Multivariate and univariate analysis of weekend phenomenon for elective lower limb joint replacements.

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Abstract

Introduction

The weekend effect is a perceived difference in outcome between medical care provided at the weekend when compared to that of a weekday. Clearly multifactorial, this effect remains incompletely understood and variable in different clinical contexts. In this study we analyse factors relevant to the weekend effect in elective lower limb joint replacement at a large NHS multi-specialty academic healthcare centre.

Materials and Methods

We reviewed the electronic medical records (EMR) of 352 consecutive patients who received an elective primary hip or knee arthroplasty. Patient variables, clinical variables and time-related variables were extracted from the EMR. The data was anonymised, then processed using a combination of univariate and multivariate statistics.

Results

We identify a significant association between the selected weekend effect outcome measure, namely post-operative length of stay (LOS), and the following; patient age, ASA classification, time to first post-operative physio and time to post-operative radiography, but not day of the week of operation.

Discussion

We were unable to demonstrate a weekend effect in elective lower limb joint replacement at our institution, nor identify a factor that would require additional weekend clinical medical staffing. Rather, resource priorities would seem to include...
measures to optimise at-risk patients pre-operatively and measures to reduce time to physio and radiography post-operatively.

Conclusions

Our findings imply that post-operative LOS could be minimised by strategies relating to patient selection and access to post-operative services. We have also identified a powerful statistical methodology that could be applied to other service evaluations in different clinical contexts.

Key words: Arthroplasty, Elective Surgical Procedures, Length of Stay, Postoperative Care, Preoperative Care.
Introduction

The weekend effect, which is defined as a deferred increase in patient mortality associated with weekend compared to weekday admission (1) (Or weekend compared to weekday operation, in elective surgery (2, 3)), has been described in both emergency and elective surgical settings in the NHS (2, 4, 5). Levels of staffing, both clinical and allied health, and case mix have been identified as potential factors, though the mechanisms of the weekend effect are yet to be satisfactorily established (1). Trust-level data suggests that the weekend effect is subject to considerable national variation. Recently, the High-intensity Specialist Led Acute Care (HiSLAC) Collaborative compared the mortality odds ratios (OR) for weekend to weekday acute admissions of 115 trusts in England. They reported ratios ranging from 0.81 to 1.35 and noted that 83% of trusts possessed an OR greater than 1 (6). By definition 17% of trusts therefore possessed an OR of less than or equal to 1. Variations in the weekend effect have also been observed across specialties, between elective and emergency admissions and according to procedure (2, 7). For example, Aylin et al. observed the presence of a weekend effect in major gastrointestinal surgery, lung excision and coronary artery bypass grafting, but not in abdominal aortic aneurysm repair, varicose vein surgery, tonsillectomy, hip and knee arthroplasty and hernia repair.

Our aim was therefore to measure several relevant potential factors relating to the weekend effect in a specific clinical setting and apply and develop statistical analysis of them. We further aimed to understand these factors in terms of weekend staffing requirements.
We examined patient outcomes and possible contributing factors, including weekday compared to weekend care, in 352 elective orthopaedic patients, who received a primary hip or knee arthroplasty at a large NHS multi-specialty academic healthcare centre (Cambridge University Hospitals (CUH) NHS Foundation Trust). The elective service benefits from weekend allied health service provision, ring-fenced beds, surgical lists six days a week (Monday to Saturday) and consultant-led weekend care.

One of the difficulties of comparing weekday and weekend patient care in this study is that the weekend effect outcome, namely 30 day mortality, has a low incidence in elective orthopaedics (0.22% for primary knee and 0.27% for primary hip arthroplasties nationally (8)). A study powered to observe changes in this parameter would require a large sample size. Therefore, for the purpose of this study, an alternative primary outcome measure - post-operative length of stay (LOS) - was used. Post-operative LOS, which is considered a “weekend effect phenomenon” (9), has been shown to increase for cases undertaken towards the end of the week and decreases following interventions to improve weekend care (10).

**Materials and Methods**

We reviewed the electronic medical records (EMR) (EPIC Systems Corporation, Verona, USA), cross-matched against National Joint Registry (NJR) submission data, of all patients who received a primary hip or knee arthroplasty, between 1\textsuperscript{st} April 2016 and 23\textsuperscript{rd} August 2016, at CUH and retrospectively assessed post-operative LOS, defined here as time to hospital discharge following cessation of intra-operative anaesthesia. The service evaluation protocol was approved by the Clinical Audit Committee at CUH.
Patient variables (date of birth (DOB), body mass index (BMI) and American Society of Anesthesiologists (ASA) physical status classification), clinical variables (case-type, lead consultant, operating surgeon grade, indication, intraoperative events and anaesthetic type) and time-related variables (month of operation, day of the week of operation and times and dates of cessation of intra-operative anaesthesia, postoperative radiography, first post-operative physio and hospital discharge) were extracted from the EMR. The post-operative period was taken to commence at the time of cessation of intra-operative anaesthesia. Patient age at operation and times to post-operative radiography, first post-operative physio and hospital discharge were calculated from the extracted data.

Patients were excluded in cases where the indication for their operation was trauma i.e. non-elective (17 patients) and where the time to discharge could not be established (1 patient - deceased prior to discharge). Overall, 352 patients (170 primary hip and 182 primary knee arthroplasties) were included in the analysis.

Anonymised data was processed using a combination of multivariate and univariate statistics. Mixed quantitative and qualitative data was imported into SIMCA-P 13.0 (Umetrics, Umeå, Sweden) and analysed using partial least squares (PLS) regression, with post-operative LOS set as the response variable, Y. Missing data was interpolated, using a least squares fit, but assigned no influence on the model. Response permutation testing (n = 100) and analysis of variance of the cross validated residuals (CV-ANOVA) were used to validate the model. Based on the results of the multivariate analysis, selected data was imported into Prism 6 (GraphPad Software, La Jolla, USA) for univariate analysis. Data was checked for normality using the D’Agostino-Pearson omnibus normality test. Non-normally distributed data was analysed using a combination of Spearman’s rank correlation
coefficient and the Kruskal-Wallis H test (“one-way ANOVA on ranks”) followed by Dunn’s multiple comparisons test.

**Results**

Case-mix, study population demographics and post-operative LOS were stratified by day of the week of operation and compared (Table 1.). Over the twenty-one Mondays, Tuesdays, Fridays and Saturdays, and twenty Wednesdays and Thursdays included in the study period, a similar number of cases were performed on Mondays, Tuesdays and Thursdays. Considerably fewer cases were performed on Wednesdays and Saturdays and considerably more cases performed on Fridays. These differences are largely attributable to the number of cases performed per day, rather than the number of times a given day of the week occurred within the study period. The ratio of elective primary hip to knee arthroplasties ranged from 0.59-1.36. Overall, there were more female than male cases (220 vs 132). Only on Thursdays were there more male than female cases. There were no differences between operations performed on different days of the week in terms of patient age and BMI, and ASA II was the most frequent patient physical status classification on all days of the week. Post-operative LOS was unaffected by day of the week of operation.

Given that post-operative LOS was unaffected by day of the week of operation, the relationships between other variables and post-operative LOS were examined. A PLS model was built by regressing post-operative LOS against the patient, clinical and time-related variables extracted from the EMR (1 latent variable from cross-validation; R2X = 3.94%, R2Y = 24.8%, Q2 = 14.4%; CV-ANOVA = 1.52 x 10⁻¹²). The loadings plot of the PLS model (Figure 1.) demonstrates that increasing patient
age, time to first post-operative physio, time to post-operative radiography and ASA classification are the most important correlates with increasing post-operative LOS.

Univariate analysis was performed to confirm the findings of the multivariate analysis. Significant positive correlations were observed between post-operative LOS and age (Spearman $r = 0.33$ [95% confidence interval (CI) = 0.23-0.43], $P < 0.0001$), post-operative LOS and time to first post-operative physio (Spearman $r = 0.17$ [95% CI = 0.06-0.27], $P = 0.0014$) and post-operative LOS and time to post-operative radiography (Spearman $r = 0.17$ [95% CI = 0.07-0.28], $P = 0.0011$). To examine the relationship between ASA classification and post-operative LOS, the Kruskal-Wallis H test, followed by Dunn’s multiple comparisons test, was performed (Figure 2.). Higher ASA classifications were associated with increased post-operative LOS (ANOVA = 0.0001; ASA I vs III, $P = 0.0073$; ASA II vs III, $P = 0.0013$).

**Discussion**

The results of this study demonstrate that post-operative LOS is unaffected by day of the week of operation and suggest that elective orthopaedic care at CUH is not subject to the weekend effect. Therefore, we did not identify a requirement for increased weekend clinical medical staff, in this setting. These findings are consistent with and extend those of Pakzad et al., who reported no association between length of stay and day of the week of operation in elective ankle surgery for end-stage ankle arthritis, at their institution (11).

In addition, the results show a significant association between increasing post-operative LOS and increasing age and ASA classification, in elective primary hip and knee arthroplasties, an effect also observed by Pakzad et al. in elective ankle surgeries (11) and Collins et al. across major elective orthopaedic, vascular,
urological and general surgeries (12). We therefore support the conclusions of Fitz-Henry et al. and advocate that older, ASA III and IV, elective orthopaedic patients receive enhanced pre- and peri-operative anaesthetic input, in order to optimise their physical condition (13).

Lastly, the results show that increasing post-operative LOS is significantly associated with increasing time to first post-operative physio and post-operative radiography, which are standard steps in the orthopaedic post-operative protocol. Time to first post-operative physio is indicative of time to mobilisation, which has previously been associated with length of stay following elective orthopaedic surgery (14-16). To the best of our knowledge, this is the first time an association between post-operative LOS and time to post-operative radiography has been reported. It is plausible that first post-operative physio and post-operative radiography represent important clinical bottlenecks in the orthopaedic post-operative protocol. However, these variables may simply be correlated, rather than causally associated, with post-operative LOS. Nevertheless, we believe that interventions to reduce time to first post-operative physio and post-operative radiography warrant further investigation, to determine whether they reduce post-operative LOS in an elective orthopaedic context.

One of the limitations of this study is that it does not explicitly control for case-mix and study population demographic variables, which might confound the results and mask a weekend effect. However, those variables associated with post-operative LOS (Age and ASA classification) do not vary across the week, whilst those variables which do vary across the week (Case-mix and gender ratio) are not associated with post-operative LOS and are therefore unlikely to confound the results.
Conclusion

Increasing age, ASA classification, time to post-operative radiography and time to first post-operative physio are significantly associated with increasing post-operative LOS, whilst there is no evidence of a weekend effect, in elective orthopaedic care at CUH. We did not identify a factor that would require additional weekend clinical medical staffing. For this service, resource priorities would seem to include measures to optimise at-risk patients pre-operatively and measures to reduce time to first post-operative physio and post-operative radiography. We have also identified a powerful statistical methodology that could be applied to other clinical settings and service evaluations.

References


### Tables

**Table 1. Study Population Demographic Features**

<table>
<thead>
<tr>
<th>Day of the week of operation</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary arthroplasties</td>
<td>60</td>
<td>59</td>
<td>26</td>
<td>70</td>
<td>111</td>
<td>26</td>
</tr>
<tr>
<td>Hip</td>
<td>26</td>
<td>22</td>
<td>15</td>
<td>32</td>
<td>62</td>
<td>13</td>
</tr>
<tr>
<td>Knee</td>
<td>34</td>
<td>37</td>
<td>11</td>
<td>38</td>
<td>49</td>
<td>13</td>
</tr>
<tr>
<td>Hip/knee ratio</td>
<td>0.76</td>
<td>0.59</td>
<td>1.36</td>
<td>0.84</td>
<td>1.27</td>
<td>1.00</td>
</tr>
<tr>
<td>Male/female ratio</td>
<td>0.67</td>
<td>0.48</td>
<td>0.44</td>
<td>1.06</td>
<td>0.44</td>
<td>0.73</td>
</tr>
<tr>
<td>Age (y)</td>
<td>72 (66-78)</td>
<td>69 (60-76)</td>
<td>67 (50-77)</td>
<td>70 (63-77)</td>
<td>70 (63-77)</td>
<td>66 (57-77)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>31.0 (27.1-34.7)</td>
<td>30.1 (26.8-37.2)</td>
<td>26.6 (24.4-33.3)</td>
<td>29.2 (26.4-35.7)</td>
<td>29.0 (25.3-35.6)</td>
<td>31.2 (26.4-35.0)</td>
</tr>
<tr>
<td>ASA</td>
<td>II</td>
<td>II</td>
<td>II</td>
<td>II</td>
<td>II</td>
<td>II</td>
</tr>
<tr>
<td>Post-operative LOS (h)</td>
<td>73 (51-100)</td>
<td>70 (53-103)</td>
<td>72 (46-120)</td>
<td>73 (53-99)</td>
<td>75 (54-99)</td>
<td>72 (51-82)</td>
</tr>
</tbody>
</table>

*Median age in years (interquartile range) 2 s.f.

*Median Body Mass Index [BMI = weight (kg)/height (m²)] (interquartile range) 3 s.f.

*Mode American Society of Anesthesiologists physical status classification [I-VI]

*Median post-operative length of stay (LOS) in hours (interquartile range) 2 s.f.

**Table 1. Study Population Demographic Features.** The table shows the number of primary hip and knee arthroplasties performed, the male-to-female ratio, the median age and BMI, the mode ASA physical status classification and the median post-operative length of stay, stratified by day of the week of operation.

### Figure Captions

**Figure 1.** Loadings Plot of PLS Model. The figure shows the correlations between the study variables. The black circle represents the response variable, Y (post-operative length of stay) and the grey circles represent the X variables. The position of the X variables on the y-axis (w*[c][1]) gives information about the sign and strength of their correlation with the Y variable. In this figure, the more positive the y-axis position of the X variables, the greater their positive correlation with post-operative
length of stay. The more negative the y-axis position of the X variables, the greater their negative correlation with post-operative length of stay. n = 352.

**Figure 2.** Post-operative Length of Stay Stratified by ASA Classification. The figure shows the post-operative length of stay stratified by ASA physical status classification. Column heights represent median post-operative length of stay. Bars represent interquartile range. Stars indicate levels of significant difference, estimated by Dunn’s multiple comparisons test. ** represent p-values between 0.01 and 0.001. n = 48 (ASA I), 206 (ASA II), 91 (ASA III) and 7 (ASA IV).