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Using social groups to locate areas with high utilization of critical care

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Abstract

Admissions over a three-year period to the general surgical and medical critical care unit at Kings College University Hospital were allocated to the output area of residence for each patient. Each output area contains around 300 persons of roughly similar social and demographic characteristics. Output area social grouping (Output Area Classification) and deprivation (Index of Multiple Deprivation) are shown to effect critical care admission rates. The admission rate doubles between the least and most deprived areas (excluding the effect of social group), however there is in excess of a 10-fold variation between the various deprivation-banded OAC social groups. Particular social groups also show differing proportions of patients admitted to the CCU for different conditions such as sepsis or drug overdose. Having identified small areas with high risk of critical care admission should enable Primary Care Organisations to target admission avoidance and/or appropriate end of life care.

Key Words

Output area classification (OAC), deprivation, critical care, admission rates, end-of-life care, admission avoidance

Abbreviations

CCG	Clinical Commissioning Group
CCU	Critical Care Unit
IMD	Index of Multiple Deprivation
OA	Output Area
OAC	Output Area Classification
LSOA	Lower Super Output Area
LOAC	London Output Area Classification

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Introduction

At 4.7-times the daily cost of a general ward, admission into critical care represents a very high-cost aspect of acute services (Welsh Government 2013). In an era of increasing focus on health care costs it is no longer acceptable to assume that critical care admissions are unavoidable.

In 2006 in the USA some 27% of Medicare costs were devoted to persons in the last year of life (Appleby 2006), and an astonishing 11% of total costs were for the last month of life. Approximately 40% of this was for ineffective stays in the critical care unit (Luce and Rubenfield 2001, Pastores et al 2012). The simplest method for estimating CCU costs remains the number of CCU available or occupied beds (Pastores et al 2012, Halpern and Pastores 2015). In the UK this number has been rising by around 2.8% per annum (NHS England 2016, Beeknoo and Jones 2016), which is around double the level expected from demographic trends, but equal to the level of growth in emergency admissions (Jones 2016). These trends are being matched by an increasing interest in risk stratification tools to predict those most at risk of death, either in the CCU or subsequent to discharge (Afessa and Keegan 2007, De Rooj et al 2005, Brestow and Badawi 2012).

The King's College University hospital (KCH) is a large specialist teaching hospital situated in the Denmark Hill area of London. The hospital contains around 1,000 beds and 65 critical care beds dedicated to surgical and medical admissions. There are another 40 other critical care beds dedicated to more specialised tertiary care. In early 2012 planning began for a dedicated and large critical care facility, designed to service parts of London and wider afield. While such expansion may be required to match increasing demand it is also necessary to identify possibilities for demand reduction. This paper will investigate three methods (deprivation, social group or mixed deprivation-social group) for segregating the population into risk categories to determine if particular small areas can be targeted for admission avoidance.

In the UK all census data is aggregated at the primary level of an Output Area (OA). In London each OA contains an average of 336 persons (interquartile range 276 to 385), and is chosen based on similarity of the social and demographic characteristics of the residents. These area groupings, called the Output Area Classification (OAC) are constructed in a similar manner to that used by commercial marketing companies (Neighbourhood Statistics 2016). Due to its unique social and ethnic composition London has its own London Output Area Classification (LOAC) which is used in this study (London Data Store 2016). The LOAC divides London into 48 sub-groups each with similar age structure, ethnic composition, occupation, housing, unemployment, etc. Each output area is then aggregated to a Lower Super Output Area (LSOA) containing around 1,500 persons, and then to higher geographies including electoral wards and local authorities.

Each LSOA has a measure of deprivation called the Index of Multiple Deprivation (IMD), which as the name suggests measures 'deprivation' across multiple domains such as income, crime, access to services, health, etc (GOV.UK 2016). The IMD is known to correlate well with all manner of health behaviours (smoking, etc), and consequent poor health outcomes such as emergency admissions, mental health and chronic poor health (Adams and White 2006, Bauld et al 2007, Heselhurst et al 2007, Kandt 2015). This paper will also present a simple method for allocating IMD values to the smaller OA groups using the LOAC, and relative population sizes. Patient admissions to the CCU are then allocated to an OA with its associated LOAC or IMD to determine the factors indicating high CCU utilisation. Population weighted OA Cartesian geographic centroids (Easting, Northing) were used to plot the location of admissions using simple Excel charts. In this context the OA code has the huge advantage of removing patient identifiable features such as postcode from any associated analysis.

This paper has been written in a style suited to a non-academic Clinical Commissioning Group (CCG) managerial audience, whose main interest is in locating small areas requiring intervention to reduce CCU admission. Tables containing admission rates are therefore ranked from highest to lowest rate. Additional analysis is available in the Appendix at the end of the study.

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Methods

Data Sources

All data sources are given in the appendix at the end of the document.

Estimating IMD for each OA

As mentioned in the Introduction, the IMD is measured at LSOA level. In London each LSOA comprises a median number of 5 OA (range 2 to 12). Given that the wealthy and poor can live within close proximity the LSOA-based IMD is insufficiently accurate for precise identification of deprivation in small social groups seen at OA level.

The IMD for each OA in London was estimated from published LSOA-based IMD data in the following way. First, the LSOA IMD was averaged across all LOAC sub-groups, and this data is presented in Table A1 in the Appendix. This enables all LOAC sub-groups to be ranked by relative IMD. For example, all B2b sub-groups have an average LSOA-based IMD of 43 (being the most deprived sub-group), while all H1c sub-groups have an average IMD of 7 (least deprived).

However, not all similar sub-groups experience the same level of deprivation across the whole of London. Adjusted values of IMD for each OA were then further refined as follows. All OA were grouped according to their respective LSOA. The LSOA value of IMD was then modified as the population weighted average across all OA's using the LOAC sub-group IMD averages calculated above. For example, say a LSOA has an IMD value of 10, but has two LOAC subgroups with averaged IMD scores of 9 (population 1,200) and 15 (population 900). Hence the adjusted IMD scores will be for LOA1 = [(10 x 1,200 + 10 x 900)/(9 x 1,200 + 15 x 900)] x 9, and for LOA2 = [10 x (1,200 + 900)/(9 x 1,200 + 15 x 900)] x 15. This process adjusts the LOAC sub-groups to their respective local IMD value. The range in adjusted values for each LOAC sub-group is given in Table A1 and Figure A1 in the supplementary material. Hence from Table A1 we see that the range in IMD across all B2b sub-groups is 23 to 71 while the range across all H1c sub-groups is 1 to 15, etc.

Estimating travel distance

Approximate travel distances between OAs and the location of various critical care units was calculated as follows. Population weighted centroids (see Appendix) give the Cartesian distance north (northings) and east (eastings) from the UK focal point in meters. The easting and northing for every London critical care unit was obtained from the postcode of the hospital, with postcode converted to easting and northing using the online tool, nearby.org.uk (http://www.nearby.org.uk/conversions.cgi). Since ambulances cannot travel in a direct straight line, the road distance was estimated as the sum of the two sides of the triangle rather than the hypotenuse (the straight line distance), i.e. approximate travel distance = absolute value of (Easting 1 – Easting 2) + absolute value of (Northing 1 – Northing 2). Value in meters divided by 1,000 to give kilometres (km).

Each OA was then assigned to its nearest hospital using the travel distance. OA populations can then be summed to give the core population surrounding each hospital, and the incremental population available to that hospital if ambulances are prepared to travel slightly further than to the nearest alternative hospital.

Estimating the admission rate

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The issue of small numbers has been addressed by using admission data over a three-year period between April 2013 and May 2016. All admission rates are for this time period, i.e. divide by three to get annual rates.

As will be demonstrated in the results section there are complex spatial/social flows to the KCH. In order to estimate the unique admission rate for each social group a pragmatic approach was adopted. Hence OAs included in the analysis of admission rate for each LOAC group were those where the KCH was the closest hospital or where the ratio of travel distance between the KCH and another hospital was less than 1.1-times that to the KCH.

On a few occasions there were no admissions per social group. An admission count of 0.5 was imputed to these groups to calculate a non-zero admission rate.

Standard Deviation (Poisson)

The standard deviation associated with the admission rate can be approximated using Poisson statistics, where, by definition, one standard deviation is equal to the square root of the average divided by the average. Hence an estimate of the standard deviation is the square root of the number of admissions divided by the number of admissions. The 95% confidence interval (CI) can likewise be approximated as twice the value of the standard deviation.

In this study the expected average admissions for each area is not known, however, the actual admissions are known. The standard deviation is therefore estimated by taking the square root of the actual admissions. This approximation works well because the square root minimises any uncertainty arising from the difference between actual and the (unknown) average.

Results

Patient flows to KCH

The KCH hospital group receives both tertiary and general patients from a wide range of locations, including emergency care for persons working in or visiting London for tourism, work or social reasons (see Figure A1). Figure 1 shows the distribution of OAs with shortest travel distance to KCH and surrounding London hospitals. The grid-lines in Figure 1 are 1 km apart. The gaps in Figure 1 are greenspace or large non-residential commercial areas. Both Figures illustrate the utility of the spatial co-ordinates associated with each OA (easting, northing) and ease of presentation in Excel (without the need for expensive geospatial software).

Note that eastings and northings, which are geographic Cartesian coordinates, are measured from a reference point off the coast of Cornwall. Some 335,000 persons live in the core area where KCH is the hospital with shortest travel distance, while an extra 85,000 persons live in the area where travel to KCH would add another 20% to the travel distance (a maximum of 1 km of extra travel distance) from the home address. Also visible in Table 1 is the highly non-symmetric nature of the spatial distribution of those living at closest travel distance to KCH, and the fact that the KCH competes for patients against seven other London hospitals.

Table A2 documents the proportion of patients attending from various Clinical Commissioning Groups (CCGs), with highly variable patient flows depending on the degree of general versus specialist component. As can be seen the surgical/medical CCU is over-represented for patients from Kent due to the KCH being the nearest tertiary hospital for these patients, and due to large daily flows into London for the purpose of work, largely enabled by a high-speed rail network. This over-representation from Kent is also clearly seen in Figure A1.

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Table 1: Estimated admission rates per 1,000 persons (4 years) for various social groups living near to the KCH site

Group Name	Sub Group	Average IMD	Raw Rate	Distance Adjusted Rate	± 1 STDEV‡
Bangladeshi enclaves	B2c	53	20.2	25.2	11.3
Elderly Asians	C4b	14	7.0	17.8	10.3
Public sector & service employees	G2a	41	8.8	17.0	6.0
Struggling suburbs	A1b	37	8.7	16.6	1.8
Affluent suburbs	F2b	12	9.1	15.7	2.5
Public sector & service employees	G2b	43	8.3	13.7	1.0
Asian owner occupiers	C1a	16	5.7	12.7	9.0
City & student fringe	E1a	29	6.8	11.4	0.4
Affordable transitions	G1a	37	7.5	11.2	6.5
Disadvantaged diaspora	B1b	42	7.2	10.9	0.6
Struggling suburbs	A1a	23	4.9	10.5	2.5
Suburban localities	A2b	17	5.9	10.1	5.0
Detached retirement	H1b	10	6.1	9.7	3.2
City & student fringe	E1b	23	5.1	9.6	0.8
Disadvantaged diaspora	B1a	40	5.3	9.5	2.3
Affluent suburbs	F2a	13	4.4	8.5	1.6
City enclaves	F1a	9	5.4	8.4	1.0
Disadvantaged diaspora	B1c	41	5.1	7.4	0.4
Students & minority mix	B3a	36	4.9	7.2	0.6
Suburban localities	A2c	28	3.7	6.9	6.9
Suburban localities	A2a	24	2.5	6.8	6.8
Graduation occupation	E2a	21	4.3	6.5	0.4
Students & minority mix	B3b	38	4.4	6.3	0.9
Graduation occupation	E2b	30	3.9	5.9	0.6
Educational advantage	D1c	25	3.6	5.3	1.1
City enclaves	F1b	10	2.9	4.7	0.8
City central	D2a	14	2.7	3.8	2.7
Educational advantage	D1b	18	2.0	3.0	4.2
Affordable transitions	G1b	27	1.6	2.9	1.3
Not quite Home Counties	H2a	9	1.4	2.7	3.8
Educational advantage	D1a	21	1.2	1.8	1.8
City central	D2b	17	0.8	1.4	0.5
City central	D2c	17	0.7	0.9	1.3

‡ The aim of this study has been to demonstrate that high admission rate locations can be determined using LOAC. Given the limitations of the data it is not amenable to the calculation of precise confidence intervals. The standard deviation is given as an indication of variation associated with the number of admissions in each LOAC. Additional uncertainty will arise due to the adjustment for distance.

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Table 2: Top 20 reasons for critical care and proportion of admissions for the 10 largest social groups

CCU Reason	Social group (LOAC)										
	All LOAC	E1a	B1b	B1c	E2a	A1b	G2b	H2b	E1b	A1a	B3a
Population		13.0%	4.8%	5.9%	5.0%	6.0%	4.8%	5.9%	4.0%	4.5%	3.2%
Sepsis	11.6%	14.1%	13.8%	13.8%	**15.9%**	13.2%	14.5%	6.8%	10.9%	9.3%	12.9%
Post cardiac arrest	7.0%	6.4%	8.6%	7.0%	7.3%	6.0%	5.5%	**12.5%**	4.2%	7.8%	5.0%
Neurologic	6.9%	6.6%	6.5%	7.0%	7.0%	**11.4%**	8.1%	5.3%	6.3%	6.9%	7.5%
Metabolic/Renal	6.1%	6.6%	**7.6%**	6.0%	5.8%	5.0%	7.1%	7.2%	4.6%	4.4%	6.0%
Gastrointestinal	6.0%	4.2%	6.0%	4.3%	3.7%	6.9%	5.5%	4.5%	**8.8%**	**8.8%**	6.0%
PO Gastrointestinal	5.7%	4.7%	3.4%	6.8%	4.0%	2.8%	2.3%	3.0%	5.9%	**8.8%**	5.5%
Neurological CH/SDH/SAH	4.9%	3.3%	1.6%	3.8%	5.2%	**6.3%**	5.5%	**6.4%**	4.2%	4.9%	5.0%
Respiratory failure Infection	4.5%	6.7%	4.9%	4.9%	**8.2%**	2.5%	5.5%	2.3%	5.9%	1.5%	4.0%
Cardiovascular	3.9%	3.2%	5.2%	5.1%	4.3%	2.8%	2.9%	5.3%	2.9%	4.4%	**7.0%**
PO Neurologic	3.6%	2.4%	3.4%	1.9%	2.7%	2.8%	2.6%	**4.9%**	**5.0%**	3.4%	2.5%
Respiratory	3.5%	3.4%	4.2%	2.7%	2.4%	**5.4%**	2.9%	0.4%	4.2%	3.9%	2.5%
COPD	3.2%	5.5%	4.2%	5.1%	2.7%	3.5%	**7.4%**	0.0%	3.4%	2.0%	2.5%
PO GI Perforation/Obstruction	2.9%	**3.7%**	2.6%	2.7%	**3.7%**	1.6%	2.6%	1.9%	**3.8%**	**3.9%**	3.5%
PO GI Surgery Neoplasm	2.8%	3.1%	2.1%	1.6%	2.1%	2.5%	2.6%	**5.7%**	1.7%	1.5%	2.0%
PO Craniotomy ICH/SDH/SAH	2.8%	2.4%	1.0%	3.3%	1.2%	2.2%	1.3%	5.7%	2.5%	4.9%	**6.0%**
PO Cardiovascular	2.7%	2.6%	2.6%	1.1%	0.6%	1.9%	3.9%	**5.3%**	1.7%	2.0%	0.5%
Head Trauma	2.4%	1.9%	1.8%	3.3%	2.7%	**3.5%**	1.6%	2.3%	2.5%	2.9%	1.5%
Gastrointestinal bleeding	2.4%	2.8%	2.1%	2.7%	**3.0%**	1.3%	3.5%	2.6%	2.5%	1.5%	1.5%
Drug Overdose	2.4%	2.6%	3.1%	3.3%	**4.3%**	1.3%	1.9%	0.0%	2.9%	0.5%	**4.5%**
PO Metabolic/Renal	1.5%	1.7%	1.8%	2.2%	1.5%	**3.2%**	1.0%	3.0%	0.8%	2.5%	0.5%

Abbreviations: PO (post-operative care), COPD (chronic obstructive pulmonary disease), GI (gastrointestinal tract)

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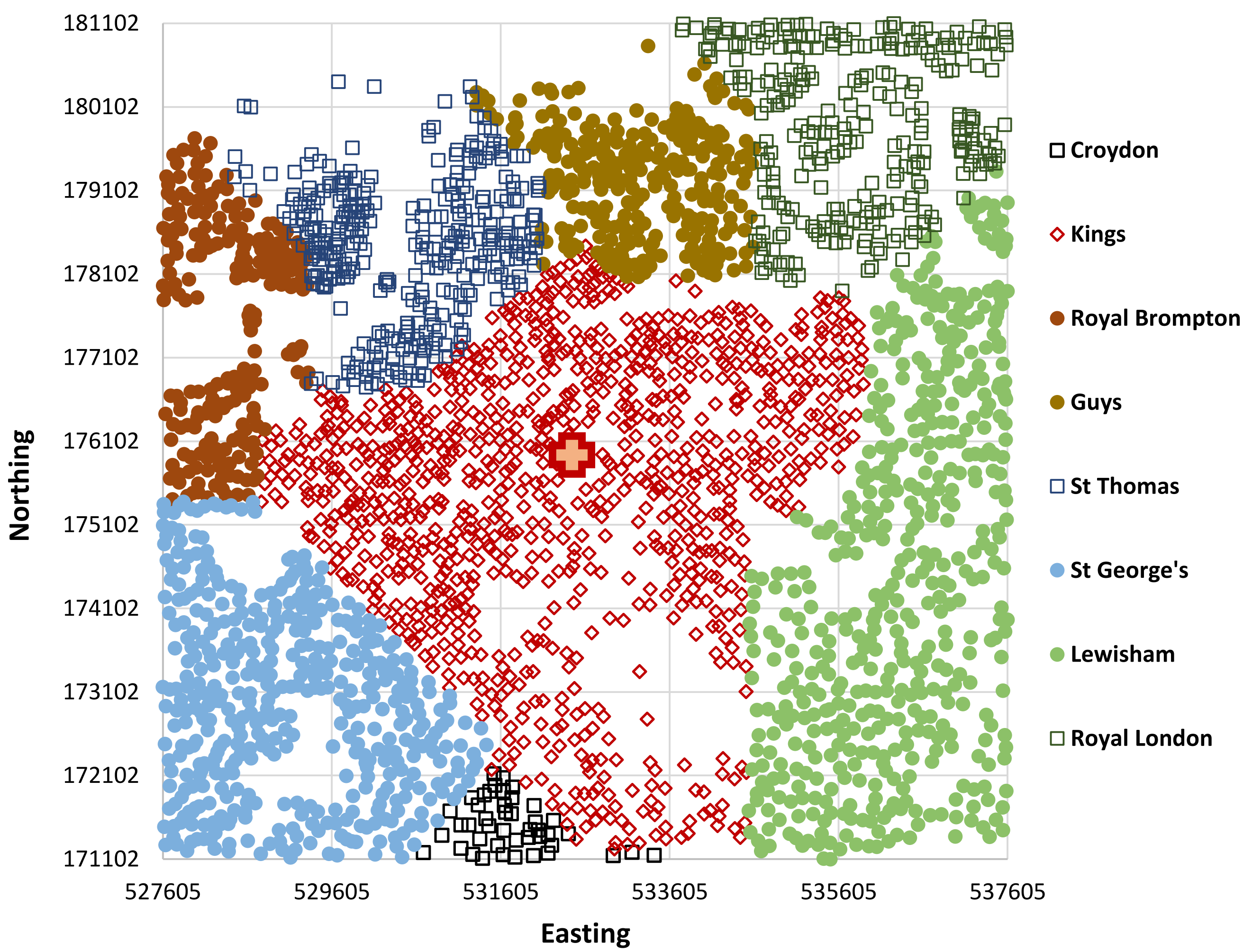
Travel distance and the admission rate

Figure 2 illustrates the role of travel distance (in 0.1 km increments) on CCU admission rate with a typical decay as distance increases. Data beyond 11 km has been smoothed by a running average across 10 increments of 0.1 km. The issue of travel distance is somewhat complicated by the fact that most hospitals are also situated near to areas of higher deprivation and/or disadvantaged social groups who are the most likely to require emergency admission and CCU care. In addition, Figure 2 is not a strict population-based view but only captures persons admitted to the KCH (see discussion). As can be seen the admission rate declines in an approximate logarithmic manner within five km of the hospital. Beyond this point the relationship with distance is more complex since these persons are now closer to multiple other hospitals. This was illustrated in Figure 1 where KCH competes at the boundary of seven other London hospitals, and with ambulance flows modifiable depending on the relative busyness of each hospital.

Figure 1: Output areas (OAs) within the closest travel distance to KCH and a variety of nearby London hospitals



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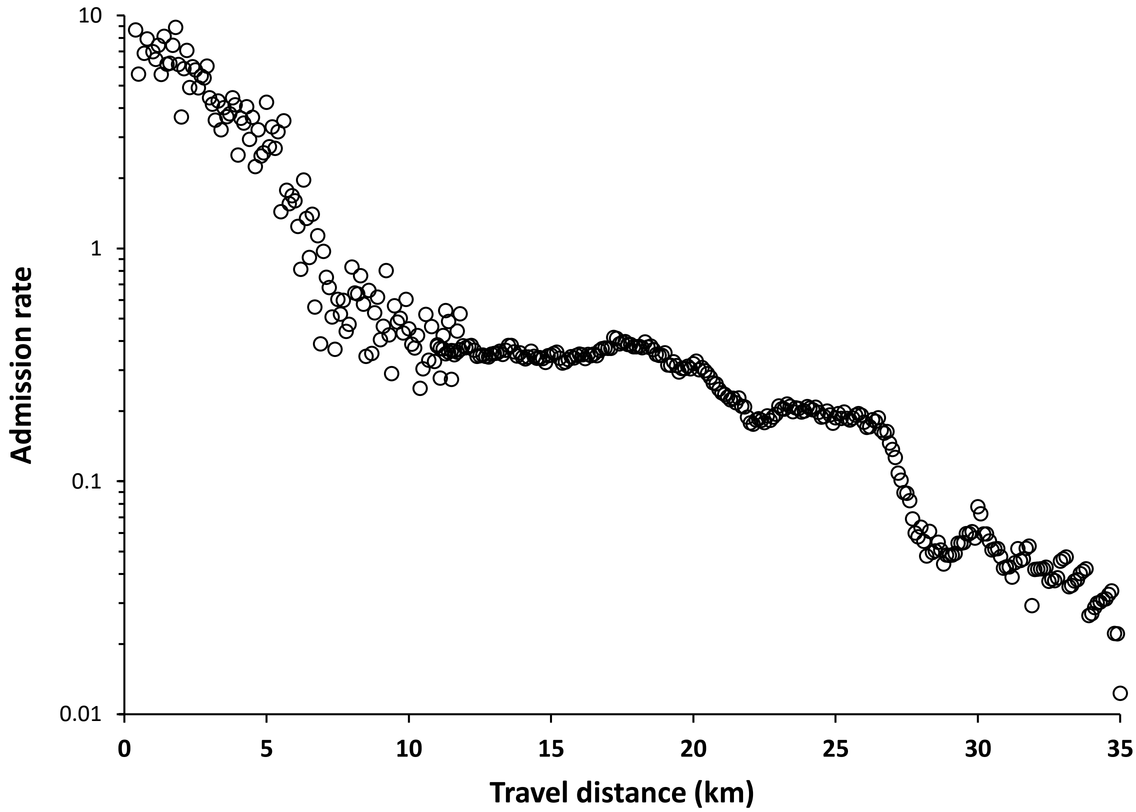
Characteristics of residents living near to KCH

Table A3 lists the LOAC for all OAs where the KCH is the hospital with the closest travel distance, i.e. the core area shown in Figure 1. Also given is the equivalent for the whole of London, along with the average OA IMD and the proportion of the population accounted for by each LOAC sub-group. Top half of the table are demographic groups which are higher than the London average. Across London the LOAC sub-group G1b (Multiethnic suburbs: Affordable transitions) is the most abundant with 5.2% of the population, while C3e (East end Asians) is least abundant with only 0.4% of the populations. The least deprived are from sub-groups H1a-c (Ageing city fringe) - see Table A3. As can be seen in Table A3 there are disproportionately high numbers of students and recent graduates (36% versus 8%) along with a high proportion of disadvantaged communities (24% versus 4%). As suggested above, the most deprived OA (IMD = 53) is indeed closest to the hospital, and the average IMD value decreases by around 4 units for every kilometre away from the hospital (data not shown). The most disadvantaged 45% of the nearby population (IMD > 30) all live at an average of only 3 km from the hospital. For comparison, the population weighted national average for IMD is around 21 units, while the maximum IMD in London is 80 units for one OA in Hackney, and the minimum is 1.4 for one OA in Havering.

Figure 2: Role of travel distance to KCH and the CCU admission rate per 1,000 population (over 3-years)



Role of deprivation

Using the population nearest to the hospital (plus a 10% higher travel distance) as outlined in the methods section, it is possible to estimate the independent effect of deprivation and this is shown in Figure 3. Due to the small numbers of admissions from each OA the data points in Figure 3 are a running average of 10 OAs with an approximate total of 30 admissions. Each data point has a standard deviation

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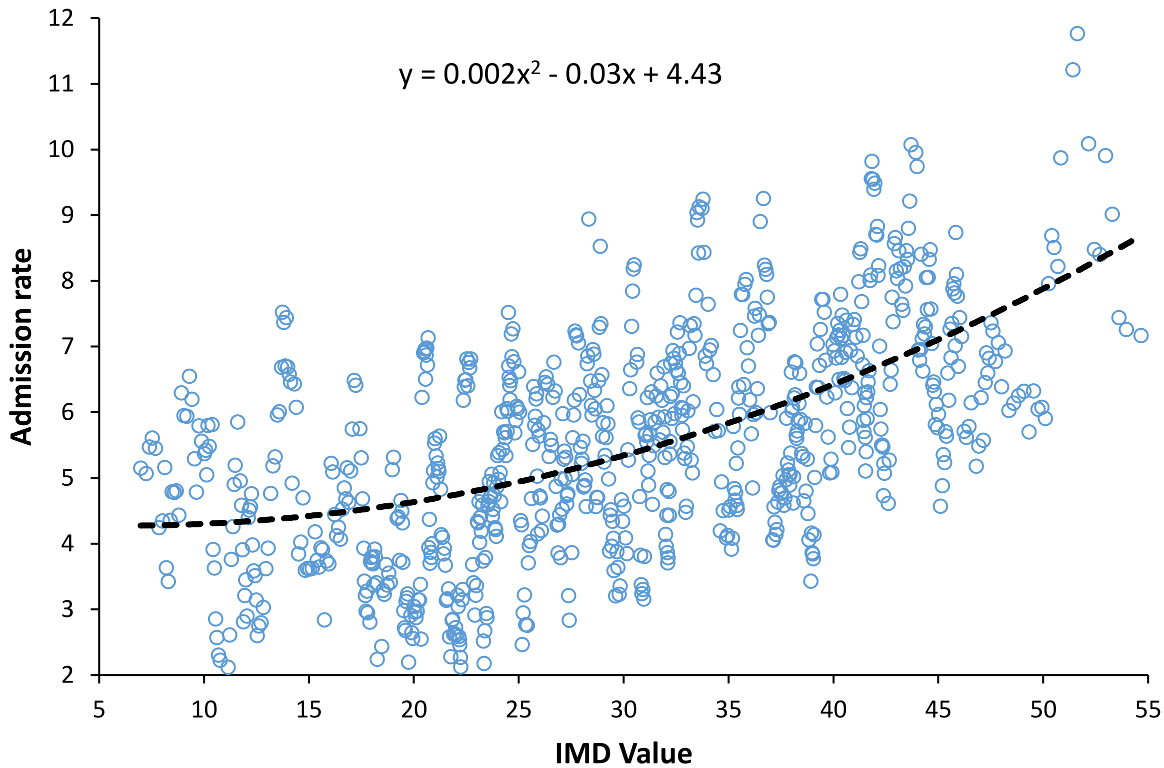
(Poisson) associated with the admission rate of an average of ± 1 (or 95% confidence interval ± 2). As can be seen the admission rate increases with IMD, especially above IMD around 20 units (the national average), and is almost double for IMD values around 45 units. A deprivation score above 30 to 35 would therefore be a variable of interest for targeting small areas in need of CCU admission avoidance strategies. In this respect some 20% of the population of London live in OAs with an IMD <11 units, while the 20% and 10% most deprived live in OA with IMD >36 and >42 units respectively. However, by ignoring the effect of social group this method risks underestimating the role of deprivation since admission rates are averaged across a variety of social groups. These issues are explored in the following sections.

Figure 3: Role of deprivation on the CCU admission rate per 1,000 head (over 3-years)



Role of social group

In order to incorporate a sufficient variety of social groups the area analysed was extended to a plus 30% higher travel distance (equivalent to a maximum of 1.8 km extra travel distance). The role of distance was estimated by calculating admission rates at 0.1 km increments and applying a second order polynomial curve fit (Microsoft Excel) for OA up to 8.5 km from the KCH site. Hence, admission rate = 9.09 – 1.267 x distance + 0.0595 x distance^2 (R^2 = 0.4176).

All admission rates were adjusted to the equivalent at 0.3 km distance from KCH (the distance of the nearest OA to the KCH). An estimate of the uncertainty in the admission rate was derived from Poisson statistics and is given as ± 1 standard deviation (STDEV). Both raw and distance-adjusted rates per 1,000 population are given in Table 1. From Table 1 it can be seen that CCU admission rates vary from around

2 per 1000 to 14 per 1000 (all at a hypothetical 0.3 km from the hospital, and after allowing for small number uncertainty).

Social group & deprivation

To investigate potential interactions between social group and deprivation, the OA IMD was divided into five groups with IMD values 0-15, 15-25, 25-35, 35-40 and 40+ respectively. Data is given in Table A4 in the Appendix where it can be seen that the highest rates are predominantly in the IMD 40+ group, however, after distance-adjustment the very low deprivation group C4b has a high admission rate (wealthy but elderly). Data in Table A4 has been ranked in order of decreasing distance-adjusted admission rate to highlight the social groups which would be of greatest interest in terms of admission avoidance initiatives. Rates range from 2 per 1000 to 20 per 1,000. This approach appears to have high utility in identifying precise small areas in need of preventative intervention. Depending on the available CCG resources, locations with a distance adjusted admission rate above 11 per 1,000 could be subject to study, although a CCG resident-based study including CCU admissions at all hospitals would avoid the need for distance adjustment.

Reasons for critical care

There are numerous reasons for an admission into the critical care unit, and hence Table 2 investigates the top 20 reasons for admission among the 10 largest social groups. The surgical & medical CCU also admits post-operative (PO) elective and emergency surgical patients. These patients are identified by PO prior to the reason for admission. The remainder are all medical emergency admissions.

The first row in Table 2 gives the relative size of each social group in terms of population. Hence all output areas comprising admissions from E1a (City & student fringe) has 13% of the total London population represented in this study – skewed to locations closest to KCH. As size reduces the numbers will become more volatile, as per the role of Poisson variation.

The second column in Table 2 gives the proportion of CCU admissions for each of the reasons for admission. Sepsis accounts for 11.6% of all CCU admissions across all social groups. The proportions admitted to the KCH surgical and medical CCU will be modified by the fact that this hospital also has a number of more specialised CCU beds.

The remaining rows and columns are devoted to proportions admitted in each social group which are to be compared against the average over all social groups (second column). Highest proportion is in red bold (across each reason). Hence social group E2a has the highest proportion of admissions due to sepsis (15.9%) but has compensating low proportions in five other reasons. Lowest proportion for sepsis is 6.8% in group H2b but there are compensating higher proportions in cardiovascular and cardiac arrest, neoplasms, and neurologic. Social groups A1a, E1a, E1b and E2a all have the highest proportion of post-operative procedures for gastro-intestinal perforation or obstruction. Drug overdose is highest in B3a and E2a which are both student/graduate social groups

Discussion

The aim of this study was to locate small area geographies where the CCU rate of admission is high, i.e. top third of Table A4. To achieve this purpose no age-standardisation is required, i.e. an old but affluent population is likely to have an equally high rate of admission to a younger Asian population (with known disposition to heart disease). From an admission avoidance perspective both are equally important.

In this respect, the social groups in Table 1 with high rates of CCU admission have either an older population or are disadvantaged. However, the contribution of distance in this study is somewhat enigmatic (Table 1 raw versus distance-adjusted rates). While distance (in general) is known to play a role in access to health services (Jordan et al 2004), Figure 1 must be understood in the context that hospitals in London are reasonably close. Residents living closest to KCH can work in other parts of London, and be admitted elsewhere (these admissions are not included in this study). Those from other parts of London can likewise be admitted to KCH, due to work or leisure activities – as in Figure A1. Hence, the rates of admission in Figure 3 are not genuine population based rates but simply raw rates of admission to the KCH site.

The methodology is relatively easy to apply and the base OA data is readily available. Tables to convert postcode to OA code are likewise available from NHS England (see Appendix). Hence this paper has demonstrated proof of concept, but suffers from the limitation of only having data for admission to a single hospital. Ideally, this study should be repeated for residents across the whole of London, and should also cover admission into any CCU (for those away from home due to work or leisure activities). This approach would generate genuine population-based admission rates, and would benefit from far higher numbers of CCU admissions (hence lower uncertainty in the calculated rates). This approach would also avoid the need for the adjustment for distance applied in this study.

It is clear that higher deprivation (IMD) is associated with higher rates of CCU admission, as are certain defined social groups. From Figure 4 it is can be appreciated that the relationship with IMD is non-linear, seemingly sigmoidal reaching a plateau somewhere beyond an IMD value of 55 units (Jones 2006). A larger study across the whole of London would clarify this relationship. An additional study has investigated the role of social group in A&E attendance and inpatient admission via A&E (Beeknoo and Jones 2016b), with similar conclusions regarding the central role of social group as the driving force behind attendances and admissions.

Further sub-division of social groups into broad IMD bands (Table A2) was shown to sharpen the specificity of the method to identifying precise OA to target for admission avoidance strategies.

The fact that the two highest groups in Table 3 are both Asian is no surprise given their known disposition to diabetes and heart disease (Moody et al 2016, Enas et al 2007), and consequent diabetes-associated end stage renal failure (Burden et al 1992).

Potential Savings

It is always tempting to calculate potential savings, however, studies in the US indicate that the real savings may lie in the reduction of futile CCU admissions, i.e. where the person either dies in the CCU, or after CCU discharge to another ward or shortly after hospital discharge (Luce and Rubenfield 2001). This information was not available in this study but warrants further investigation as part of wider issues regarding futile acute intervention in the last weeks of life (Beeknoo and Jones 2016c).

Future Direction

This study has been limited to CCU admissions at a single hospital and the need to adjust for distance. A population-based study is now required covering a wider number of London local authority areas containing a higher proportion of social groups which are under-represented in this study. Clinical Commissioning Groups (CCGs) will then need to understand the epidemiological basis for the disparate rates of CCU admission and the necessary steps to address these problems. CCU admissions also need to be linked to time from death to determine if futile end-of-life intervention represents a major issue. Hopefully this approach will form part of the Sustainability and Transformation Plans (STPs) which CCGs are currently preparing.

Conclusions

The output area classification and associated measure of deprivation (IMD) provide a readily accessible way to segment the population into small areas (approximately 300 persons) with high risk of CCU admission. These small areas can then be targeted to reduce contributing health behaviours, or to ensure that appropriate primary care consultation and follow-up has been sought by the residents. The method is also more widely applicable to emergency admissions and A&E attendances where deprivation is also associated with higher utilization rates (Beeknoo and Jones 2016b, Jones 2006).

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Appendix

Data Sources

The London Output Area Classification was obtained from the Greater London Authority, London Datastore website (http://data.london.gov.uk/dataset/london-area-classification).

The 2011 Output Area (OA) population weighted centroids (Easting and Northing) were obtained from the Office for National Statistics (ONS) website (http://www.ons.gov.uk/ons/guide-method/geography/products/census/spatial/centroids/index.html).

The 2011 OA to lower super output area (LSOA) lookup was obtained from the ONS website, sub-section 'Lookups between 2011 Census output areas and other geographies' (http://www.ons.gov.uk/ons/guide-method/geography/products/census/lookup/2011/index.html)

The 2015 Index of Multiple Deprivation was obtained from the GOV.UK website (https://www.gov.uk/government/statistics/english-indices-of-deprivation-2015)

Mid-2013 population estimates for London OA's were obtained from the ONS website (http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-367629)

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Table A1: Index of multiple deprivation (IMD) derived from LSOA or population weighted OA average for LOAC sub-groups across London

LOAC sub-group	Average IMD		IMD Range (OA)		Proportion of Population
	LSOA	OA	Minimum	Maximum	
A1a	23.9	22.9	10.2	39.4	4.0%
A1b	34.8	38.3	20.8	64.4	3.8%
A2a	25.5	28.5	11.7	57.5	1.1%
A2b	17.1	16.1	6.3	31.7	2.1%
A2c	28.2	31.4	12.1	52.1	1.7%
B1a	38.8	44.1	26.0	69.0	1.7%
B1b	40.2	45.8	25.4	79.8	1.6%
B1c	40.7	45.2	22.6	69.0	2.0%
B2a	37.0	38.6	21.0	56.3	0.8%
B2b	42.8	47.4	22.8	71.0	1.0%
B2c	40.9	45.5	28.7	64.7	0.8%
B3a	33.4	35.2	13.3	55.9	1.9%
B3b	35.7	39.7	19.9	60.5	2.3%
C1a	20.3	18.2	7.5	31.8	2.8%
C1b	17.0	14.8	6.6	26.5	1.6%
C2a	25.1	25.3	13.0	42.8	1.7%
C2b	23.0	22.3	10.8	36.1	2.3%
C3a	28.9	28.9	10.7	43.4	0.5%
C3b	30.1	30.4	23.8	51.5	0.6%
C3c	26.5	26.3	14.5	38.5	0.5%
C3d	23.0	22.8	12.0	35.1	0.5%
C3e	19.6	17.8	11.6	26.4	0.4%
C4a	15.2	13.0	5.1	21.2	1.4%
C4b	16.3	14.4	4.5	25.5	1.7%
D1a	23.0	20.4	10.0	33.9	1.0%
D1b	22.7	20.6	9.1	38.4	0.6%
D1c	25.1	24.3	9.6	39.4	2.5%
D2a	15.5	12.8	6.0	21.2	0.8%
D2b	17.5	14.6	7.0	29.6	1.2%
D2c	16.0	11.8	5.4	21.9	0.6%
D2d	15.2	12.9	5.7	22.1	1.2%
E1a	28.4	28.6	12.2	56.5	4.1%
E1b	23.7	22.7	6.3	40.8	3.1%
E2a	21.4	19.9	8.5	33.6	3.2%
E2b	29.8	31.0	11.9	50.4	2.8%
F1a	10.7	7.8	2.9	16.7	2.4%
F1b	12.4	9.5	3.3	17.1	3.0%
F2a	13.2	10.8	3.1	29.7	3.7%
F2b	12.3	10.0	3.3	27.7	2.6%
G1a	31.3	31.8	11.5	47.7	2.9%
G1b	26.6	26.5	9.8	47.5	5.2%
G2a	34.4	38.1	19.4	61.3	4.2%
G2b	37.7	41.3	13.9	61.9	4.2%
H1a	9.2	7.0	2.5	18.2	1.8%
H1b	9.2	7.2	2.5	18.2	1.7%
H1c	6.8	4.8	1.4	15.2	1.9%
H2a	10.8	8.5	2.5	18.5	3.1%
H2b	11.2	9.5	2.3	21.9	3.3%

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Table A2: Proportion of patients arriving from the top 10 locations to the Kings College Hospitals group

Clinical Commissioning Group (CCG)	Out-patients	Emer-gency	Critical Care‡‡	Elective	Day-case	Non-Elective†	Regular Attender‡
Bromley	27%	35%	13%	25%	34%	30%	7%
Southwark	18%	19%	18%	10%	14%	20%	25%
Lambeth	16%	18%	16%	10%	13%	16%	29%
Lewisham	8%	6%	7%	6%	8%	7%	9%
Bexley	7%	5%	4%	7%	6%	4%	5%
Greenwich	5%	3%	4%	5%	4%	3%	5%
Croydon	4%	5%	5%	4%	4%	6%	4%
Dartford, Gravesham & Swanley	3%	1%	3%	3%	2%	1%	2%
West Kent/Kent††	3%	3%	12%	6%	3%	3%	2%
Wandsworth	1%	1%	1%	1%	1%	1%	1%
All others (including overseas)	9%	6%	13%	25%	11%	10%	14%

Footnote: Each CCG comprises one or more local authority areas, † Non-elective (transfers) patients are usually more complex tertiary cases transferred to KCH from a nearby general hospital for specialist surgery/treatment, which are then transferred back for subsequent recovery/rehabilitation. ‡ Regular attenders are patients with long-term care needs such as dialysis or chemotherapy, who have a regular series of attendances as part of their treatment. Proportions for this group are highly dependent on the needs of particular individuals. ‡‡ Critical care is for the KCH London site and is only for the surgical/medical CCU, †† Critical care figure is for whole of Kent.

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Table A3: Relative frequency of LOAC sub-groups in the core population nearest to KCH compared to that for the whole of London

Super Group	Group	Sub Group	Kings College		London	
			Average IMD	Proportion	Average IMD	Proportion
City Vibe	City & student fringe	E1a	29	20.0%	29	4.2%
City Vibe	Graduation occupation	E2a	21	16.1%	20	3.6%
High Density & High Rise	Disadvantaged diaspora	B1c	42	13.1%	45	2.1%
High Density & High Rise	Disadvantaged diaspora	B1b	43	10.6%	46	1.7%
High Density & High Rise	Students & minority mix	B3a	36	6.4%	35	1.8%
City Vibe	Graduation occupation	E2b	31	6.1%	31	3.0%
Multi-ethnic Suburbs	Public sector & service employees	G2b	43	4.3%	41	3.8%
City Vibe	City & student fringe	E1b	24	4.0%	23	3.3%
London Life-Cycle	City enclaves	F1a	9	3.5%	8	2.6%
High Density & High Rise	Students & minority mix	B3b	38	3.1%	40	2.7%
London Life-Cycle	City enclaves	F1b	11	2.8%	10	3.5%
Urban Elites	Educational advantage	D1c	26	1.7%	24	2.8%
Urban Elites	City central	D2b	19	1.7%	15	1.5%
Intermediate Lifestyles	Struggling suburbs	A1b	38	1.4%	38	3.8%
London Life-Cycle	Affluent suburbs	F2a	12	1.0%	11	3.9%
London Life-Cycle	Affluent suburbs	F2b	12	0.9%	10	2.9%
Intermediate Lifestyles	Struggling suburbs	A1a	22	0.5%	23	3.9%
High Density & High Rise	Disadvantaged diaspora	B1a	42	0.5%	44	1.8%
Ageing City Fringe	Detached retirement	H1b	10	0.4%	7	1.6%
Urban Elites	Educational advantage	D1a	22	0.3%	20	1.3%
Urban Elites	City central	D2a	14	0.3%	13	1.1%
Urban Elites	City central	D2c	17	0.3%	12	0.8%
Multi-ethnic Suburbs	Affordable transitions	G1b	31	0.3%	27	4.7%
Intermediate Lifestyles	Suburban localities	A2b	17	0.2%	16	2.1%
Intermediate Lifestyles	Suburban localities	A2a	29	0.1%	28	1.4%
High Density & High Rise Flats	Bangladeshi enclaves	B2c	53	0.1%	46	0.7%
Multi-ethnic Suburbs	Affordable transitions	G1a	37	0.1%	32	2.4%
Multi-ethnic Suburbs	Public sector & service employees	G2a	41	0.1%	38	4.0%

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Table A4: Deprivation-banded admission rates for LOAC groups within +30% travel distance to KCH

IMD Band	Sub Group	Average Distance	Distance Adjustment	Admissions	Population	Raw Rate	Distance-adjusted Rate	1 STDEV
40+	A1b	5.0	2.06	28	1841	15.2	31.3	2.9
40+	B2c	1.8	1.24	5	247	20.2	25.2	9.1
40+	G2a	4.0	1.74	7	576	12.2	21.1	4.6
35-40	E1b	2.5	1.38	3	227	13.2	18.3	7.6
1-15	C4b	6.4	2.55	3	430	7.0	17.8	4.0
25-35	A1b	4.5	1.89	22	2430	9.1	17.1	1.9
35-40	E1a	3.3	1.56	76	7029	10.8	16.9	1.2
1-15	F2b	3.9	1.72	36	3946	9.1	15.7	1.5
15-25	F2b	4.1	1.78	3	344	8.7	15.5	5.0
40+	G2b	3.6	1.63	128	13999	9.1	14.9	0.8
25-35	D2b	2.9	1.47	3	308	9.7	14.3	5.6
40+	E1a	3.8	1.70	43	5426	7.9	13.5	1.2
15-25	F1b	3.6	1.64	2	249	8.0	13.2	5.7
15-25	C1a	5.5	2.22	2	350	5.7	12.7	4.0
25-35	B1b	2.6	1.41	50	5729	8.7	12.3	1.2
40+	B1a	4.7	1.94	7	1121	6.2	12.1	2.4
1-15	E1a	0.7	1.06	4	354	11.3	12.0	5.6
35-40	A1b	4.4	1.85	35	5466	6.4	11.9	1.1
1-15	A2b	2.9	1.47	3	383	7.8	11.5	4.5
25-35	A2a	5.6	2.26	1	198	5.1	11.4	5.1
40+	B1b	3.1	1.53	240	32432	7.4	11.3	0.5
35-40	G1a	3.0	1.50	3	400	7.5	11.2	4.3
35-40	G2b	3.8	1.71	37	5652	6.5	11.2	1.1
25-35	E1a	3.6	1.64	388	57368	6.8	11.1	0.3
25-35	E1b	4.3	1.83	59	9775	6.0	11.0	0.8
15-25	A1a	5.2	2.11	13	2518	5.2	10.9	1.4
25-35	G2b	3.3	1.57	10	1449	6.9	10.9	2.2
40+ Total	All	3.1	1.51	718	101108	7.1	10.7	0.3
40+	B3a	2.4	1.36	48	6143	7.8	10.6	1.1
40+	B3b	3.1	1.51	20	2903	6.9	10.4	1.5
15-25	E1a	3.9	1.73	190	32343	5.9	10.2	0.4
1-15	H1b	3.4	1.58	9	1465	6.1	9.7	2.0
25-35	A1a	5.6	2.26	4	972	4.1	9.3	2.1
25-35 Total	All	3.4	1.60	711	125339	5.7	9.0	0.2
35-40 Total	All	3.2	1.55	375	64725	5.8	9.0	0.3
All	All	3.4	1.59	2571	462714	5.6	8.9	0.1
1-15	F2a	4.5	1.91	26	5603	4.6	8.8	0.9
15-25	E1b	4.6	1.92	88	19171	4.6	8.8	0.5
35-40	B1a	3.3	1.56	11	1993	5.5	8.6	1.7
1-15	E2a	3.5	1.61	13	2488	5.2	8.4	1.4
1-15	F1a	3.3	1.56	76	14131	5.4	8.4	0.6
15-25	A2a	8.0	3.15	0.5	196	2.6	8.0	3.6
35-40	B1c	3.0	1.51	103	20010	5.1	7.8	0.5
40+	B1c	2.7	1.43	188	35000	5.4	7.7	0.4
1-15 Total	All	3.6	1.65	207	45470	4.6	7.5	0.3
15-25 Total	All	3.7	1.66	560	126072	4.4	7.4	0.2
35-40	B3a	3.3	1.58	40	8646	4.6	7.3	0.7
35-40	B1b	2.9	1.47	31	6269	4.9	7.3	0.9
35-40	G2a	5.9	2.36	1	333	3.0	7.1	3.0
25-35	A2c	4.5	1.90	1	273	3.7	6.9	3.7

15-25	A2b	4.9	2.02	1	300	3.3	6.7	3.3
15-25	F2a	5.4	2.17	3	991	3.0	6.6	1.7
15-25	E2a	3.1	1.52	233	54742	4.3	6.5	0.3
25-35	D1c	2.7	1.42	16	3563	4.5	6.4	1.1
1-15	E2b	0.4	1.01	2	320	6.3	6.3	4.4
35-40	E2b	2.6	1.40	18	4077	4.4	6.2	1.0
25-35	E2b	3.0	1.49	63	15223	4.1	6.2	0.5
15-25	D2a	3.7	1.66	2	538	3.7	6.2	2.6
25-35	D1a	3.0	1.50	0.5	123	4.1	6.1	5.7
25-35	E2a	3.1	1.52	17	4286	4.0	6.0	1.0
25-35	B3a	2.8	1.44	52	13695	3.8	5.5	0.5
35-40	B3b	2.4	1.36	17	4623	3.7	5.0	0.9
15-25	E2b	3.8	1.69	10	3522	2.8	4.8	0.9
25-35	B1a	6.8	2.70	0.5	284	1.8	4.8	2.5
1-15	F1b	3.6	1.64	34	12231	2.8	4.5	0.5
25-35	B3b	2.8	1.45	9	2981	3.0	4.4	1.0
40+	E2b	3.0	1.50	4	1420	2.8	4.2	1.4
25-35	B1c	3.1	1.53	12	4560	2.6	4.0	0.8
15-25	D1c	3.1	1.51	8	3047	2.6	4.0	0.9
25-35	G1b	3.9	1.73	4	2122	1.9	3.3	0.9
15-25	D1b	2.9	1.47	0.5	248	2.0	3.0	2.9
1-15	E1b	3.8	1.70	0.5	311	1.6	2.7	2.3
1-15	H2a	4.8	1.99	0.5	368	1.4	2.7	1.9
1-15	D2a	0.5	1.03	0.5	193	2.6	2.7	3.7
15-25	G1b	5.2	2.10	1	1006	1.0	2.1	1.0
15-25	D1a	2.7	1.43	1	693	1.4	2.1	1.4
15-25	D2b	3.7	1.67	3	5046	0.6	1.0	0.3
15-25	D2c	2.7	1.42	0.5	768	0.7	0.9	0.9
1-15	D2b	4.1	1.78	1	3247	0.3	0.5	0.3

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Figure A1: Data from Table A1 as a chart demonstrating wide variation in deprivation between similar social groups across London

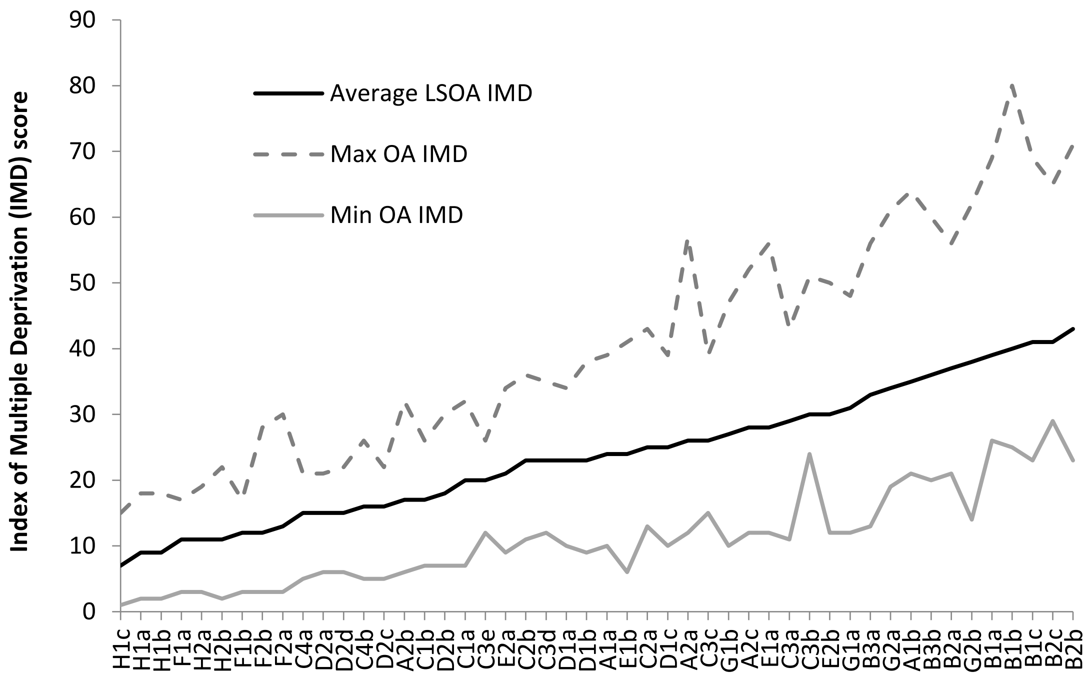

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Figure A2: Patients attending the KCH medical/surgical CCU over a 3-year period