Consumer segmentation and time interval between types of hospital admission: a clinical linkage database study

Umesh T. Kadam1, Claire A. Lawson1, Dawn K. Moody1, Lucy Teece1, John Uttley2, John Harvey3, Z. Iqbal4, P.W. Jones1

1Health Services Research Unit, Guy Hilton Research Centre, Keele University, Stoke-on-Trent ST4 7QB, UK
2e-Innovation Unit, Midlands and Lancashire Commissioning Support Unit, Stoke-on-Trent ST4 4LX, UK
3North Staffordshire Clinical Commissioning Group, Morston House, Newcastle-under-Lyme ST5 1QG, UK
4Public Health Directorate, City of Stoke-on-Trent, Civic Centre, Stoke-on-Trent ST4 1HH, UK
Address correspondence to Umesh T. Kadam, E-mail: u.kadam@keele.ac.uk

ABSTRACT

Background Healthcare policies target unplanned hospital admissions and 30-day re-admission as key measures of efficiency, but do not focus on factors that influence trajectories of different types of admissions in the same patient over time.

Objectives To investigate the influence of consumer segmentation and patient factors on the time intervals between different types of hospital admission.

Research design, subjects and measures A cohort design was applied to an anonymised linkage database for adults aged 40 years and over (N = 58,857). Measures included Mosaic segmentation, multimorbidity defined on six chronic condition registers and hospital admissions over a 27-month time period.

Results The shortest mean time intervals between two consecutive planned admissions were: 90 years and over (160 days (95% confidence interval (CI): 146–175)), Mosaic groups ‘Twilight subsistence’ (171 days (164–179)) or ‘Welfare borderline’ and ‘Municipal dependency’ (177 days (172–182)) compared to the reference Mosaic groups (186 days (180–193)), and multimorbidity count of four or more (137 days (130–145)). Mosaic group ‘Twilight subsistence’ (rate ratio (RR) 1.22 (95% CI: 1.08–1.36)) or ‘Welfare borderline’ and ‘Municipal dependency’ RR 1.20 (1.10–1.31) were significantly associated with higher rate to an unplanned admission following a planned event. However, associations between patient factors and unplanned admissions were diminished by adjustment for planned admissions.

Conclusion Specific consumer segmentation and patient factors were associated with shorter time intervals between different types of admissions. The findings support innovation in public health approaches to prevent by a focus on long-term trajectories of hospital admissions, which include planned activity.

Keywords chronic disease, social determinants, socioeconomics factors

Background

There is an enduring international policy interest in reducing the rising costs of hospital admissions and re-admissions by implementing timely and earlier care interventions based on the community.1–3 Potential interventions could be targeted at any point including from the first hospital admission or for those patients who have recurrent admissions over time or targeting factors relating to the patient or clinical status and location of care.4,5 Healthcare policy initiatives have targeted the reduction of unplanned hospital admissions through a focus on reducing 30-day re-admissions,6,7 and prevention approaches have either tried to use social, clinical or...
healthcare indicators to target patients at higher risk of unplanned hospital admission. However, there is little current evidence on effective interventions to prevent unplanned hospital admissions. Developing effective interventions is likely to include (i) clear identification of the population at risk, (ii) identifying the appropriate teams co-ordinating the respective clinical pathway and (iii) on-going assessment of interventions in preventing or reducing the risk of future hospital admissions.

Currently, clinical and healthcare data identifies patients at risk but these could also be considerably enhanced by detailed consumer segmentation methods. An example, is the Mosaic geodemographic segmentation which has been used to profile populations in consumer marketing. It is a broader area-based classification which uses residential postcodes to create profiles based on census, lifestyle, socio-economic and sociocultural behaviour indicators. These are more likely to capture important determinants of health and lifestyles and with further stratification by clinical factors could provide novel methods for identification and new tailored interventions in preventing unplanned hospital admissions.

Hospital provision includes planned and unplanned activity, and recurrent admissions in a patient provide a window on the on-going potential impact of any interventions and longer term outcomes. For example, the diabetes pathway care provision includes outpatient assessments, hospital reviews and elective admissions. The diabetic patient will also engage with community services, so developing broader interventions could integrate planned hospital care with community-based markers of patients at-risk of an unplanned admission.

Using a large anonymised database linking the Mosaic segmentation measure, socio-demographic data and six specified long-term conditions (LTCs) to hospital admissions, we investigated how such factors influenced the time intervals between different types of consecutive hospital admissions. Specific factors influence the risk of unplanned hospital admission, but by investigating time intervals between repeated planned or unplanned admissions provides the opportunity for more detailed characterization of the risk of admission. The null hypothesis then was that all consumer segmentation would have the same time intervals between different types of consecutive admissions and alternative hypothesis that planned hospital admission will increase the time or rate to an unplanned admission compared to two unplanned admissions.

**Methods**

**Design**

A cohort design nested in an anonymised clinical linkage database was used to investigate the population aged 40 years and over (N = 58,857), with data available for a 27-month time-period to 31 March 2009. The LTCs registers were drawn from 53 Stoke-on-Trent general practices and linked to hospital admissions covering the same time period. The 40-year-age threshold was chosen as the selected LTCs are more common from this age group and when hospital activity and admission escalates above this age.

The provision of the database was made under Clinical Commissioning Group and Public Health governance agreements to support and evaluate local quality improvement programmes focusing on LTCs and their outcomes. Linkage of the Mosaic segmentation, socio-demographic patient factors and LTC registers to hospital admissions for the same time period was done using the unique NHS number allocated to an individual patient prior to the provision of the anonymised data set for analyses.

**LTC registers**

The general practices had participated in national quality outcomes framework and local quality improvement frameworks for specific LTCs, including hypertension, diabetes, ischaemic heart disease, chronic obstructive airways disease, chronic heart failure (CHF) and chronic kidney disease (CKD) to develop registers for their population. The standard UK Read classification was used by clinicians to code the actual consultation, providing the individual LTC status for each patient, and this set of six conditions also identified patients with multimorbidity of two or more conditions.

**Consumer segmentation**

The Mosaic segmentation measure is based on individual patient residential postcodes and relates to ~15 households, with individuals living in these households assigned the same Mosaic profiling category according to their ‘average’ characteristics. The profiling is drawn from the 2011 UK census, lifestyle survey, consumer credit databases, the electoral roll, shareholder registers, land registry data, council tax information, the British Crime Survey, Expenditure and Food Survey and other sources. There are 61 distinct ‘lifestyle types’, which are aggregated into a main set of 11 lifestyle groups to describe the socio-economic and likely sociocultural behaviours of populations.

**Linked hospital admission data**

Admissions were based on Hospital Episode Statistics (HES) in England, which contain records for all NHS admissions to any hospitals in each financial year. The data are means by which purchasing commissioning organizations arrange payment to the acute hospital providers and linking these...
Clinical databases allow the possible tracking of healthcare patterns of patient populations. Overall admissions’ types are either planned or unplanned and data included the date of admission and discharge allowing for the determination of time intervals between repeated consecutive admissions. There were in total 65298 admissions in the study time window.

Statistical analyses
The overall study population is first described by age categorized as 40–49, 50–59, 60–69, 70–79, 80–89 and 90 years and over, gender, the 11 Mosaic groups, gender, six LTCs and up to six multimorbidity counts for admissions defined by planned only, unplanned only and patients who had both types of admissions.

For regression analysis, the 11 Mosaic groups were categorized into six ordinal groups because some were small in number. Re-categorization was done by cross-tabulating with the mean Index of Multiple Deprivation score for each of the 11 groups resulting in six ordinal groups starting from most affluent as follows: (i) A (symbols of success), B (happy families), C (suburban comfort) and K (rural isolation) as the most ‘affluent’ group; (ii) J (grey perspectives) as a single group; (iii) D (ties of community) as a single group; (iv) E (urban intelligence) and H (blue collar enterprise); (v) I (twilight subsistence) as a single group and (vi) F (welfare borderline) and G (municipal dependency) as the most deprived group. Multimorbidity was defined as four count categories of the six study LTCs (1, 2, 3 and four or more). Individual LTCs were excluded from regression analyses as they would correlate with the multimorbidity categories.

Cox regression was used to present associations between individual factors and hospital admissions in unadjusted analyses and then adjusting for the stated co-variates (age, gender, Mosaic groups and multimorbidity counts). These analyses included censored observations, which is the time between the occurrence of the last event (a planned or unplanned admission) and the end of the study, and were adjusted to take account of possible multiple intervals for the same patient.

The three nested structure analyses with time interval expressed as rate were as follows: (i) between two planned admissions, (ii) between two unplanned admissions and (iii) planned to unplanned admission, with rates adjusted for co-variates. Additional adjustment by the number of planned admissions was used to test the hypothesis that any planned care can impact on two unplanned admissions. Means and confidence intervals (CIs) adjusted for possible multiple observations on the same patients are presented where there were at least two admissions. Rate ratios (RRs) are presented with two-tailed significance level testing at 5% using Stata 13 and no adjustments were made for multiple testing.

Results
Overall type of admissions
In the ‘youngest’ age group 40–49 years, 15% had planned hospital admissions only but 9% an unplanned admission only (Table 1). The respective planned admissions only and ‘both types’ figures for 80–89 years were 10 and 17%, and for 90 years and over 3 and 10%. The respective figures for men and women were similar. The Mosaic groups with the highest proportion of planned hospital admissions only were ‘suburban comfort’ (Group C—18%) and ‘symbols of success’ (Group A—17%) with figures for ‘both type’ of admissions at 11 and 9%, respectively. The Mosaic groups with the lowest proportion of planned admissions only were ‘welfare borderline’ (Group F—14%) and ‘twilight subsistence’ (Group I—15%) with figures for ‘both type’ of admissions at 13 and 16%, respectively.

Coronary heart disease (CHD) group had the highest proportion of planned admissions only (17%) and the figure for ‘both’ types of admissions was 17%. CHF had the lowest proportion of planned admissions only (10%) and the figure for ‘both’ types of admissions was 21%. CHF and chronic obstructive pulmonary disease (COPD) had the highest levels of unplanned admissions (19%). The proportion of planned admissions only decreased with increasing multimorbidity count but the proportion with ‘both’ type of admissions in contrast increased (Table 1). For the group with a single count of the study specified LTCs, the proportion with planned hospital admissions only was 16 and 9% who also had unplanned admissions only, and the respective figures for the multimorbidity group with five counts were 10 and 25%.

Study factors and time intervals
Increasing age was associated with decreased time intervals between two planned admissions, with a mean time interval of 200 days (95% CI: 190–210 days) for the 40–49 year age group compared to 160 days (95% CI: 146–175) for the age group 90 years and over (Table 2). The mean time intervals for women and men were similar. Compared to most ‘affluent’ Mosaic groups, all other groups with the exception of E and H had shorter mean time intervals between two planned hospital admissions. The respective mean time intervals for the ‘most’ deprived Mosaic Groups I or F and G were 171 days (95% CI: 164–179) and 177 days (172–182), respectively, compared to the reference group of 186 days (180–193). The
mean time interval for the multimorbidity count group four or more was 137 days (130–145) compared to reference group of one at 192 days (187–196).

The time intervals for two unplanned (Table 3) and planned to unplanned admissions (Table 4) were, respectively, as follows: a mean time interval of 102 versus 133 days for the 40–49 year age group compared to 89 versus 143 days for the age group 90 years and over; 94 versus 136 days for women and 93 versus 124 days for men; 88 versus 140 days for Mosaic Group I and 94 versus 130 days for F and G compared to the reference group of 88 versus 127 days. The respective figures for the multimorbidity count group four or more were 81 versus 116 days, respectively.

**Associations between study factors and time intervals**

After adjusting for age, gender, Mosaic groups and multimorbidity counts, the associations between age and higher

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number</th>
<th>None (%)</th>
<th>Hospital admissions</th>
<th>Planned only (%)</th>
<th>Unplanned only (%)</th>
<th>Both (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n = 34 810</td>
<td></td>
<td>n = 9635</td>
<td>n = 7385</td>
<td>n = 7027</td>
</tr>
</tbody>
</table>

**Table 1** Socio-demographic characteristics of the study population and hospital admissions
Table 2  Study factors associations with time intervals between any two planned admissions

<table>
<thead>
<tr>
<th>Factors</th>
<th>Categories (n)</th>
<th>Time interval (days)</th>
<th>RR</th>
<th>RR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Unadjusted (95% CI)</td>
</tr>
<tr>
<td></td>
<td>Days (SE)</td>
<td>95% CI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age groups (years)</td>
<td>40–49 (599)</td>
<td>200 (5.3)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>50–59 (1089)</td>
<td>194 (3.8)</td>
<td>1.09 (1.01–1.12)</td>
<td>1.04 (0.99–1.09)</td>
</tr>
<tr>
<td></td>
<td>60–69 (1742)</td>
<td>180 (2.8)</td>
<td>1.32 (1.23–1.41)</td>
<td>1.18 (1.13–1.24)</td>
</tr>
<tr>
<td></td>
<td>70–79 (2197)</td>
<td>176 (2.3)</td>
<td>1.55 (1.45–1.65)</td>
<td>1.46 (1.39–1.54)</td>
</tr>
<tr>
<td></td>
<td>80–89 (1298)</td>
<td>171 (2.5)</td>
<td>1.56 (1.47–1.67)</td>
<td>1.61 (1.52–1.70)</td>
</tr>
<tr>
<td></td>
<td>90+ (102)</td>
<td>160 (7.2)</td>
<td>1.27 (1.13–1.41)</td>
<td>1.22 (1.09–1.37)</td>
</tr>
<tr>
<td>Gender</td>
<td>Men (3326)</td>
<td>178 (2.0)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Women (3701)</td>
<td>184 (1.8)</td>
<td>0.97 (0.94–1.00)</td>
<td>0.98 (0.96–1.00)</td>
</tr>
<tr>
<td>Mosaic groupsb</td>
<td>A, B, C, K (1240)</td>
<td>186 (3.3)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>J (289)</td>
<td>181 (6.7)</td>
<td>1.08 (0.99–1.18)</td>
<td>1.04 (0.98–1.12)</td>
</tr>
<tr>
<td></td>
<td>D (2118)</td>
<td>180 (2.5)</td>
<td>1.06 (1.00–1.11)</td>
<td>1.03 (0.99–1.07)</td>
</tr>
<tr>
<td></td>
<td>E, H (761)</td>
<td>190 (4.4)</td>
<td>1.04 (0.98–1.11)</td>
<td>1.08 (1.02–1.13)</td>
</tr>
<tr>
<td></td>
<td>I (603)</td>
<td>171 (3.8)</td>
<td>1.34 (1.26–1.42)</td>
<td>1.29 (1.21–1.36)</td>
</tr>
<tr>
<td></td>
<td>F, G (2016)</td>
<td>177 (2.4)</td>
<td>1.20 (1.15–1.26)</td>
<td>1.17 (1.12–1.21)</td>
</tr>
<tr>
<td>Multimorbidity count</td>
<td>1 (3052)</td>
<td>192 (2.2)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>2 (2210)</td>
<td>183 (2.4)</td>
<td>1.24 (1.20–1.29)</td>
<td>1.24 (1.20–1.28)</td>
</tr>
<tr>
<td></td>
<td>3 (1223)</td>
<td>166 (2.9)</td>
<td>1.58 (1.52–1.65)</td>
<td>1.58 (1.52–1.65)</td>
</tr>
<tr>
<td></td>
<td>4 or more (542)</td>
<td>137 (3.7)</td>
<td>1.97 (1.86–2.08)</td>
<td>1.91 (1.80–2.03)</td>
</tr>
</tbody>
</table>

*Adjusted for other co-variates.

bMosaic group ordered with category A, B, C, K most affluent; total number of defined intervals = 17 486.

rate of two unplanned hospital admissions were significant for the age groups 70–79 years (RR 1.42 (95% CI: 1.21–1.68)), 80–89 years (2.55 (2.04–3.18)) and 90 years and over (2.54 (2.04–3.18)) compared to the reference youngest age group (Table 3). There were no significant differences for gender. All five study-defined Mosaic groups were significantly associated with higher rate of two unplanned hospital admissions compared to the reference group. The associations between Mosaic Groups I (‘Twilight subsistence’ or F and G (‘Welfare borderline’ and ‘Municipal dependency’) and rate of two unplanned hospital admissions compared to the reference category were, respectively, RR 1.73 (95% CI: 1.52–1.98) and 1.56 (1.39–1.75). All multimorbidity groups compared to the single morbidity group were significantly associated with shorter time intervals between two unplanned admissions. The adjusted estimates of associations were: two multimorbidity counts (1.37, 1.25–1.49), three counts (1.89, 1.71–2.08) and four counts or more (RR 2.88 (2.55–3.26)).

The adjusted associations between age and rate of an admission from planned to unplanned admissions were significant for the age Groups 60–69 years (RR 1.17 (1.04–1.32)), 70–79 years (1.46, 1.30–1.64) and 80–89 years (1.50, 1.33–1.71) (Table 4). Women were significantly more likely to have a longer time interval between a planned and an unplanned admission than men (0.92, 0.86–0.97). Of the Mosaic groups, the only significant associations were for the ‘most’ deprived Mosaic Groups I (1.22, 1.08–1.36) and F and G (1.20, 1.10–1.31) with a higher rate from a planned to an unplanned admission compared to the reference category. All multimorbidity groups compared to the single morbidity group were significantly associated with shorter time intervals. The adjusted estimates of associations were: two multimorbidity counts (1.32, 1.23–1.42), three counts (1.83, 1.68–1.99) and counts four or more (RR 2.34 (2.10–2.60)). After adjustment for any number of planned admissions the strengths of these associations diminished but remained statistically significant, with exception of Mosaic Group J (Supplementary data Table S1).

Discussion

Main findings of this study

This large population-based study over the two and half year time-period showed that older age, deprived Mosaic status and higher multimorbidity were associated with a lower proportion of planned admissions and higher proportion of planned and unplanned hospital admissions. ‘Welfare borderline’ and ‘Twilight subsistence’ group had the highest proportion of both planned and unplanned hospital admissions.
The LTC population type showed different hospital admission types, with CHD populations showing more planned hospital admission whereas CHF and COPD populations experiencing more unplanned hospital admissions.

When the time interval between two planned admissions was measured, the range was from 5 months for the oldest age group to 7 months for the youngest age group. The average time interval was 6 months when stratified by Mosaic groups. The time interval ranged from 4 months for the multimorbid group with a count of four or more, to 7 months for the youngest age group. The average time interval for women and men was similar. Older age and specific Mosaic groups were significantly associated with an increased rate of two unplanned hospital admissions. The average time interval between unplanned admissions was 3 months, with around 15 days difference between youngest and oldest age group, around 1 week between different Mosaic groups, but almost 2 weeks between the highest and lowest multimorbidity count groups. Men also had a time interval 2 weeks shorter than women.

**What is already known on this topic**

Older age, deprivation and LTCs including ambulatory care sensitive conditions and healthcare indicators such as different types or frequency of contact have been shown to increase the risk of unplanned admission. These indicators are being combined as risk stratification scores to identify populations at risk. However, the impact of these approaches is modest and critical gaps in better identification and tailoring interventions remains to be established. These novel segmentation measures provide the potential routes to both identification and implementation of tailored interventions through profiles of a person's 'consumer behaviour'.

**What this study adds**

The healthcare implications of the findings are 3-fold. First, the results highlight the potential of consumer segmentation to identify patients at higher risk of a subsequent hospital admission, especially unplanned admissions, and adjusting for other factors. Whilst the current focus on risk stratification methods...
which incorporate social, clinical and healthcare factors\textsuperscript{8,10} is likely to remain important, the addition of segmentation measure offers the potential interventions through targeting of behaviours and ‘consuming’ lifestyle.\textsuperscript{22–24} Such interventions have been used in USA approaches to improve exercise activity and reduce smoking levels.\textsuperscript{25} Second, linking time intervals between planned and unplanned admission status offers an alternative to the focus on 30-day re-admission. Whilst the 30-day interval offers a convenient target from a hospital perspective, our method provides the longer term perspective on linked hospital admissions. Hospital engagement, especially unplanned activity, requires pro-active longer term engagement and co-ordination of the different pathways (community, interface and hospital) rather than short-term intensive interventions, which have little impact on the rise in admissions.\textsuperscript{20,27} Third, our study shows that higher multimorbidity was associated with shorter time intervals between admissions, less planned activity, but more unplanned admissions. Combined with segmentation, the type and nature of multimorbidity may provide additional approaches for clinically specific interventions.\textsuperscript{28,29}

**Limitations of this study**

The strength of the study is in linking the richness of socio-demographic profiles to LTCs derived from Quality Outcomes Framework registers, to hospital admissions data, for a large regional population. The socio-demographic profiles were based on an internationally used classification, the recording of LTCs in primary care is almost fully recorded, and since hospitals are paid by episodes, the simple descriptors of ‘planned’ and ‘unplanned’ is likely to be accurate. We had to group individual Mosaic segments into groups due to sample size considerations and ranked by deprivation; however, the study showcases the usefulness of segmentation for translating into individual segments for fuller consumer profiles. Additionally, our analyses did not incorporate general practice-level measures such as access and continuity of care, which may also explain variations in admissions.\textsuperscript{30} The limitation of interpretation in time intervals is the precise nature of planned admissions and how or whether it links to subsequent type of unplanned admissions. However, the current analyses show the potential utility of linking such information. We employed a relatively simple approach in this study, which sampled defined time windows in each patient as a basis of outcome measurement and further work needs to address the fact patients may have multiple planned and unplanned admissions. Finally, such linkage approaches in clinical practice are becoming routine, so that it will be feasible to develop better interventions to reduce unplanned hospital admission or re-admission.\textsuperscript{31,32}

Conclusions

Our study shows that deprived segmentation profiles were associated with shorter time interval between two consecutive unplanned hospital admissions and also between planned to unplanned hospital admissions compared to the affluent Mosaic groups. Older age, specific LTC multimorbidity also showed similar outcomes in terms of shorter time intervals. The potential of this work is in terms of developing innovative public health approaches to admission prevention, shifting the target from 30-day re-admission to time intervals in long-term care, and developing interventions at the point of planned hospital admission.

Supplementary data

Supplementary data are available at Journal of Public Health online.

Acknowledgements

The authors would like to thank Dr Mehluli Ndlovu for discussions on multiple failure time models.

References


