A novel approach to estimate the local population denominator to calculate disease incidence for hospital-based health events in England

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Abstract
While incidence studies based on hospitalisation counts are commonly used for public health decision-making, no standard methodology to define hospitals’ catchment population exists. We conducted a review of all published community-acquired pneumonia studies in England indexed in PubMed and assessed methods for determining denominators when calculating incidence in hospital-based surveillance studies. Denominators primarily were derived from census-based population estimates of local geographic boundaries and none attempted to determine denominators based on actual hospital access patterns in the community. We describe a new approach to accurately define population denominators based on historical patient healthcare utilisation data. This offers benefits over the more established methodologies which are dependent on assumptions regarding healthcare-seeking behaviour. Our new approach may be applicable to a wide range of health conditions and provides a framework to more accurately determine hospital catchment. This should increase the accuracy of disease incidence estimates based on hospitalised events, improving information available for public health decision making and service delivery planning.

Introduction
When considering the introduction of an immunisation programme, it is paramount that the incidence of the diseases of interest is estimated as accurately as possible. Calculating annual incidence rates (expressed as the number of cases per 100 000 population) depends on the accurate estimation of two parameters: (1) the number of people diagnosed with the disease during a specified time interval, (2) the size of the population from which the cases originated at the start of the time interval of interest. Measuring each parameter has its own challenges, but here we focus on challenges associated with estimating the size of local populations within England, hereafter referred to as the denominator. For national datasets where the catchment area is determined based on clear geographic boundaries, the denominator can be estimated using census data which are maintained through annually adjusted estimates. However, many surveillance studies use health centres such as clinics and hospitals, and in these cases, the denominator population usually is not clearly defined.

To estimate healthcare facility catchment populations, a few map-based approaches have previously been proposed (e.g. defined urban conurbation area, crow-fly distance, road distance and road time access) [1–5], all of which rely on census data to provide population estimates based on where the boundary is drawn on the map from the given approach. However, in England, and for several reasons, geographically defined denominators may provide a poor estimate of the population accessing care at a particular health centre. The National Health Service (NHS) provides healthcare free of charge for all residents in England and allows patients to choose where they receive medical care, which is an important principle of the English healthcare system. Although geography plays an important role in influencing this choice, other factors may be important including public transport, parking, waiting times, traffic considerations both for patients and visiting family members, experience with a particular hospital, GP recommendation, ambulance preference, hospital capacity, specialist services and hospital reputation [6]. Moreover, while it might be expected that those who live close to a
hospital would preferentially choose that location, many people live equidistant to more than one hospital (both in terms of distance and travel time). In summary, no standardised methodology exists to estimate incidence based on the person seeking healthcare at a given facility.

In this report, we describe a novel methodology to estimate local population denominators for the Bristol AvonCAP study—a study set up with the specific aim of measuring the burden of hospitalised respiratory disease in England, to provide evidence for informed decision making for public health interventions including vaccines, that have the potential to alleviate some of this burden. The study was designed to measure the incidence of hospitalised community-acquired pneumonia (CAP) and other acute lower respiratory tract diseases (aLRTD) in two large secondary care hospitals located in Bristol. We think this methodology could be replicated for other health outcomes and other regions in England (or elsewhere if a high level of formal primary care practice registration exists), which could substantially improve disease incidence estimates and thus accurate public health decision-making.

Methods

Methodology overview

The conceptual distinction between previously proposed approaches to determine population denominators and our methodology is that the former are based on assumptions about which hospitals patients are expected to use. Our new methodology attempts to minimise the use of assumptions by utilising multiple data sources to assess which hospitals these populations have used in the past.

The NHS in England allocates an annual budget to local geographically defined clinical commissioning groups (CCGs) broadly based on population numbers and utilisation in prior years. In April 2021, there were 106 CCGs across England and their boundaries were drawn to complement local healthcare resources [7]. See the Method step 1 section for an important organisational change for the NHS.

Robust systems are used by CCGs to reimburse hospital care, therefore we hypothesised that CCG geographical regions may be helpful in determining hospital catchment areas and local populations. To test our hypothesis, we utilised Hospital Episode Statistics (HES) data which were re-used with the permission of NHS Digital via Harvey Walsh Limited. aLRTD admissions at the study hospitals between April 2017–March 2020 were linked to aggregated general practitioner (GP) data to understand from which CCG the hospitals’ patients came (Methods Part 1). Then, we estimated the proportion of patients hospitalised at the study hospitals among all patients hospitalised with LRTD for each practice and multiplied that by count of patients registered at that GP practice to calculate the Bristol hospital catchment population (Methods Part 2).

In England, all hospitalisations in NHS hospitals are captured in HES and all acute care is provided by NHS hospitals. HES contains information on bed days, length of admission, outpatient appointments, attendances at Accident and Emergency Departments at NHS hospitals in England, discharge diagnoses and hospital death [8]. The primary diagnosis and other clinical conditions are specified using the tenth revision of the International Classification of Diseases version 10 (ICD-10) [9]. Furthermore, in England a high proportion of the population are registered with General Practice where it is not possible to be registered at two practices concurrently [10, 11].

Method step 1 — defining GP practices associated with patients treated at study hospitals

To understand from where patients treated at the study hospitals originated (i.e. to which CCG the patients’ GP practices belong), HES data were extracted for all adult patients coded for aLRTD between April 2017–March 2020 and filtered to include only patients treated at the study hospitals: North Bristol NHS Trust (NBT), and University Hospitals Bristol NHS Foundation Trust & Weston NHS Foundation Trust (UHBW). Finally, data were analysed to determine in which CCG area the patients lived based on their GP registration. There are 6 CCG regions in the South West of England within a 1-hour drive of the study hospitals, as illustrated in Figure 1.

Fig. 1 shows a map of the CCGs described in the results pie chart (Fig. 2) along with the location of relevant hospitals. In July 2022 NHS England established 42 integrated care systems (ICS) and as a consequence CCGs were closed down and new statutory organisations called integrated care boards (ICB) were introduced. The remit of an ICB includes managing the NHS budget and arranging for the provision of health services in the ICS area. The boundaries of the new ICSs in the south-west of England remain unchanged from the previous CCG boundaries and therefore this change does not impact this analysis (https://www.england.nhs.uk/integratedcare/).

Method step 2 — defining the catchment population of study hospitals

As patients registered in the CCG might seek care at a different hospital for a variety of reasons, we could not assume every patient registered with a GP in the Bristol, North Somerset and South Gloucestershire (BNSSG) CCG used the study hospitals. Therefore, we estimated the proportion of patients from each GP practice treated at the study hospitals among all BNSSG CCG patients, stratified by age group. This proportion was used to calculate the study hospitals’ catchment population. All aLRTD hospitalisations (based on ICD-10 codes; Appendix 1) occurring between April 2017 – March 2020 among patients registered in the BNSSG CCG were analysed by GP practice. For each GP practice, the per cent of hospitalisations occurring at study hospitals was calculated within each age-group (18–34, 35–49, 50–64, 65–74, 75–84 and ⩾85 years). The percentage of hospitalisations occurring at study hospitals was the number of patients at each GP practice who were admitted for aLRTD at study hospitals (study hospital aLRTD patients) divided by the total number of patients at that GP practice who were hospitalised for aLRTD at any English hospital in the time period (overall aLRTD inpatients). This proportion (i.e. per cent of aLRTD inpatients using study hospitals) was multiplied by the practice population for each GP practice by age strata to provide an expected Bristol hospital catchment population contribution for each GP practice (once all age groups summed). GP populations were obtained from NHS Digital ‘Patients Registered at a GP Practice’ data for October 2019. Finally, the catchment population contribution for each GP practice in the BNSSG CCG was combined to provide an expected total Bristol hospital catchment population. In summary, if:

- \( E = \) Calculated catchment population
- \( SHP = \) Number of patients at a GP practice hospitalised at a study hospital with aLRTD during 2017–2019
- \( OL = \) Overall number of patients at a GP practice hospitalised in England with aLRTD during 2017–2019
- \( POP = \) Local GP population
- \( i = \) Each individual practice

\[ C = \frac{E}{\frac{SHP}{POP}} \times \frac{OL}{i} \]

This equation is used to estimate the number of patients expected to use the hospital for aLRTD inpatient care, for each GP practice.

Example: if a GP practice treated 100 patients with aLRTD at a hospital, the expected number of patients would be calculated as follows:

- \( E = 100 \) (number of patients treated with aLRTD at the hospital)
- \( SHP = 200 \) (number of patients treated at the hospital for aLRTD)
- \( POP = 1000 \) (local GP population)
- \( OL = 2000 \) (total number of patients treated in England for aLRTD)

\[ C = \frac{100}{\frac{200}{1000}} \times \frac{2000}{i} = \frac{100}{0.2} \times \frac{2000}{i} = 500 \times \frac{2000}{i} \]

This would result in an expected catchment population of 1,000,000 patients for that GP practice.
Then:

\[ E = \sum \left( \frac{\text{SHP}_i}{\text{OL}_i} \right) \text{POP}_i \]

**Drive-time methodology**

The BNSSG CCG used a 20-minute drive-time for their healthcare utilisation mapping purposes [12]. We have included this alternative methodological approach to allow comparison between our methodology and other methodologies in current use. We obtained data from the BNSSG CCG which divides the CCG region into small geographical areas used by the UK census known as lower layer super output areas (LSOA). LSOAs have a population of between 1000–3000 people or 400–1200 households [13]. Data were filtered according to estimated drive-time from each LSOA to the study hospitals according to the Automobile Association (AA) route planner, (AA, Hampshire, UK) [14]. UK population data by LSOA for all ages (0 – ≥90 years) were downloaded from the UK Office of National Statistics census website. Population estimates were derived for the following drive-times from the study hospitals 20, 25, 30, 40 and 60 minutes by matching the LSOA population data with the drive-time data.

**Results**

In 2019, there were 82 GP practices in the BNSSG CCG. Figure 2 shows the proportion of patients that attended the study hospitals in 2019 that were registered at GP practices in both the BNSSG CCG as well as six other CCGs that, combined, represented where >99% of patients hospitalised at study hospitals were registered. The majority of hospitalised patients (96%) were registered at BNSSG CCG GP practices, with most of the remaining 4% based in the surrounding CCGs.

Substantial variability existed by GP practice in the per cent of all persons hospitalised for aLRTD who were hospitalised at a study hospital with much less variability by age (Fig. 3) (based on a representative sample of 10 anonymised GP practices within the BNSSG CCG). Lower proportions were reported for GP practices that were located either close to the CCG boundary or close to Weston hospital (a non-study hospital situated in the BNSSG CCG). Full tables reporting these data for all GP practices located in the BNSSG CCG for 2017, 2018, 2019 and the combined data can be found in Appendix 2.

The degree to which the estimates from our methodology compared to estimates produced by other methods varied, including within specific age groups (Table 1 and Fig. 4). The total CCG population (the sum of the population of all GP practices in the CCG) overestimated the catchment population compared to our estimates by 15% to 24%. By contrast, the population living within a 20 minute drive of the study hospitals underestimated the catchment population by 10% to 29%. As drive-time increased linearly, the estimated population increased non-linearly such that the population based on a 60 minute drive-time overestimated the catchment population by 276% to 428%. The degree of underestimation or overestimation from other methods did not vary substantially by age group.

The map in Fig. 5 shows the location of the study hospitals and Weston General Hospital. The BNSSG CCG boundary is shown in
Fig. 2. 2017–2019 study hospital admissions by clinical commissioning group of the patients’ GP practices.

Fig. 3. A bar chart showing the proportion of persons hospitalised for acute lower respiratory tract disease who were hospitalised at a study hospital, stratified by individual anonymised general practice and patient age group.
Table 1. Comparison of study hospital catchment population estimates based on different approaches

| Age group       | Estimated catchment (Study method) | Total CCG catchment | Estimated based on ≤20 min drive-time | Estimated based on ≤25 min drive-time | Estimated based on ≤30 min drive-time | Estimated based on <40 min drive-time | Estimated based on <60 min drive-time |
|-----------------|----------------------------------|---------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| Five adult age groupings |                                  |                     |                                      |                                      |                                      |                                      |                                      |
| 18–34           | 231 342                          | 268 093 (16%)       | 208 924 (10%)                        | 238 301 (13%)                       | 295 130 (128%)                      | 442 590 (191%)                      | 870 841 (276%)                      |
| 35–49           | 184 269                          | 211 568 (15%)       | 130 881 (129%)                       | 162 469 (12%)                       | 211 462 (19%)                       | 337 781 (183%)                      | 714 415 (288%)                      |
| 50–64           | 152 380                          | 178 970 (17%)       | 108 404 (129%)                       | 143 508 (16%)                       | 196 307 (129%)                      | 331 795 (111%)                      | 732 702 (381%)                      |
| 65–74           | 74 245                           | 89 015 (20%)        | 52 954 (127%)                        | 73 368 (11%)                        | 102 148 (138%)                      | 175 757 (137%)                      | 391 718 (428%)                      |
| 75–84           | 45 989                           | 55 720 (121%)       | 33 712 (127%)                        | 46 919 (12%)                        | 65 244 (142%)                       | 111 109 (142%)                      | 239 310 (420%)                      |
| 85+             | 19 229                           | 23 938 (124%)       | 15 280 (121%)                        | 20 400 (16%)                        | 28 261 (147%)                       | 47 108 (149%)                       | 99 865 (439%)                       |
| Two adult age groupings |                                  |                     |                                      |                                      |                                      |                                      |                                      |
| 18–64           | 567 991                          | 658 611 (16%)       | 448 209 (212%)                       | 544 278 (12%)                       | 702 889 (124%)                      | 1 112 166 (196%)                    | 2 317 958 (308%)                    |
| ≥65             | 139 463                          | 168 673 (212%)      | 101 946 (127%)                       | 140 687 (11%)                       | 195 653 (140%)                      | 333 974 (139%)                      | 730 893 (424%)                      |
| Total           | 707 454                          | 827 304 (17%)       | 550 155 (222%)                       | 684 965 (13%)                       | 898 542 (127%)                      | 1 446 140 (104%)                    | 3 048 851 (331%)                    |

Discussion

Accurate estimation of incidence denominators is critical for accurate epidemiological studies. Traditional methods, which rely on census data to define catchment areas, can be problematic, especially in areas with a large number of hospitals. This is because error can be introduced at any stage, from the definition of the catchment area to the inclusion of patients. For example, a drive-time of 20 minutes would have underestimated incidence to the same degree. At the other extreme, defining the catchment population as those people living within a 60-minute drive from a study hospital would have overestimated the true catchment population by 24%.

Other issues must be considered when using our approach. For example, the percentage of people with aLRTD hospitalisation who were hospitalised in a study hospital was relatively stable within a particular census area. This suggests that for some practices and age groups less than 20% of cases were hospitalised in a study hospital. Since the only way to document the catchment area of any health centres inherent in traditional estimates would be to first present the methods described here, we suggest a better approach is simply to use our methods or some similar approach to define incidence denominators.

Other studies have demonstrated that for some practices and age groups less than 20% of cases were hospitalised in a study hospital. Since the only way to document the catchment area of any health centres inherent in traditional estimates would be to first present our methods or some similar approach to define incidence denominators.
The AvonCAP study was designed primarily to inform decisions on respiratory vaccine use among older adults, including vaccines to prevent the pneumococcal, respiratory syncytial virus, and SARS-CoV-2 infection. Policymakers, including vaccine technical committees, have consistently indicated that disease burden is the number one factor in setting priorities for vaccines [16, 17]. Disease incidence, and usually severe disease incidence using hospitalisation as a proxy, is the cornerstone of disease burden and usually is the key outcome driving cost-effectiveness models. Cost-effectiveness values in turn are often used for policy and pricing decisions. For example in England, a vaccine must be below a threshold of £ 30 000 per Quality Adjusted Life Year.
(QALY) saved to meet the criteria to be recommended for a national immunisation programme [8]. Since disease incidence underlies all these downstream measures, its accurate determination is critical for policy decisions. This requires a focus not just on the accurate determination of case counts (that is, numerators) but also the catchment population for the surveillance system (that is, denominators).

Our approach has a few limitations. We could not account for people who were not registered with a GP; although, nearly all English residents are registered [10]. Our methodology also did not include the 4% of people that use the study hospitals but are registered with a GP practice outside of the CCG. However, this will be largely addressed in Avon-CAP by excluding from incidence calculations patients with a study outcome living outside the CCG. Our approach requires a new estimate to be calculated for each disease of interest because some conditions will be disproportionately observed in some hospitals due to therapy area specialism. As discussed above, our approach may not be suitable for rare diseases or surveillance systems with small populations. Lastly, our methodology is appropriate for the particular circumstances of England and remains so with the recent transition to the ICS structure. The extent to which this approach can be generalised to other countries will need to be evaluated on a case-by-case basis, but other areas where nearly all persons are formally registered with a primary care provider could consider its use.

We will use the described methodology to define denominators for incidence calculations within the Avon-CAP study, which in turn should contribute to providing better data for informing decisions related to adult respiratory vaccine use. A similar approach could be used to refine previous estimates where these are being used to inform respiratory disease vaccine decision making. A historical study reporting disease incidence of hospitalised pneumonia in England was conducted in Hull and the East Riding of Yorkshire [5]. This study included 8 hospitals in the region and a geography-based approach was used to define the denominator. Whilst an effort was made to specifically exclude defined postcode areas reflecting a geographic region unlikely to use the study hospitals, the accuracy of the denominator used in this study remains uncertain. A more recent study published hospitalised CAP incidence estimates from Nottingham, England and used a denominator based on the entire population of the Greater Nottingham area, but the market share of the two study hospitals used was not formally defined [3, 18]. Since the Greater Nottingham area is surrounded by other urban areas with hospitals that also treat CAP, it is unclear how well Greater Nottingham census data matches the hospital catchment population, and this could be formally evaluated by replicating our methodology. More generally, the method we describe may be used for other disease incidence calculations and for relatively common diseases could be extended to focus on specific groups such as those with underlying comorbidities. While the approach we describe takes considerably more human and financial resources than using census data (through commissioning a specialist vendor that holds an appropriate license to analyse the data), this cost is negligible compared to the inefficiencies introduced when inaccurate disease incidence estimates are used as a core basis for public health decision making.

**Conclusion**

Use of the entire CCG or drive-times does not account for the nuanced ways that populations access healthcare and may overestimate or underestimate denominators and distort incidence estimates. Our data-driven method provides more accurate incidence estimates and thus can improve public health decision-making. Denominators for hospital-based incidence studies should be based on healthcare usage rather than geographical boundaries.

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**Conflict of interest.** JC, EB, AV, JS, HM, BG & GE are employees of Pfizer Vaccines and hold stock or stock options. DH is an employee of Harvey Walsh Ltd. CH is the Principal Investigator of the Avon CAP study which is an investigator-led University of Bristol study funded by Pfizer and has previously received support from the NIHR in an Academic Clinical Fellowship. AF is a member of the Joint Committee on Vaccination and Immunization (JCVI) and chair of the World Health Organization European Technical Advisory Group of Experts on Immunization (ETAGE) committee. In addition to receiving funding from Pfizer as Chief Investigator of the Avon CAP study, he leads another project investigating the transmission of respiratory bacteria in families jointly funded by Pfizer and the Gates Foundation.

**Data availability statement.** The data that support the findings of this study are available from Harvey Walsh, Open Group. Restrictions apply to the availability of these data, which were used under licence for this study. Data are available from the authors with the permission of Harvey Walsh, Open Group.

**Disclosure.** This study was conducted as a collaboration between the University of Bristol, Pfizer and Open Health Group. Pfizer is the study sponsor.

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Appendix 1: ICD-10 codes used for the analysis

| ICD-10 Code | ICD-10 Description |
|-------------|-------------------|
| J110        | Hypertensive heart disease with (congestive) heart failure |
| J130        | Hypertensive heart and renal disease with (congestive) heart failure |
| J132        | Hypertensive heart and renal disease with both (congestive) heart failure and renal failure |
| I500        | Heart failure |
| I500        | Congestive heart failure |
| J010        | Heart failure, unspecified |
| J09         | Influenza due to identified avian influenza virus |
| J09X        | Influenza due to identified zoonotic or pandemic influenza virus |
| J10         | Influenza due to identified seasonal influenza virus |
| J100        | Influenza with pneumonia, seasonal influenza virus identified |
| J101        | Influenza with other respiratory manifestations, seasonal influenza virus identified |
| J108        | Influenza with other manifestations, seasonal influenza virus identified |
| J11         | Influenza, virus not identified |
| J110        | Influenza with pneumonia, virus not identified |
| J111        | Influenza with other respiratory manifestations, virus not identified |
| J118        | Influenza with other manifestations, virus not identified |
| J12         | Viral pneumonia, not elsewhere classified |
| J120        | Adenoviral pneumonia |
| J121        | Respiratory syncytial virus pneumonia |
| J122        | Parainfluenza virus pneumonia |
| J123        | Human metapneumovirus pneumonia |
| J128        | Other viral pneumonia |
| J129        | Viral pneumonia, unspecified |
| J13         | Pneumonia due to Streptococcus pneumoniae |
| J13X        | Pneumonia due to Streptococcus pneumoniae |
| J14         | Pneumonia due to Haemophilus influenzae |
| J14X        | Pneumonia due to Haemophilus influenzae |
| J15         | Bacterial pneumonia, not elsewhere classified |
| J150        | Pneumonia due to Klebsiella pneumoniae |
| J151        | Pneumonia due to Pseudomonas |

(Continued)
| ICD-10 Code | ICD-10 Description |
|------------|--------------------|
| J152       | Pneumonia due to staphylococcus |
| J153       | Pneumonia due to streptococcus, group B |
| J154       | Pneumonia due to other streptococci |
| J155       | Pneumonia due to *Escherichia coli* |
| J156       | Pneumonia due to other Gram-negative bacteria |
| J157       | Pneumonia due to *Mycoplasma pneumoniae* |
| J158       | Other bacterial pneumonia |
| J159       | Bacterial pneumonia, unspecified |
| J16        | Pneumonia due to other infectious organisms, not elsewhere classified |
| J160       | Chlamydial pneumonia |
| J168       | Pneumonia due to other specified infectious organisms |
| J17        | Pneumonia in diseases classified elsewhere |
| J170       | Pneumonia in bacterial diseases classified elsewhere |
| J171       | Pneumonia in viral diseases classified elsewhere |
| J172       | Pneumonia in mycoses |
| J173       | Pneumonia in parasitic diseases |
| J178       | Pneumonia in other diseases classified elsewhere |
| J18        | Pneumonia, organism unspecified |
| J180       | Bronchopneumonia, unspecified |
| J181       | Lobar pneumonia, unspecified |
| J182       | Hypostatic pneumonia, unspecified |
| J188       | Other pneumonia, organism unspecified |
| J189       | Pneumonia, unspecified |
| J20        | Acute bronchitis |
| J200       | Acute bronchitis due to *Mycoplasma pneumoniae* |
| J201       | Acute bronchitis due to *Haemophilus influenzae* |
| J202       | Acute bronchitis due to streptococcus |
| J203       | Acute bronchitis due to *coxackievirus* |
| J204       | Acute bronchitis due to parainfluenza virus |
| J205       | Acute bronchitis due to respiratory syncytial virus |
| J206       | Acute bronchitis due to rhinovirus |
| J207       | Acute bronchitis due to *echovirus* |
| J208       | Acute bronchitis due to other specified organisms |
| J209       | Acute bronchitis, unspecified |
| J21        | Acute bronchiolitis |
| J210       | Acute bronchiolitis due to respiratory syncytial virus |
| J211       | Acute bronchiolitis due to human metapneumovirus |
| J218       | Acute bronchiolitis due to other specified organisms |
| J219       | Acute bronchiolitis, unspecified |
| J22        | Unspecified acute lower respiratory infection |
| J22X       | Unspecified acute lower respiratory infection |
| J40        | Bronchitis, not specified as acute or chronic |
| J40X       | Bronchitis, not specified as acute or chronic |
| ICD-10 Code | ICD-10 Description |
|-------------|--------------------|
| J41         | Simple and mucopurulent chronic bronchitis |
| J410        | Simple chronic bronchitis |
| J411        | Mucopurulent chronic bronchitis |
| J418        | Mixed simple and mucopurulent chronic bronchitis |
| J42         | Unspecified chronic bronchitis |
| J42X        | Unspecified chronic bronchitis |
| J43         | Emphysema |
| J430        | MacLeod syndrome |
| J431        | Panlobular emphysema |
| J432        | Centrilobular emphysema |
| J438        | Other emphysema |
| J439        | Emphysema, unspecified |
| J44         | Other chronic obstructive pulmonary disease |
| J440        | Chronic obstructive pulmonary disease with acute lower respiratory infection |
| J441        | Chronic obstructive pulmonary disease with acute exacerbation, unspecified |
| J448        | Other specified chronic obstructive pulmonary disease |
| J449        | Chronic obstructive pulmonary disease, unspecified |
| J45         | Asthma |
| J450        | Predominantly allergic asthma |
| J451        | Nonallergic asthma |
| J458        | Mixed asthma |
| J459        | Asthma, unspecified |
| J46         | Status asthmaticus |
| J46X        | Status asthmaticus |
| J47         | Bronchiectasis |
| J47X        | Bronchiectasis |
| J85         | Abscess of lung and mediastinum |
| J850        | Gangrene and necrosis of lung |
| J851        | Abscess of lung with pneumonia |
| J852        | Abscess of lung without pneumonia |
| J853        | Abscess of mediastinum |
| J86         | Pyothorax |
| J860        | Pyothorax with fistula |
| J869        | Pyothorax without fistula |
| J90         | Pleural effusion, not elsewhere classified |
| J90X        | Pleural effusion, not elsewhere classified |
| J91         | Pleural effusion in conditions classified elsewhere |
| J91X        | Pleural effusion in conditions classified elsewhere |
| J95         | Postprocedural respiratory disorders, not elsewhere classified |
| J950        | Tracheostomy malfunction |
| J951        | Acute pulmonary insufficiency following thoracic surgery |
| J952        | Acute pulmonary insufficiency following nonthoracic surgery |
| J953        | Chronic pulmonary insufficiency following surgery |
| ICD-10 Code | ICD-10 Description                                      |
|------------|--------------------------------------------------------|
| J954       | Mendelson syndrome                                     |
| J955       | Postprocedural subglottic stenosis                      |
| J958       | Other postprocedural respiratory disorders             |
| J959       | Postprocedural respiratory disorder, unspecified       |
| J96        | Respiratory failure, not elsewhere classified          |
| J960       | Acute respiratory failure                              |
| J9600      | Acute respiratory failure, Type I [hypoxic]            |
| J9601      | Acute respiratory failure, Type II [hypercapnic]       |
| J9609      | Acute respiratory failure, Type unspecified            |
| J961       | Chronic respiratory failure                            |
| J9610      | Chronic respiratory failure, Type I [hypoxic]          |
| J9611      | Chronic respiratory failure, Type II [hypercapnic]     |
| J9619      | Chronic respiratory failure, Type unspecified          |
| J969       | Respiratory failure, unspecified                       |
| J9690      | Respiratory failure, unspecified, Type I [hypoxic]     |
| J9691      | Respiratory failure, unspecified, Type II [hypercapnic]|
| J9699      | Respiratory failure, unspecified, Type unspecified     |
| J98        | Other respiratory disorders                            |
| J980       | Diseases of bronchus, not elsewhere classified         |
| J981       | Pulmonary collapse                                     |
| J982       | Interstitial emphysema                                 |
| J983       | Compensatory emphysema                                 |
| J984       | Other disorders of lung                                |
| J985       | Diseases of mediastinum, not elsewhere classified      |
| J986       | Disorders of diaphragm                                 |
| J988       | Other specified respiratory disorders                  |
| J989       | Respiratory disorder, unspecified                      |
| J99        | Respiratory disorders in diseases classified elsewhere  |
| J990       | Rheumatoid lung disease                                |
| J991       | Respiratory disorders in other diffuse connective tissue disorders |
| J998       | Respiratory disorders in other diseases classified elsewhere |
## Appendix 2: Anonymised GP Practice Data

GP Practice names are anonymised and presented as Practice 1, Practice 2 etc...

### 18 to 34

| Practice name | Proportion | Population | Proportion | Population | Proportion | Population | Proportion | Population | Proportion | Population |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Practice 1    | 19%        | 507        | 10%        | 216        | 15%        | 375        | 18%        | 276        | 17%        | 169        |
| Practice 2    | 100%       | 3254       | 93%        | 2839       | 100%       | 2342       | 100%       | 1043       | 100%       | 773        |
| Practice 3    | 100%       | 979        | 100%       | 1176       | 100%       | 1132       | 100%       | 482        | 100%       | 362        |
| Practice 4    | 97%        | 3899       | 98%        | 2891       | 97%        | 1825       | 98%        | 717        | 100%       | 377        |
| Practice 5    | 100%       | 2714       | 94%        | 2364       | 100%       | 2030       | 100%       | 894        | 100%       | 469        |
| Practice 6    | 100%       | 2383       | 100%       | 1914       | 100%       | 1262       | 100%       | 558        | 97%        | 294        |
| Practice 7    | 100%       | 1488       | 89%        | 660        | 89%        | 239        | 100%       | 38         | 100%       | 8          |
| Practice 8    | 88%        | 4467       | 97%        | 4750       | 100%       | 2750       | 100%       | 721        | 96%        | 335        |
| Practice 9    | 90%        | 11794      | 100%       | 9416       | 100%       | 5370       | 100%       | 2301       | 98%        | 1429       |
| Practice 10   | 88%        | 7402       | 97%        | 2091       | 100%       | 597        | 100%       | 362        | 100%       | 161        |
| Practice 11   | 89%        | 2731       | 88%        | 1906       | 77%        | 1895       | 88%        | 894        | 80%        | 466        |
| Practice 12   | 95%        | 4707       | 100%       | 4042       | 99%        | 2850       | 100%       | 717        | 100%       | 457        |
| Practice 13   | 60%        | 767        | 42%        | 298        | 28%        | 260        | 19%        | 87         | 11%        | 33         |
| Practice 14   | 71%        | 2816       | 83%        | 2445       | 86%        | 2914       | 68%        | 1389       | 63%        | 826        |
| Practice 15   | 62%        | 1459       | 79%        | 986        | 83%        | 1395       | 67%        | 555        | 68%        | 292        |
| Practice 16   | 94%        | 3400       | 100%       | 3203       | 99%        | 2780       | 96%        | 1303       | 99%        | 692        |
| Practice 17   | 100%       | 2462       | 100%       | 2112       | 100%       | 1838       | 100%       | 774        | 100%       | 609        |
| Practice 18   | 97%        | 2967       | 100%       | 2781       | 99%        | 2832       | 99%        | 1528       | 99%        | 1018       |
| Practice 19   | 100%       | 3148       | 97%        | 2718       | 100%       | 1415       | 100%       | 395        | 100%       | 253        |
| Practice 20   | 100%       | 2578       | 87%        | 2532       | 91%        | 1768       | 100%       | 666        | 98%        | 349        |
| Practice 21   | 100%       | 1611       | 92%        | 1932       | 100%       | 2100       | 100%       | 1136       | 100%       | 684        |
| Practice 22   | 93%        | 5815       | 92%        | 5152       | 95%        | 3682       | 100%       | 1720       | 99%        | 1002       |
| Practice 23   | 96%        | 3097       | 93%        | 2962       | 93%        | 2735       | 100%       | 1240       | 100%       | 668        |
| Practice 24   | 91%        | 2522       | 100%       | 2610       | 99%        | 3070       | 98%        | 1604       | 100%       | 1223       |
| Practice 25   | 95%        | 4476       | 100%       | 4634       | 97%        | 3004       | 100%       | 1322       | 100%       | 613        |
| Practice 26   | 25%        | 1887       | 42%        | 442        | 18%        | 331        | 19%        | 188        | 15%        | 91         |
| Practice 27   | 100%       | 2714       | 100%       | 2193       | 100%       | 1847       | 100%       | 761        | 100%       | 467        |
| Practice 28   | 100%       | 2057       | 97%        | 1841       | 100%       | 1406       | 100%       | 689        | 100%       | 483        |
| Practice 29   | 79%        | 4204       | 100%       | 3303       | 89%        | 3792       | 88%        | 3825       | 86%        | 2077       |
| Practice 30   | 100%       | 1657       | 100%       | 1657       | 94%        | 2397       | 94%        | 1763       | 100%       | 825        |

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James Campling et al.
| Practice 31 | 95% | Practice 32 | 100% | Practice 33 | 100% | Practice 34 | 100% | Practice 35 | 100% | Practice 36 | 100% | Practice 37 | 100% | Practice 38 | 100% | Practice 39 | 100% | Practice 40 | 100% | Practice 41 | 100% |
|------------|-----|------------|------|------------|------|------------|------|------------|------|------------|------|------------|------|------------|------|------------|------|------------|------|------------|------|
| 1871       | 1348| 1322       | 516  | 342        | 163  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1124       | 1212| 1437       | 846  | 658        | 222  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1779       | 1156| 1176       | 353  | 250        | 98   |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 5366       | 3798| 2498       | 1175 | 667        | 249  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1467       | 1112| 854        | 354  | 172        | 41   |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2625       | 1978| 2690       | 1164 | 602        | 200  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 3148       | 2360| 2112       | 1150 | 790        | 413  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2447       | 2243| 1376       | 534  | 434        | 183  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1776       | 1927| 1934       | 1163 | 795        | 374  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1397       | 1527| 1495       | 946  | 678        | 244  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1516       | 1419| 627        | 213  | 144        | 81   |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 7943       | 8350| 9129       | 5466 | 3173       | 1211 |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2183       | 1527| 1006       | 445  | 259        | 154  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 7909       | 5507| 2884       | 848  | 329        | 110  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 3642       | 3841| 2733       | 1248 | 663        | 246  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1116       | 490 | 171        | 23   | 7          | 4    |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2591       | 2526| 2253       | 1088 | 791        | 338  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 5580       | 3486| 2631       | 1245 | 599        | 232  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 863        | 826 | 981        | 504  | 283        | 117  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 5097       | 4548| 3372       | 1671 | 863        | 432  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2945       | 3684| 3650       | 2554 | 1681       | 661  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2287       | 2483| 2126       | 1066 | 654        | 274  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1396       | 1437| 1239       | 750  | 518        | 311  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2637       | 2211| 2004       | 1014 | 567        | 262  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2719       | 2173| 1740       | 892  | 583        | 303  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1453       | 1486| 1608       | 871  | 724        | 298  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2425       | 2671| 1992       | 905  | 473        | 181  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2161       | 1848| 1856       | 999  | 808        | 295  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 3953       | 3462| 2943       | 1224 | 772        | 387  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1006       | 928 | 1086       | 675  | 396        | 182  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 18188      | 188 | 11         | 1    | 1          | 0    |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 3551       | 3011| 3333       | 1811 | 1129       | 459  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 2837       | 2784| 3126       | 1900 | 1241       | 552  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 1642       | 1473| 1051       | 397  | 204        | 69   |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |
| 5289       | 5309| 4780       | 2495 | 1795       | 915  |            |      |            |      |            |      |            |      |            |      |            |      |            |      |            |      |

(Continued)
## Total Practice Population by Age and Proportion

| Total Practice Population by Age | 18–34 | 35–49 | 50–64 | 65–74 | 75–84 | 85+ |
|---------------------------------|-------|-------|-------|-------|-------|-----|
|                                 | Proportion | Population | Proportion | Population | Proportion | Population | Proportion | Population | Proportion | Population | Proportion | Population | Proportion | Population | Proportion | Population | Proportion | Population | Proportion | Population |
| Practice name                   |       |       |       |       |       |     |
| Practice 67                     | 88%  | 4834  | 95%  | 3684  | 100% | 2392  | 100% | 1084  | 98%  | 549  | 100% | 230  |
| Practice 68                     | 100% | 2016  | 95%  | 1548  | 93%  | 1482  | 100% | 775   | 100% | 515  | 100% | 271  |
| Practice 69                     | 100% | 1626  | 98%  | 1359  | 100% | 1124  | 100% | 424   | 100% | 243  | 100% | 83   |
| Practice 70                     | 25%  | 395   | 17%  | 270   | 24%  | 470   | 24%  | 288   | 11%  | 85   | 11%  | 41   |
| Practice 71                     | 92%  | 14846 | 100% | 2141  | 97%  | 1513  | 100% | 708   | 99%  | 527  | 100% | 298  |
| Practice 72                     | 95%  | 2709  | 100% | 2514  | 100% | 1149  | 100% | 423   | 100% | 245  | 100% | 93   |
| Practice 73                     | 100% | 1346  | 100% | 1372  | 100% | 1749  | 100% | 1341  | 100% | 894  | 99%  | 311  |
| Practice 74                     | 41%  | 679   | 29%  | 457   | 40%  | 901   | 27%  | 307   | 26%  | 195  | 32%  | 91   |
| Practice 75                     | 19%  | 367   | 4%   | 78    | 16%  | 351   | 22%  | 303   | 17%  | 153  | 16%  | 65   |
| Practice 76                     | 94%  | 4571  | 98%  | 6106  | 98%  | 6722  | 97%  | 4114  | 96%  | 2706 | 94%  | 1168 |
| Practice 77                     | 60%  | 381   | 100% | 552   | 100% | 683   | 100% | 355   | 100% | 240  | 100% | 73   |
| Practice 78                     | 90%  | 2270  | 93%  | 2254  | 97%  | 1360  | 98%  | 522   | 100% | 308  | 100% | 105  |
| Practice 79                     | 100% | 2697  | 100% | 2479  | 100% | 2657  | 100% | 1464  | 100% | 1251 | 99%  | 349  |
| Practice 80                     | 100% | 1579  | 100% | 2622  | 100% | 1866  | 100% | 1107  | 100% | 669  | 99%  | 379  |
| Practice 81                     | 82%  | 4003  | 94%  | 3752  | 93%  | 2913  | 98%  | 1609  | 100% | 738  | 100% | 252  |
| Practice 82                     | 43%  | 600   | 25%  | 403   | 26%  | 519   | 26%  | 363   | 22%  | 200  | 18%  | 77   |
| Practice 83                     | 18–34 | 231 342 | 35–49 | 184 269 | 50–64 | 152 380 | 65–74 | 74 245 | 75–84 | 45 989 | ≥85 | 19 229 |

**Appendix 2 (Continued)**

James Campling et al.