54·1)	21 540 (53·0)	21 470 (53·0)	202 162 (53·7)	
Charlson co-morbidity score									<0·001
0	24 048 (36·9)	22 386 (37·6)	20 998 (36·9)	20 605 (36·7)	20 835 (36·3)	15 807 (38·9)	15 696 (38·8)	140 375 (37·3)	
1–4	21 412 (32·9)	19 336 (32·5)	18 916 (33·2)	18 630 (33·2)	19 372 (33·7)	13 635 (33·6)	13 508 (33·4)	124 809 (33·2)	
≥5	19 681 (30·2)	17 826 (29·9)	17 041 (29·9)	16 842 (30·0)	17 215 (30·0)	11 175 (27·5)	11 270 (27·8)	111 050 (29·5)	
Deprivation score									0·006
1 (most)	16 016 (29·6)	14 727 (29·7)	14 182 (29·9)	13 688 (29·3)	14 019 (29·4)	9867 (29·6)	10 007 (30·0)	92 506 (29·6)	
2	13 615 (25·1)	12 735 (25·7)	11 832 (25·0)	11 841 (25·3)	11 925 (25·0)	8370 (25·1)	8291 (24·8)	78 609 (25·2)	
3	9016 (16·7)	8242 (16·6)	7810 (16·5)	7764 (16·6)	8004 (16·8)	5575 (16·7)	5566 (16·7)	51 977 (16·6)	
4	7040 (13·0)	6294 (12·7)	6237 (13·2)	6135 (13·1)	6244 (13·1)	4530 (13·6)	4477 (13·4)	40 957 (13·1)	
5 (least)	8456 (15·6)	7553 (15·2)	7353 (15·5)	7350 (15·7)	7489 (15·7)	5013 (15·0)	5049 (15·1)	48 263 (15·5)	
Operation									<0·001
No	53 485 (82·1)	49 210 (82·6)	47 321 (83·1)	46 701 (83·3)	48 088 (83·7)	33 870 (83·4)	33 565 (82·9)	312 240 (83·0)	
Yes	11 656 (17·9)	10 338 (17·4)	9634 (16·9)	9376 (16·7)	9334 (16·3)	6747 (16·6)	6909 (17·1)	63 994 (17·0)	
Admission method									<0·001
A&E	18 553 (34·6)	17 547 (35·4)	16 439 (34·8)	15 942 (34·4)	15 829 (33·2)	16 640 (51·4)	17 611 (54·9)	118 561 (38·4)	
GP	22 749 (42·4)	20 486 (41·3)	19 882 (42·0)	19 535 (42·1)	20 660 (43·4)	10 275 (31·7)	9383 (29·3)	122 970 (39·8)	
Consultant clinic	2238 (4·2)	2140 (4·3)	1942 (4·1)	1754 (3·8)	1796 (3·8)	310 (1·0)	230 (0·7)	10 410 (3·4)	
Other	10 131 (18·9)	9398 (19·0)	9031 (19·1)	9133 (19·7)	9351 (19·6)	5165 (15·9)	4849 (15·1)	57 058 (18·5)	
Clinical risk group									<0·001
1 (lowest)	42 227 (65·0)	38 739 (65·2)	37 196 (65·5)	36 550 (65·3)	37 740 (65·9)	27 001 (66·6)	26 687 (66·1)	246 140 (65·6)	
2	13 272 (20·4)	12 115 (20·4)	11 540 (20·3)	11 302 (20·2)	11 511 (20·1)	8263 (20·4)	8230 (20·4)	76 233 (20·3)	
3	6671 (10·3)	6086 (10·2)	5700 (10·0)	5753 (10·3)	5731 (10·0)	3604 (8·9)	3653 (9·1)	37 198 (9·9)	
4 (highest)	2796 (4·3)	2437 (4·1)	2366 (4·2)	2325 (4·2)	2248 (3·9)	1645 (4,1)	1785 (4·4)	15 602 (4·2)	

Values in parentheses are percentages unless indicated otherwise; *values are mean (95 per cent c.i.). Percentages and proportions were derived by excluding missing data from the variable. A&E, accident and emergency department; GP, general practitioner. †χ^2 test for difference, except ‡ANOVA.

Table 3 Crude 30-day inpatient mortality rate and hazard ratios associated with day of admission and day of operation

	Day of the week								
	Overall	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	*P*
Day of admission									
Emergency admissions	376 234	65 141	59 548	56 955	56 077	57 422	40 617	40 474	
Deaths	12 100	2072	1909	1786	1780	1790	1350	1413	
Crude rate (%)	3·3	3·2	3·2	3·1	3·2	3·1	3·3	3·5	<0·001
Unadjusted HR		1·02 (0·96, 1·09)	1·03 (0·96, 1·10)	1·00 (reference)	1·01 (0·94, 1·08)	1·00 (0·93, 1·07)	1·11 (1·03, 1·19)†	1·13 (1·05, 1·22)†	
Adjusted HR		0·91 (0·78, 1·06)	0·95 (0·81, 1·11)	1·00 (reference)	0·94 (0·81, 1·10)	0·87 (0·74, 1·03)	1·00 (0·84, 1·19)	0·90 (0·76, 1·08)	
Day of operation									
Emergency operations	63 994	9223	10 471	10 633	10 390	10 066	7159	6052	
Deaths	2661	344	411	452	441	426	303	284	
Crude rate (%)*	5·2	4·7	4·8	5·3	5·3	5·2	5·2	5·7	0·143
Unadjusted HR		0·96 (0·83, 1·11)	0·94 (0·82, 1·07)	1·00 (reference)	0·96 (0·84, 1·09)	0·99 (0·87, 1·13)	1·12 (0·97, 1·30)	1·28 (1·10, 1·49)†	
Adjusted HR		1·01 (0·86, 1·18)	1·00 (0·86, 1·16)	1·00 (reference)	0·95 (0·82, 1·10)	1·01 (0·87, 1·17)	1·15 (1·01, 1·41)†	1·40 (1·17, 1·68)†	

Values in parentheses are 95 per cent confidence intervals. *Crude mortality rates were derived by excluding patients with missing mortality data. Hazard ratios (HRs) were adjusted for the following co-variables: age, co-morbidity, socioeconomic deprivation, year of admission, admission method, day of procedure and clinical risk group. †$P < 0·050$.

Changes over time

When admissions were divided by day of the week into three time intervals (2000–2004, 2005–2009 and 2010–2014, the proportion occurring at the weekend (Saturday and Sunday) compared with weekdays (Monday to Friday) remained static at approximately 21 per cent ($P = 0{\cdot}762$) (*Table S1*, supporting information). The crude mortality rate for all admissions decreased significantly over the 15-year interval from 5·4 per cent in 2000–2004, to 4·0 per cent in 2005–2009 and 2·9 per cent in 2010–2014 ($P < 0{\cdot}001$). Emergency surgical admission was associated with improved survival in 2010–2014: HR 0·65 (95 per cent c.i. 0·58 to 0·72) *versus* 2000–2004 (*Table 4*). Following adjustment for co-variables, there was no difference in survival for patients depending on day of admission, and this was consistent across all study time intervals.

Effect of day of operation on mortality

Emergency general surgical operations undertaken at the weekend were found significantly to predict 30-day in-hospital mortality in adjusted analyses (HR 1·15 (95 per cent c.i. 1·01 to 1·41) for Saturday and 1·40 (1·17 to 1·68) for Sunday) (*Fig. 3*, *Table 4*). In addition to day of operation, increasing age (HR 1·04, 1·03 to 1·04), Charlson co-morbidity score of at least 5 (HR 1·63, 1·24 to 2·14) and higher clinical risk group (HR 3·99, 3·43 to 4·66; highest *versus* lowest) were significant predictors of death. Affluence (HR 0·84, 0·74 to 0·96; most affluent *versus* most deprived), admission directly from consultant clinic (HR 0·71, 0·56 to 0·91) and the most recent admission time interval (2010–2014: HR 0·65, 0·58 to 0·72) were significantly associated with lower mortality (*Table 4*).

Changes over time

Over the 15-year study the proportion of admissions requiring surgery did not show any significant trend, with 16·7 per cent of all admissions requiring surgery in 2000–2004 compared with 16·2 per cent in 2005–2009 and 17·0 per cent in 2010–2014. There was no significant difference in the proportion of operations performed at the weekend (*Table S2*, supporting information), with 20·4% of all operations occurring at the weekend in 2000–2004, compared with 20·9 per cent in 2005–2009, and 21·4 per cent in 2010–2014 ($P = 0{\cdot}202$).

The mortality rate after emergency surgery improved significantly, from 7·5 per cent in 2000–2004, to 5·4 per cent in 2005–2009 and 3·6 per cent in 2010–2014 ($P < 0{\cdot}001$). The effect of day of the operation on mortality reduced: in 2000–2004 the HR for surgery on a Saturday was 1·46 (95 per cent c.i. 1·02 to 1·98) and for Sunday was 1·55 (1·04 to 2·30). By 2010–2014 the HR was 1·18 (0·89 to 1·57) for Saturday ($P = 0{\cdot}148$) and 1·12 (0·83 to 1·53) for Sunday ($P = 0{\cdot}436$), and no longer significant (*Table S2*, supporting information).

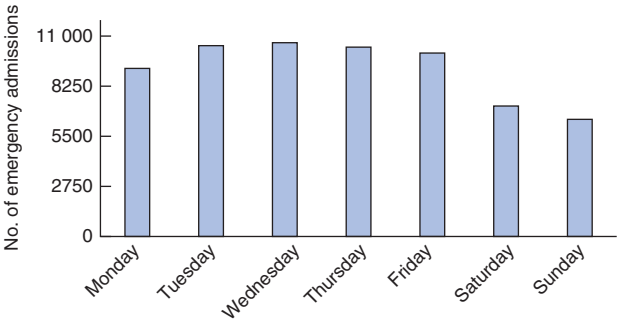

Fig. 2 Total number of general surgical operations in patients admitted as an emergency, by day of the week of operation

Association of day of the week of operation, duration of stay and time to operation

There was a significant reduction in duration of hospital stay, from 7·1 days in 2000–2004, to 6·1 days in 2005–2009 and 5·5 days in 2010–2014 ($P < 0{\cdot}001$). The mean time to theatre significantly reduced from 2·2 days in 2000–2004 to 1·8 days in 2010–2014 ($P < 0{\cdot}001$); consequently the proportion of patients who were operated on within 24 or 48 h increased significantly over the study: from 7·1 per cent in 2000–2004 to 7·7 per cent in 2010–2014 within 24 h ($P < 0{\cdot}001$), and from 12·7 to 14·5 per cent respectively within 48 h ($P < 0{\cdot}001$).

The overall mean duration of hospital stay was 6·13 (95 per cent c.i. 6·09 to 6·17) days, with patients who died having a mean duration of stay of 15·6 (15·1 to 16·0) days and those who survived 5·74 (5·70 to 5·78) days ($P < 0{\cdot}001$). For patients who had an operation, the mean duration of stay was 8·49 (8·38 to 8·59) days compared with 5·64 (5·60 to 5·68) days in those who did not have surgery ($P < 0{\cdot}001$). The mean duration of stay for operated patients decreased significantly during the study, from 10·1 days in 2000–2004 to 7·45 days in 2010–2014 ($P < 0{\cdot}001$). In operated patients who died, the mean time from admission to theatre was 3·29 (3·12 to 3·46) days, whereas it was significantly shorter in patients who survived (1·91 (1·88 to 1·94) days; $P < 0{\cdot}001$).

Patients who had surgery at the weekend had a significantly shorter mean time from admission to theatre (1·44 (95 per cent c.i. 1·38 to 1·50) days for Saturday and 1·20 (1·15 to 1·26) days for Sunday *versus* (2·17

Table 4 Multivariable Cox regression model of significant factors associated with 30-day in-hospital mortality in emergency general surgical admissions

	Unadjusted		Adjusted	
	HR	*P*	HR	*P*
Age (years)	1·04 (1·04, 1·05)	< 0·001	1·04 (1·03, 1·04)	< 0·001
Sex				
M	1·00 (reference)			
F	0·98 (0·94, 1·01)	0·206		
Charlson co-morbidity score				
0	1·00 (reference)		1·00 (reference)	
1–4	3·15 (2·82, 3·52)	< 0·001	0·80 (0·61, 1·06)	0·116
≥ 5	9·35 (8·42, 10·39)	< 0·001	1·63 (1·24, 2·14)	< 0·001
Year				
2000–2004	1·00 (reference)		1·00 (reference)	
2005–2009	0·92 (0·88, 0·97)	< 0·001	0·92 (0·83, 1·02)	0·110
2010–2014	0·69 (0·66, 0·73)	< 0·001	0·65 (0·58, 0·72)	< 0·001
Deprivation quintile				
1 (most)	1·00 (reference)		1·00 (reference)	
2	1·06 (1·00, 1·12)	0·055	0·98 (0·87, 1·10)	0·739
3	1·05 (0·99, 1·12)	0·113	0·84 (0·73, 0·96)	0·010
4	0·99 (0·93, 1·06)	0·783	0·87 (0·76, 1·00)	0·041
5 (least)	1·01 (0·95, 1·08)	0·757	0·84 (0·74, 0·96)	0·010
Admission source				
A&E	1·00 (reference)		1·00 (reference)	
GP	1·29 (1·23, 1·35)	< 0·001	1·11 (0·98, 1·25)	0·093
Consultant clinic	0·83 (0·76, 0·93)	0·001	0·71 (0·56, 0·91)	0·006
Other	0·89 (0·84, 0·95)	< 0·001	0·85 (0·72, 1·01)	0·066
Clinical risk group				
1 (lowest)	1·00 (reference)		1·00 (reference)	
2	2·18 (2·05, 2·33)	< 0·001	1·58 (1·34, 1·87)	< 0·001
3	4·76 (4·48, 5·06)	< 0·001	1·96 (1·69, 2·27)	< 0·001
4 (highest)	10·49 (9·88, 11·14)	< 0·001	3·99 (3·43, 4·66)	< 0·001
Operation				
No	1·00 (reference)			
Yes	0·94 (0·90, 0·98)	0·005		
Day of admission				
Monday	1·02 (0·96, 1·09)	0·513	0·91 (0·78, 1·06)	0·225
Tuesday	1·03 (0·96, 1·10)	0·451	0·95 (0·81, 1·11)	0·500
Wednesday	1·00 (reference)		1·00 (reference)	
Thursday	1·01 (0·94, 1·08)	0·743	0·94 (0·81, 1·10)	0·468
Friday	1·00 (0·93, 1·07)	0·940	0·87 (0·74, 1·03)	0·106
Saturday	1·11 (1·03, 1·19)	0·007	1·00 (0·84, 1·19)	0·992
Sunday	1·13 (1·05, 1·22)	0·001	0·90 (0·76, 1·08)	0·265
Day of death				
Monday	0·98 (0·92, 1·06)	0·659		
Tuesday	0·98 (0·92, 1·05)	0·603		
Wednesday	1·00 (reference)			
Thursday	1·00 (0·93, 1·07)	0·915		
Friday	1·05 (0·98, 1·12)	0·204		
Saturday	0·98 (0·91, 1·05)	0·572		
Sunday	0·99 (0·93, 1·07)	0·884		
Day of operation				
Monday	0·96 (0·83, 1·11)	0·565	1·01 (0·86, 1·18)	0·772
Tuesday	0·94 (0·82, 1·07)	0·356	1·00 (0·86, 1·16)	0·801
Wednesday	1·00 (reference)		1·00 (reference)	
Thursday	0·96 (0·84, 1·09)	0·503	0·95 (0·82, 1·10)	0·530
Friday	0·99 (0·87, 1·13)	0·885	1·01 (0·87, 1·17)	0·723
Saturday	1·12 (0·97, 1·30)	0·124	1·15 (1·01, 1·41)	0·021
Sunday	1·28 (1·10, 1·49)	0·001	1·40 (1·17, 1·68)	< 0·001

Values in parentheses are 95 per cent confidence intervals. HR, hazard ratio; A&E, accident and emergency department; GP, general practitioner.

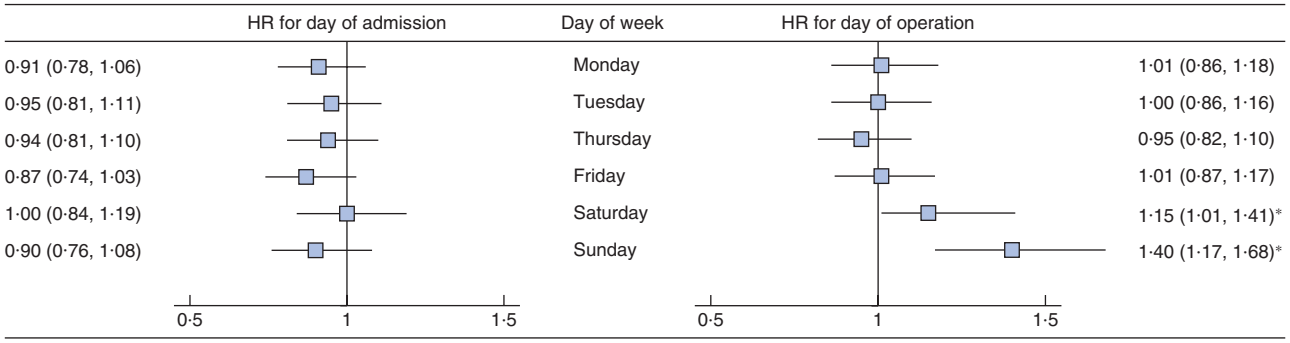

Fig. 3 Cox proportional hazards model of 30-day in-hospital death associated with admission to hospital by day of the week of admission and day of operation. Hazard ratios (HRs) with 95 per cent confidence intervals are compared with Wednesday as reference. *$P < 0{\cdot}050$

(2·10 to 2·24) days for Wednesday; $P < 0{\cdot}001$) and duration of stay (7·91 (7·62 to 8·20) days for Saturday and 7·47 (7·17 to 7·77) days for Sunday *versus* 8·71 (8·45 to 8·97) days for Wednesday; $P < 0{\cdot}001$) (*Table S3*, supporting information).

In patients who had surgery at the weekend, a significantly higher proportion were operated on within 48 h of admission (76·8 per cent on Saturday, 77·0 per cent on Sunday *versus* 66·4 per cent on Wednesday; both $P < 0{\cdot}001$) (*Table S3*, supporting information).

Discussion

Multiple studies have confirmed a weekend effect for mortality in many different care settings; the focus has now changed to defining the cause[22]. This study examined the weekend effect in a specified population: general surgical emergency admissions in the North of England.

The most striking results from this study relate to the significant reductions in mortality for all emergency general surgery admissions, from 5·4 per cent in 2000–2004 to less than 2·9 per cent in 2010–2014, a relative reduction of 46 per cent, and particularly for postoperative mortality, which fell from 7·5 per cent in 2000–2004 to 3·6 per cent in 2010–2014, a 52 per cent relative reduction. Analysis of postoperative mortality based on day of operation showed a significant weekend effect, although, along with reducing mortality, this effect also appears to have diminished over the past 15 years.

Other studies on urgent surgery have confirmed increased complication rates, but not mortality, at weekends for diverticular disease[23], emergency low-risk surgery[24] and emergency surgery for inflammatory bowel disease[25]. Day of operation was shown in one study[26] to be a factor that may influence patient outcomes, particularly when operating out-of-hours.

The improvements identified could potentially be accounted for by the changes in surgical working patterns and the improvements in provision of hospital services that have occurred over the past 15 years. Working patterns have changed following implementation of the European Working Time Directive; junior doctors now work shift patterns. This provides consistent levels of cover for surgical emergency admissions and inpatients throughout the week and weekend. Continuity of care is now provided by consultants. The shift towards consultant-delivered care with heightened consultant presence for emergency patient assessment and surgery is in accordance with recent recommendations[27,28]. This was confirmed when the National Emergency Laparotomy Audit[26] identified similar proportions of consultant surgeons supervising emergency laparotomies throughout the week (85 per cent on weekdays and 83 per cent at the weekend). This has improved in the past 5 years[29].

In conjunction with surgical working patterns, associated specialties have increased the consultant input to out-of-hours services, with more consultant delivery of intensive care, anaesthetic and radiology services. A lowering of thresholds for access to out-of-hours radiology has led to improvements in the recognition of pathologies in a timely fashion to improve outcomes and duration of hospital stay[30].

The present analysis of outcomes based on day of hospital admission demonstrates that when appropriate co-variables are accounted for there is no increased mortality in patients admitted under emergency general surgery over the weekend. It has been postulated that patients admitted at the weekend are sicker and care processes less effective; however, this was not confirmed in the present study. Here, the data show that patients admitted at the weekend were significantly younger, there were more men, with lower Charlson co-morbidity scores, and less severe

aetiology judged by clinical risk grouping, suggesting that weekend patients were actually less sick than those admitted during the week. The rates at which patients required surgery remained static at around 17 per cent, irrespective of day of admission, which would suggest that thresholds for admission to surgery and surgical aetiology remained relatively consistent. Assuming that disease does not respect the working week, this may be due to issues with accessing healthcare, or patient behaviour at weekends. Younger, fitter patients may find it easier to present to health services at the weekend via A&E, thus avoiding a delay in presentation that may affect outcomes adversely. This is reinforced by A&E admissions being less sick than GP admissions. The elderly are more likely to access emergency care via their GP; reduced access to general practice at the weekend results in a delay in presentation. This results in a Monday effect for GP admissions, and could provide encouragement for increasing weekend access to GPs.

Considering the processes of care, markers such as duration of stay and timing of surgery after admission all indicate that key hospital processes occur in a timely fashion for surgical patients admitted at the weekend, and have improved consistently over the past 15 years in North East England.

Questions have been raised as to the accuracy of UK hospital coding data, but currently no other system is available to identify and analyse such large data sets. A study comparing UK HES data and those from the American College of Surgeons National Surgical Quality Improvement Program[31] has suggested that certain parts of hospital coding are less accurate, such as the coding of complications, whereas recording of operative procedures is accurate. The present study did not focus on specific outcomes or complications, but rather hard endpoints such as inpatient mortality and procedures performed, which are more accurate in coded data sets. Systematic bias of coding over time is unlikely to be present and inaccuracies in coding are instead reflected in statistical noise, which is largely obviated in such a large data set. Reassuringly, data sets from individual hospital Trusts were generally complete, without obvious systematic missing data.

The present study cannot define cause-and-effect, but in an area where RCTs are not practical and prospective studies area also prone to bias[22], the data presented here are a valuable addition to the existing literature when interpreted appropriately. In this population there was a considerable reduction in mortality over the past 15 years. There was a weekend effect, but this was based on day of operation, not day of admission.

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Supporting information

Additional supporting information may be found in the online version of this article:

Table S1 Thirty-day in-hospital mortality over time by day of the week of admission (Word document)

Table S2 Thirty-day in-hospital mortality over time by day of the week of operation (Word document)

Table S3 Length of stay and time to theatre by day of admission and day of operation (Word document)

Appendix S1 OPCS classification of interventions and procedures version 4 codes used to define a general surgical procedure (Word document)