Weekend effect in non-elective abdominal aortic aneurysm repair

G. K. Ambler[1,2], N. B. G. Mariam[3], U. Sadat[3], P. A. Coughlin[3], I. M. Loftus[4] and J. R. Boyle[3], in association with the audit and quality improvement committee of the Vascular Society of Great Britain and Ireland

[1]Division of Population Medicine, Cardiff University, Cardiff, and [2]South East Wales Vascular Network, Aneurin Bevan University Health Board, Royal Gwent Hospital, Newport, [3]Cambridge Vascular Unit, Cambridge University Hospitals NHS Foundation Trust, Cambridge, and [4]Saint George's Vascular Institute, University of London, London, UK
Correspondence to: Mr G. K. Ambler, South East Wales Vascular Network, Aneurin Bevan University Health Board, Royal Gwent Hospital, Cardiff Road, Newport NP20 2UB, UK (e-mail: graeme.ambler@gmail.com; 🐦 @GraemeAmbler)

Background: The 'weekend effect' describes the phenomenon where patient outcomes appear worse for those admitted at the weekend. It has been used recently to justify significant changes in UK health policy. Recent evidence has suggested that the effect may be due to a combination of inadequate correction for confounding factors and inaccurate coding. The effects of these factors were investigated in patients with acute abdominal aortic aneurysm (AAA).

Methods: Patients undergoing non-elective AAA repair entered into the UK National Vascular Registry from January 2013 until December 2015 were included in a case–control study. The patients were divided according to whether they were treated during the week (Monday 08.00 hours to Friday 17.00 hours) or at the weekend. Data extracted included demographics, co-morbidities, preoperative medications and baseline blood test results, as well as outcomes. Coding issues were investigated by looking at patients treated for ruptured, symptomatic or asymptomatic AAA within the non-elective cohort. The primary outcome was in-hospital mortality. Secondary outcomes included length of inpatient stay, and cardiac, respiratory and renal complications.

Results: The mortality rate appeared to be higher at the weekend (odds ratio (OR) 1·69, 95 per cent c.i. 1·47 to 1·94; $P < 0·001$), but this effect disappeared when confounding factors and coding issues were corrected for (corrected OR for ruptured AAA 1·09, 0·92 to 1·29; $P = 0·330$). Differences in outcomes were similar for prolonged length of hospital stay (uncorrected OR 1·21, 95 per cent c.i. 1·06 to 1·37, $P = 0·005$; corrected OR for ruptured AAA 1·06, 0·91 to 1·10, $P = 0·478$), and morbidity outcomes.

Conclusion: After appropriate correction for confounding factors and coding effects, there was no evidence of a significant weekend effect in the treatment of non-elective AAA in the UK.

Introduction

The 'weekend effect', first described in 2001[1], is a hotly debated topic both within the UK[2] and worldwide[3,4]. It describes the phenomenon of increased mortality rates among patients admitted to hospital at the weekend, and has been found in different cohorts of patients treated for conditions as diverse as acute stroke[5] and elective joint replacement[6]. Recently, debate on the issue has focused on whether the effect is real, or just a reflection of inadequate case-mix adjustment or erroneous coding of diagnosis in large administrative databases, as highlighted by a recent high-quality study[7] of patients treated for acute stroke. Despite ongoing debate, the effect has been used as justification for major restructuring of health services within the UK National Health Service[8].

Repair of abdominal aortic aneurysm (AAA) is a high-risk procedure with an elective mortality rate of 1–2 per cent in contemporary series[9]. This compares favourably with the

mortality risk associated with ruptured AAA, which is at least 20 times higher among patients in whom aneurysm repair is attempted[10], and higher still once patients who are not offered aneurysm repair are considered[11]. Ruptured AAA remains a common acute surgical admission in the UK, and the high operative mortality makes it an ideal condition in which to investigate the weekend effect.

Three broad groups of patients are treated as an emergency for AAA: patients with a large but asymptomatic AAA considered to be at high risk of rupture, those with a symptomatic but intact AAA and patients with a ruptured AAA. Patients in the first two groups have more in common with those undergoing truly elective repair than with those who have a ruptured aneurysm; they do not experience the massive physiological stress associated with aneurysm rupture although, owing to their perceived risk of impending rupture, patients at higher operative risk are more likely to be offered repair than those in the elective group[12]. In fact, given their symptom-free state, asymptomatic patients may benefit from preoperative optimization and multidisciplinary input.

The weekend effect was originally highlighted for patients undergoing acute AAA repair in Canada[1], and has more recently been explored using the American National Inpatient Sample[13]. Both studies found a significant effect for patients admitted at the weekend, but used large administrative coding databases, similar to the one found to suffer from inaccuracies in the context of acute stroke[7], with no attempt to check diagnostic codes with treating clinicians. Many patients had surgery at least 1 day after admission, making a diagnosis of ruptured aneurysm unlikely.

Patients treated acutely for AAA also experience significant morbidity, as highlighted by recent reports[14,15] focusing on acute kidney injury after ruptured AAA repair. Assessments of differences in morbidity rates for patients treated at the weekend are notably absent from previous studies, perhaps because the large administrative databases used tend not to record these outcomes.

The National Vascular Registry (NVR) is a UK-wide database used for audit purposes within vascular surgery. Data are collected on five broad procedure types: repair of AAA, carotid endarterectomy (CEA), lower limb angioplasty, lower limb bypass and lower limb amputation. Although data input was voluntary in previous years, it has been mandatory for elective AAA and CEA in England since the (much criticized[16−18]) introduction of compulsory surgeon-level outcome reporting for elective AAA repair and CEA in 2013. Case ascertainment rates have been shown to be in excess of 85 per cent for elective AAA repair[19]. With much talk of broadening the scope of

compulsory reporting, there is an increasing trend towards reporting of all cases, so the database also contains information on many non-elective procedures, such as repair of ruptured AAA. In fact, case ascertainment rates for non-elective AAA have recently reached those of elective AAA repair, with analysis in the 2016 annual report of the registry finding case ascertainment for non-elective AAA in excess of 85 per cent[20]. The AAA subset of the NVR includes information about whether the patient was treated for ruptured, symptomatic or asymptomatic AAA, in addition to elective or non-elective status. This more detailed coding allows exploration of the influence of coding issues on any weekend effect that might be present in non-elective AAA repair. Although most databases used to examine the weekend effect are controlled by hospital administrators, owing to its use for publication of surgeon-specific outcomes in the UK, data entry is either performed by, or closely supervised by, the treating surgeon, so is also less likely to be subject to the coding inaccuracies seen in other large databases.

The aim of this study was to return to the context in which the weekend effect was originally described – acute AAA repair – to see whether case-mix and coding issues might explain the phenomenon in this context, by correcting for case mix and dividing patients into more homogeneous groups (codes).

Methods

The data set used included all AAA repairs coded as non-elective in the NVR. Although most patients coded as non-elective have a ruptured AAA, a subset of patients have a symptomatic but intact AAA, or large but asymptomatic AAA. A prespecified subgroup analysis was performed which looked separately at procedures that were coded as ruptured, symptomatic or asymptomatic AAA repairs. Approval to use anonymous data from the database for the purpose of this study was granted by the NVR committee and approved by the UK Healthcare Quality Improvement Partnership (HQIP) on the basis of a protocol proposing analysis in line with that discussed below.

Data were requested from HQIP on a total of 33 variables identified specifically in accordance with the aims of the study for all patients undergoing non-elective AAA repair from January 2013 until December 2015 inclusive, and were extracted in December 2016. These variables included: patient demographics, admission date, operation start date and time, operative procedure, co-morbidities, blood test results, preoperative medications, discharge date and discharge status (alive/dead), and reported complication rates. This was a case–control study, with cases defined

as operations performed at the weekend and controls being operations performed during the normal working week. The normal working week was defined as Monday 08.00 hours until Friday 17.00 hours. A secondary analysis was carried out, with controls being operations performed within normal working hours (from 08.00 to 17.00 hours, Monday to Friday), and cases those performed either at the weekend or out of hours on a weekday.

The primary outcome was in-hospital mortality. Secondary outcomes were prolonged length of hospital stay, defined as a length of stay greater than the median value in the data set, and postoperative cardiac, respiratory or renal complications, as defined in the NVR data dictionary[21].

Missing data

As with most large data registries, although some data fields are compulsory and thus well completed, there are issues with missing data in the NVR. These were addressed to a significant extent by a redesign of the NVR in 2012, which increased the proportion of compulsory fields. Much work has been done within the statistical literature on the best methods for handling this issue, and several techniques exist. By far the most commonly used is the method of multiple imputation[22], which is recommended by expert reviews for use in clinical studies[23]. Multiple imputation has the advantage of being robust to the presence of missing data whose missingness is dependent on measured co-variables such as outcome, whereas simpler techniques such as mean value imputation or exclusion of cases with missing values rely on data being missing completely at random. Its application to large vascular surgery databases has been described previously by this group[12]. Patients with missing primary outcome data (in-hospital mortality) were excluded. For the remainder, the chained equations multiple imputation technique[24], found in mice software version 2.25[25], was used; 50 completed data sets were generated and the pooling algorithms within the software were used to handle statistical analysis appropriately. Variables with more than 50 per cent missing values were excluded, as in previous work[12]. A list of variables measured together with the proportion of data missing for each is given in *Table S1* (supporting information).

Statistical analysis

Univariable analysis was carried out using Fisher's exact test for categorical variables, and the Mann–Whitney *U* test for continuous variables. Logistic regression was used for unadjusted analysis and to perform multivariable adjustment for measured confounders, with parameters selected using the Schwartz–Bayes criterion to reduce overfitting.

A list of measured confounders used for adjustment can be found in *Table S1* (supporting information). The analysis initially included all non-elective cases and was then repeated on the predefined subsets of patients undergoing ruptured or intact (symptomatic or asymptomatic) AAA repair. Before 2014, when these fields became compulsory, postoperative morbidity data were poorly completed in the NVR, so morbidity outcomes were analysed in two ways: first by using multiple imputation to impute missing values, and then after removing patients with missing morbidity outcomes. This was done in order to assess the sensitivity of the results to the way in which missing morbidity data were handled. All statistical modelling was performed using the R statistics package[26] version 3.3.1. Results are presented in line with the RECORD extension of the STROBE checklist for reporting of observational studies[27].

Results

Some 5495 non-elective AAA repairs were recorded in the NVR from 1 January 2013 until 31 December 2015. Fifty-six patients with unspecified discharge status were excluded, leaving 5439 patients. Among these patients, 3121 aneurysms were ruptured, 1495 were symptomatic but not ruptured, 518 were asymptomatic, and there were 94 others. The latter comprised aortic transections, acute dissections and chronic dissections, which were excluded from further analysis. The aneurysm status was not recorded for 211 patients.

The analysis included 5345 patients. There were 3236 open and 2028 endovascular repairs; the repair type was not recorded for 81 patients. The proportion of patients who received endovascular treatment varied according to whether the aneurysm was ruptured (26·9 per cent endovascular), symptomatic (56·5 per cent endovascular) or asymptomatic (59·9 per cent endovascular). Further details of patients, along with co-morbidities and admission medications, are shown in *Table 1*.

Operations were performed at the weekend 26·1 per cent of the time, and out of hours 49·7 per cent of the time. They were done at the weekend for asymptomatic, symptomatic and ruptured aneurysms 7·1, 16·7 and 33·7 per cent of the time respectively; and 11·6, 29·6 and 64·8 per cent respectively were performed out of hours. These rates were all significantly different from those expected if operations were distributed evenly over time, as the weekend covers 37·5 per cent of each 7-day period, and 73·2 per cent of each 7-day period is out of hours ($P < 0.001$ for all comparisons). Delay between admission and operation varied according to whether the AAA was ruptured, symptomatic or asymptomatic, with 16·0 per cent of ruptured AAAs, 68·6 per cent

Table 1 Baseline patient characteristics

	No. of patients* (n = 5345)
Age (years)†	76 (70–81)
Sex ratio (M : F)‡	4416 : 928
ASA fitness grade†	IV (III–IV)
Co-morbidities (n = 4125)	
Diabetes mellitus	652 (15·8)
Ischaemic heart disease	1518 (36·8)
Cardiac failure	227 (5·5)
Lung disease	933 (22·6)
Chronic kidney disease	475 (11·5)
Hypertension	2448 (59·3)
Previous stroke	281 (6·8)
Admission medications (n = 4603)	
Antiplatelet	2660 (57·8)
Statin	2771 (60·2)
Beta-blocker	1297 (28·2)
ACE inhibitor/ARB	1390 (30·2)

*With percentages in parentheses unless indicated otherwise; †values are median (i.q.r.). ‡Missing for one patient. Percentages for co-morbidities and admission medications based on those with completed fields. Co-morbidities are defined in the National Vascular Registry data dictionary[21]. ACE, angiotensin-converting enzyme; ARB, angiotensin II receptor blocker.

of symptomatic AAAs and 82·7 per cent of asymptomatic AAAs not having surgery on the same date as admission.

No variable had a missing data rate higher than 31·8 per cent (*Table S1*, supporting information), so all were available for confounder correction in multivariable regression modelling following multiple imputation.

Mortality

The overall in-hospital mortality rate was 25·4 per cent (*Table 2*). This rose to 33·2 per cent for the subset of patients who were operated on at the weekend. There was a significant difference in in-hospital mortality between procedures undertaken at the weekend and those in the week (odds ratio (OR) 1·69, 95 per cent confidence interval 1·47 to 1·94; *P* < 0·001), and this remained even after adjusting for demographics, co-morbidities, medications and preoperative test results (OR 1·20, 1·02 to 1·40; *P* = 0·025). When analysis was restricted to patients with a ruptured AAA, the overall in-hospital mortality rate rose to 37·1 per cent. Even in this subset, the mortality rate was higher when the operation was performed at the weekend (39·5 *versus* 35·8 per cent; OR 1·17, 1·00 to 1·36; *P* = 0·045), although the difference was not significant after adjustment for confounders (OR 1·09, 0·92 to 1·29; *P* = 0·330). Results were similar when all out-of-hours operations were analysed (*Table 2*). Mortality was also high for patients with asymptomatic aneurysms operated on out of hours.

Table 2 In-hospital mortality according to timing of procedure

	All operations	Weekend	Not weekend	Out of hours	Normal working week
In-hospital mortality (%)					
All AAAs	25·4	33·2	22·7	32·8	18·3
Ruptured AAAs	37·1	39·5	35·8	38·2	35·0
Symptomatic AAAs	7·9	9·2	7·6	9·7	7·1
Asymptomatic AAAs	5·8	13·5	5·2	21·7	3·7
Unadjusted analysis*					
All AAAs					
Odds ratio		1·69 (1·47, 1·94)		2·19 (1·92, 2·49)	
P		< 0·001		< 0·001	
Ruptured AAAs					
Odds ratio		1·17 (1·00, 1·36)		1·15 (0·99, 1·34)	
P		0·045		0·074	
Symptomatic AAAs					
Odds ratio		1·23 (0·76, 1·99)		1·40 (0·95, 2·07)	
P		0·390		0·093	
Asymptomatic AAAs					
Odds ratio		2·85 (1·02, 7·96)		7·18 (3·28, 15·72)	
P		0·046		< 0·001	
Adjusted analysis*					
All AAAs					
Odds ratio		1·20 (1·02, 1·40)		1·22 (1·05, 1·42)	
P		0·025		0·008	
Ruptured AAAs					
Odds ratio		1·09 (0·92, 1·29)		1·00 (0·84, 1·18)	
P		0·330		0·972	
Symptomatic AAAs					
Odds ratio		0·95 (0·57, 1·61)		0·95 (0·61, 1·47)	
P		0·859		0·801	
Asymptomatic AAAs					
Odds ratio		2·21 (0·65, 7·53)		3·73 (1·44, 9·62)	
P		0·205		0·007	

Values in parentheses are 95 per cent confidence intervals. Odds ratios are shown for weekend *versus* not weekend, and for out of hours *versus* normal working week. Weekend: Friday 17.00 hours until Monday 08.00 hours; not weekend: Monday 08.00 hours until Friday 17.00 hours; out of hours: at the weekend, or before 08.00 hours or after 17.00 hours on a weekday; normal working week: between 08.00 and 17.00 hours on a day other than Saturday or Sunday. AAA, abdominal aortic aneurysm. *Logistic regression analysis.

Length of hospital stay

The overall median postoperative length of hospital stay was 9 (i.q.r. 4–16) days. Any weekend effect on hospital stay was investigated in adjusted analyses. Patients operated on at the weekend had significantly higher odds of having a prolonged inpatient stay than those operated on during the week (OR 1·21, 95 per cent c.i. 1·06 to 1·37; *P* = 0·005). The difference was not significant when the analysis was restricted to those with a ruptured AAA (OR 1·06, 0·91 to 1·10; *P* = 0·478). Results were again similar when all out-of-hours operations were analysed (overall OR 1·28, 1·13 to 1·44, *P* < 0·001; ruptured AAA OR 1·13, 0·97 to 1·31, *P* = 0·109).

Length of stay was significantly shorter following endovascular compared with open repair (median 6 (i.q.r. 3–13) *versus* 10 (5–19) days respectively; *P* < 0·001), so the

Table 3 Morbidity outcomes for all patients and for those with a ruptured abdominal aortic aneurysm according to timing of repair

	All operations (%)	Weekend (%)	Not weekend (%)	Odds ratio	P	Out of hours (%)	Normal working week (%)	Odds ratio	P
Cardiac morbidity									
All AAAs	17·8	22·3	16·2	1·13 (0·95, 1·36)	0·174	22·7	13·0	1·25 (1·04, 1·48)	0·014
Ruptured AAA	24·4	25·6	23·7	1·05 (0·87, 1·27)	0·616	25·7	21·8	1·11 (0·91, 1·35)	0·288
Respiratory morbidity									
All AAAs	23·7	29·5	21·6	1·16 (0·98, 1·37)	0·085	28·9	18·6	1·17 (0·99, 1·37)	0·058
Ruptured AAA	31·3	33·5	30·2	1·08 (0·91, 1·29)	0·383	32·1	29·8	1·02 (0·85, 1·22)	0·811
Renal morbidity									
All AAAs	20·2	26·2	18·1	1·20 (1·01, 1·44)	0·043	25·6	14·9	1·22 (1·02, 1·45)	0·028
Ruptured AAA	27·5	30·0	26·2	1·11 (0·92, 1·34)	0·281	28·5	25·6	1·04 (0·85, 1·26)	0·718

Values in parentheses are 95 per cent confidence intervals. Odds ratios are shown for weekend *versus* not weekend, and for out of hours *versus* normal working week. Weekend: Friday 17.00 hours until Monday 08.00 hours; not weekend: Monday 08.00 hours until Friday 17.00 hours; out of hours: at the weekend, or before 08.00 hours or after 17.00 hours on a weekday; normal working week: between 08.00 and 17.00 hours on a day other than Saturday or Sunday. AAA, abdominal aortic aneurysm. Odds of patients treated at the weekend or out of hours having each complication, compared with those treated not at the weekend or treated during the normal working week respectively, were calculated by logistic regression analysis corrected for case mix.

analysis was repeated separately for open and endovascular surgery. For endovascular repair, the odds of patients operated on at the weekend having a prolonged inpatient stay was significantly higher than that of patients operated on during the week (OR 1·40, 1·10 to 1·77; $P = 0·006$), but not when results were restricted to ruptured AAA repair (OR 1·17, 0·86 to 1·60; $P = 0·321$). For open repair, there was no significant difference between operations performed in the week *versus* at weekends, for all procedures (OR 1·12, 0·96 to 1·30; $P = 0·147$) or ruptured AAA repairs only (OR 1·00, 0·84 to 1·19; $P = 0·984$).

Morbidity

Perioperative morbidity outcome data were missing for 22·8 per cent of the patients. Morbidity analysis was performed using both multiple imputation and also after removing patients with missing outcomes to allow assessment of the sensitivity of results to the imputation process. Results were remarkably similar from both analyses (*Table S2*, supporting information), showing that apparent differences in out-of-hours or weekend operating disappeared once non-ruptured aneurysms were excluded (*Table 3*). Uncorrected ORs using multiply imputed data for cardiac, respiratory and renal morbidity were 1·48 (95 per cent c.i. 1·25 to 1·75), 1·51 (1·29 to 1·76) and 1·57 (1·33 to 1·85) respectively. Fully corrected ORs for patients with ruptured AAA were 1·05 (0·87 to 1·27), 1·08 (0·91 to 1·29) and 1·11 (0·92 to 1·34) respectively.

Discussion

The present study showed an apparent weekend effect in terms of both mortality and morbidity outcomes as well as increased length of stay for non-elective AAA repair; however, after adjustment for confounders such as

co-morbidity (case-mix effects) and whether the aneurysm was ruptured (coding effects), this effect essentially disappeared. In subgroup analysis, there was a significantly increased risk of death for asymptomatic patients treated out of hours, although numbers were small so this may be a type I error.

These results highlight the pitfalls associated with studies of the weekend effect in large databases, and call into question the results of previous studies[1,13] showing an apparent weekend effect in the treatment of ruptured AAA. They suggest that two significant effects contribute to, or perhaps even account for, the weekend effect. The most significant of these is the effect of coding issues. Li and Rothwell[7] compared verified data with hospital coding data to identify acute stroke admissions, and found that many patients coded as acute stroke admissions during the week were actually previous stroke patients who had been admitted in an elective or semielective way. The addition of this group created sufficient bias for an apparent weekend effect to appear, which was absent when only true acute stroke admissions were included.

The second is the effect of case mix. Freemantle and co-workers[28] looked at this issue when considering the effect of day of the week in all non-elective admissions in England, concluding that, although case mix had a significant influence, a strong weekend effect remained; the OR for 30-day mortality was 1·10 for Saturday admissions and 1·15 for Sunday admissions compared with patients admitted on a Wednesday. Their work was based on the same hospital coding data found to contain coding issues in the context of stroke[7], however, so it is likely that significant miscoding bias exists in these results.

The present analysis shows effects similar to those addressed in both of these previous studies. When adjustments were made for case mix alone, the *P* value for the

primary outcome just remained significant at the 5 per cent level. Similarly, when adjustments were made for coding alone, the *P* value for the primary outcome was statistically significant. When adjustments were made for both factors, however, any significant difference in outcomes between the two groups disappeared entirely.

One somewhat surprising result is the high mortality rate for asymptomatic non-elective AAA repair performed out of hours, which persisted despite adjustments for case mix. These were generally very large aneurysms (mean diameter 88 mm), which is likely to be the reason that they were repaired urgently. It is possible that patients with aneurysms operated on out of hours were not good surgical candidates for a combination of anatomical and physiological reasons, which may have been picked up more readily if there had been a formal review by the multidisciplinary team, or at least an informal discussion with other senior surgical staff and specialist vascular anaesthetic staff, as might have happened in normal working hours. Further work would be required to fully understand the reasons behind this, but clearly out-of-hours repair of large but asymptomatic aneurysms cannot be recommended at present, pending further analysis of these results.

The strengths of this work include the rigorous approach to missing data and statistical modelling, as well as the large size of the data set, which includes the vast majority of patients treated across the UK over 3 years. It also looks at whether there are differences in morbidity rates for patients treated at the weekend or out of hours in more detail than existing work – an important consideration given the high rates of morbidity experienced by this patient population[14,15]. The mortality rate for patients with ruptured aneurysms in this data set was 37·1 per cent, which is in line with figures from the recent IMPROVE study[10], an RCT comparing endovascular and open repair strategies for ruptured AAA, giving confidence that outcomes are in line with other published figures from a UK cohort.

Weaknesses include the fact that the data were self-reported by units, which can introduce subtle biases, and the retrospective nature of the study, although data are input into the registry in a prospective manner. A further weakness is the fact that the NVR records the time when an operation began, not the time of admission, so it is possible that differences in staffing at the weekend might cause delays in getting patients from the emergency department to the operating theatre and thus affect outcomes in this way, although this would not be relevant for the asymptomatic aneurysms. Given the lack of a significant weekend effect after adjustments for case mix and coding (with the exception of out-of-hours operations on asymptomatic aneurysms) it is difficult to

believe that these issues would have a material effect on the results.

Further research is clearly needed in other specialties to confirm whether accounting for case mix and coding inaccuracies also eliminates significant weekend effects in these specialties. Vascular surgery is also now a largely centralized, consultant-delivered service, which is undertaken increasingly in regional centres, so it would be important to consider whether the results are equivalent for conditions that are treated in smaller, less well staffed hospitals, with fewer out-of-hours services. This remains an issue even in a largely centralized service such as vascular surgery, as evidenced by the fact that only 26·9 per cent of ruptured AAAs underwent endovascular repair. Although this is a significant improvement on published figures from 2005–2010, when only 8·5 per cent of ruptured AAAs were treated with endovascular repair in the UK[11], another study[29] has reported that at least 50 per cent of AAAs may be suitable for endovascular repair, suggesting that there may still be issues around availability of emergency endovascular repair out of hours.

After appropriate correction for case-mix and coding effects, there is no evidence of a significant weekend effect in the treatment of ruptured AAA in the UK.

Acknowledgements

References

1 Bell CM, Redelmeier DA. Mortality among patients admitted to hospitals on weekends as compared with weekdays. *N Engl J Med* 2001; **345**: 663–668.

2 Metcalfe D, Perry DC, Bouamra O, Salim A, Lecky FE, Woodford M *et al.* Is there a 'weekend effect' in major trauma? *Emerg Med J* 2016; **33**: 836–842.

3 Hamada T, Yasunaga H, Nakai Y, Isayama H, Matsui H, Fushimi K *et al.* No weekend effect on outcomes of severe acute pancreatitis in Japan: data from the diagnosis procedure combination database. *J Gastroenterol* 2016; **51**: 1063–1072.

4 Manfredini R, Gallerani M, De Giorgi A, Boari B, Lamberti N, Manfredini F *et al.* Lack of a 'weekend effect' for renal transplant recipients: the hospital database of the

Emilia-Romagna region of Italy. *Angiology* 2017; **68**: 366–373.

5 Roberts SE, Thorne K, Akbari A, Samuel DG, Williams JG. Mortality following stroke, the weekend effect and related factors: record linkage study. *PLoS One* 2015; **10**: e0131836.

6 Muppavarapu RC, Chaurasia AR, Schwarzkopf R, Matzkin EG, Cassidy CC, Smith EL. Total joint arthroplasty surgery: does day of surgery matter? *J Arthroplasty* 2014; **29**: 1943–1945.

7 Li L, Rothwell PM. Biases in detection of apparent 'weekend effect' on outcome with administrative coding data: population based study of stroke. *BMJ* 2016; **353**: i2648.

8 Department of Health. *NHS 7 Day Services*; 2015. https://www.gov.uk/government/collections/nhs-7-day-services [accessed 20 February 2017].

9 Waton S, Johal A, Heikkila K, Cromwell D, Loftus I. *National Vascular Registry 2015 Annual Report*; 2015. https://www.vsqip.org.uk/content/uploads/2015/12/NVR-2015-Annual-Report.pdf [accessed 20 February 2017].

10 IMPROVE Trial Investigators, Powell JT, Sweeting MJ, Thompson MM, Ashleigh R, Bell R *et al.* Endovascular or open repair strategy for ruptured abdominal aortic aneurysm: 30 day outcomes from IMPROVE randomised trial. *BMJ* 2014; **348**: f7661.

11 Karthikesalingam A, Holt PJ, Vidal-Diez A, Ozdemir BA, Poloniecki JD, Hinchliffe RJ *et al.* Mortality from ruptured abdominal aortic aneurysms: clinical lessons from a comparison of outcomes in England and the USA. *Lancet* 2014; **383**: 963–969.

12 Ambler GK, Gohel MS, Mitchell DC, Loftus IM, Boyle JR. The Abdominal Aortic Aneurysm Statistically Corrected Operative Risk Evaluation (AAA SCORE) for predicting mortality after open and endovascular interventions. *J Vasc Surg* 2015; **61**: 35–43.

13 Groves EM, Khoshchehreh M, Le C, Malik S. Effects of weekend admission on the outcomes and management of ruptured aortic aneurysms. *J Vasc Surg* 2014; **60**: 318–324.

14 Ambler GK, Coughlin PA, Hayes PD, Varty K, Gohel MS, Boyle JR. Incidence and outcomes of severe renal impairment following ruptured abdominal aortic aneurysm repair. *Eur J Vasc Endovasc Surg* 2015; **50**: 443–449.

15 van Beek SC, Legemate DA, Vahl A, Bouman CS, Vogt L, Wisselink W *et al.* Acute kidney injury defined according to the 'Risk,' 'Injury,' 'Failure,' 'Loss,' and 'End-stage' (RIFLE) criteria after repair for a ruptured abdominal aortic aneurysm. *J Vasc Surg* 2014; **60**: 1159–1167, 1167.e1.

16 Walker K, Neuburger J, Groene O, Cromwell DA, van der Meulen J. Public reporting of surgeon outcomes: low numbers of procedures lead to false complacency. *Lancet* 2013; **382**: 1674–1677.

17 Alderson D, Cromwell D. Publication of surgeon-specific outcomes. *Br J Surg* 2014; **101**: 1335–1337.

18 Radford PD, Derbyshire LF, Shalhoub J, Fitzgerald JEF; Council of the Association of Surgeons in Training. Publication of surgeon specific outcome data: a review of implementation, controversies and the potential impact on surgical training. *Int J Surg* 2015; **13**: 211–216.

19 Mitchell DC, Hindley H, Naylor R, Wyatt M, Loftus IM. *Outcomes after Elective Repair of Infra-Renal Abdominal Aortic Aneurysm.* Vascular Society of Great Britain and Ireland: London, 2012.

20 Waton S, Johal A, Heikkila K, Cromwell D, Loftus I. *National Vascular Registry 2016 Annual Report*; 2016. https://www.vsqip.org.uk/content/uploads/2016/12/National-Vascular-Registry-2016-Annual-Report.pdf [accessed 20 February 2017].

21 Waton S. *NVR Data Dictionary*; 2016. https://www.vsqip.org.uk/resources/guides/nvr-data-dictionary [accessed 20 February 2017].

22 Little RJ, Rubin DB. *Statistical Analysis with Missing Data* (2nd edn). John Wiley & Sons: New York, 2002.

23 Little RJ, D'Agostino RB, Cohen M, Dickersin K, Emerson SS, Farrar JT *et al.* The prevention and treatment of missing data in clinical trials. *N Engl J Med* 2012; **367**: 1355–1360.

24 van Buuren S, Groothuis-Oudshoorn K. Mice: multivariate imputation by chained equations in R. *J Stat Softw* 2011; **45**: 1–67.

25 van Buuren S. *Package 'Mice'*. https://cran.r-project.org/web/packages/mice/mice.pdf [accessed 28 September 2017].

26 R Core Team. *R: A Language and Environment for Statistical Computing.* R Core Team: Vienna, 2012.

27 Benchimol EI, Smeeth L, Guttmann A, Harron K, Hemkens LG, Moher D *et al.*; RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Med* 2015; **12**: e1001885.

28 Freemantle N, Ray D, McNulty D, Rosser D, Bennett S, Keogh BE *et al.* Increased mortality associated with weekend hospital admission: a case for expanded seven day services? *BMJ* 2015; **351**: h4596.

29 Armon MP, Yusuf SW, Latief K, Whitaker SC, Gregson RH, Wenham PW *et al.* Anatomical suitability of abdominal aortic aneurysms for endovascular repair. *Br J Surg* 1997; **84**: 178–180.

Supporting information

Additional supporting information can be found online in the supporting information tab for this article.

Graphical Abstract

The contents of this page will be used as part of the graphical abstract of HTML only. It will not be published as part of main article.
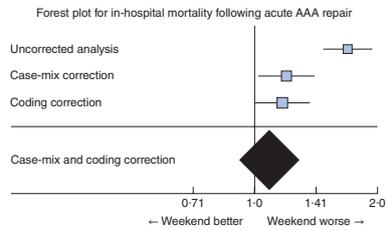
Forest plot for in-hospital mortality at the weekend *versus* not at the weekend following acute abdominal aneurysm repair. Odds ratios are shown with 95 per cent confidence intervals. AAA, abdominal aortic aneurysm.