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*Published in:*
Journal of Antimicrobial Chemotherapy

*DOI:*
10.1093/jac/dkx502

J Antimicrob Chemother 2018; **73** Suppl 2: ii19–ii26
doi:10.1093/jac/dkx502

Journal of Antimicrobial Chemotherapy

# Actual versus 'ideal' antibiotic prescribing for common conditions in English primary care

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**Objectives:** Previous work based on guidelines and expert opinion identified 'ideal' prescribing proportions—the overall proportion of consultations that should result in an antibiotic prescription—for common infectious conditions. Here, actual condition-specific prescribing proportions in primary care in England were compared with ideal prescribing proportions identified by experts.

**Methods:** All recorded consultations for common infectious conditions (cough, bronchitis, exacerbations of asthma or chronic obstructive pulmonary disease, sore throat, rhinosinusitis, otitis media, lower respiratory tract infection, upper respiratory tract infection, influenza-like illness, urinary tract infection, impetigo, acne, gastroenteritis) for 2013–15 were extracted from The Health Improvement Network (THIN) database. The proportions of consultations resulting in an antibiotic prescription were established, concentrating on acute presentations in patients without relevant comorbidities. These actual prescribing proportions were then compared with previously established 'ideal' proportions by condition.

**Results:** For most conditions, substantially higher proportions of consultations resulted in an antibiotic prescription than was deemed appropriate according to expert opinion. An antibiotic was prescribed in 41% of all acute cough consultations when experts advocated 10%. For other conditions the proportions were: bronchitis (actual 82% versus ideal 13%); sore throat (actual 59% versus ideal 13%); rhinosinusitis (actual 88% versus ideal 11%); and acute otitis media in 2- to 18-year-olds (actual 92% versus ideal 17%). Substantial variation between practices was found.

**Conclusions:** This work has identified substantial overprescribing of antibiotics in English primary care, and highlights conditions where this is most pronounced, particularly in respiratory tract conditions.

## Introduction

In the light of the threat of rising antibiotic resistance rates[1–3] and in response to the antimicrobial resistance (AMR) review,[4] the UK government expressed its ambition to lower inappropriate antibiotic prescribing by 50% by 2020.[5] To be able to meet this target, it is crucial to first quantify the extent of inappropriate prescribing to determine the current level and monitor future changes. Antibiotic prescribing predominantly occurs in general practice (74% of prescribing events occurring in this setting).[2] Several studies indicate that there is substantial overprescribing of antibiotics in general practice, especially for respiratory tract infections.[6–11] Even in low-prescribing countries, unnecessary prescriptions for respiratory tract infections are not uncommon.[9–11] Furthermore, substantial variation exists in antibiotic prescribing rates between general practices,[12–14] with some evidence indicating that part of this variation may be due to variation in inappropriate antibiotic prescribing.[8,12]

To gain insight into the extent of inappropriate antibiotic prescribing, empirical estimates of prescribing proportions can be compared with 'ideal' proportions derived from prescription guidelines and expert elicitations.[6,15–20] For example, Hawker *et al.*[21] previously observed that in the UK prescribing proportions for cough/cold consultations were far above what one would expect based on guidelines. Moreover, extensive variation by practice was interpreted as an indication that there is significant potential to improve prescribing.[21]

To enable quantification of inappropriate (defined here as clinically unnecessary) antibiotic prescribing in England, we evaluated antibiotic prescribing proportions for more conditions than previously considered[21] and using more recent data. These prescribing proportions can be compared with the results of our recent expert elicitation and/or the results of the European Surveillance of Antimicrobial Consumption (ESAC) expert elicitation to identify the potential for reductions in antibiotic prescribing.[15,16]

# Methods

## Ethics

The Health Improvement Network (THIN) data were used for this work. The data collection scheme for THIN is approved by the UK Multicentre Research Ethics Committee (reference number 07H1102103). In accordance with this approval, the study protocol was reviewed and approved by an independent Scientific Review Committee (reference numbers 16THIN071 and 16THIN071-A1).

## Data

This cross-sectional study used data from THIN, a large primary care electronic medical record database covering more than 3.7 million active patients, covering ∼7% of the general UK population.[22–25] The population covered has demographic characteristics similar to those of the national UK population and the recording of consultations and prescriptions is comparable to national levels.[22,23] We extracted patient, consultation and prescribing data from English practices meeting an acceptable standard for research data collection between January 2013 and December 2015.

## Attributing consultations to prescriptions

For each consultation we evaluated whether a systemic antibiotic was being prescribed on the same day as the consultation. We included all systemic antibiotics from British National Formulary (BNF) chapter 5.1, except antituberculosis and antileprosy drugs.[17] Given the more chronic character of acne, we evaluated whether a systemic antibiotic was being prescribed within 90 days of the first consultation instead of the same day for acne. To increase the likelihood that the prescription was for acne and not for an unrelated condition we focused on the following systemic antibiotics for this analysis: oral oxytetracycline, tetracycline, doxycycline, lymecycline, minocycline and erythromycin.[26] Prescriptions for <28 days and erythromycin suspensions were excluded because they are less likely to have been prescribed for acne.[26]

## Estimating prescribing proportions

We evaluated prescribing proportions—the proportion of consultations with an antibiotic prescription on the same day—for the following common infection-related conditions: acute cough; acute bronchitis; asthma exacerbations; COPD exacerbations; acute sore throat; acute rhinosinusitis; acute otitis media (AOM); upper respiratory tract infection (URTI); lower respiratory tract infection (LRTI); influenza-like illness (ILI); urinary tract infection (UTI); impetigo; acne; and gastroenteritis. For UTIs, we restricted the analysis to female patients aged >14 years; for AOM, separate analyses were performed for patients aged 2–18 years and patients aged <2 years; and for gastroenteritis the analyses were restricted to patients older than 2 years. Only data for acute and uncomplicated consultations were analysed. Therefore, consultations for chronic infectious conditions, e.g. chronic rhinosinusitis or chronic UTI, and complicated infectious conditions, e.g. recurrent UTI or bilateral otitis media, were excluded. To avoid inclusion of re-consultations for a disease episode that may be worsening, only consultations without a similar consultation in the prior 30 days were included.[27–30] For acne, we focused on first consultations without any acne consultations in the previous year.

To further ensure that we were evaluating uncomplicated cases, we excluded patients that had any relevant comorbidities.[31,32] These comorbidities were asthma, chronic respiratory disease, chronic kidney disease, diabetes, chronic heart disease, chronic liver disease, immunosuppressive diseases and chronic neurological disease.[31,32] Patients that received at least two prescriptions of immunosuppressive drugs or inhaled/systemic corticosteroids in the 365 days before the consultation of interest were also excluded for this reason.[31,32] When evaluating prescribing proportions for asthma or COPD exacerbations, we necessarily included patients with asthma, chronic respiratory disease and systemic or inhaled corticosteroid use.

Prescribing proportions for all the considered conditions were calculated using robust standard errors, to take into account within-person dependence for patients contributing multiple episodes. Variations in prescribing proportions between general practices were visualized by plotting the prescribing proportions of individual practices. All analyses were performed using STATA 13.1 and R version 3.1.

## Subanalyses

We also evaluated whether consultations in which only symptoms were coded were associated with lower prescribing proportions than consultations in which a diagnosis was coded, reflecting diagnostic uncertainty of coded symptoms, for UTI consultations. In addition, we evaluated whether certain codes indicating more complex cases of the same condition were associated with higher prescribing proportions, by comparing prescribing proportions for unilateral AOM without discharge and/or perforation with potentially more complicated forms of AOM (bilateral/discharge/perforation).[20]

## Sensitivity analyses

We performed several sensitivity analyses. First, we evaluated prescribing proportions within patients with relevant comorbidities and receiving at least two prescriptions of immunosuppressives or inhaled/systemic steroids in the year before the consultation. Second, we evaluated prescribing proportions excluding consultations that had a consultation for a similar condition within the prior 180 days, to increase the likelihood that the consultation was not for an ongoing or recurrent condition. Third, prescribing proportions were determined based on a prescription of a systemic antibiotic within 30 days after the consultation instead of only the same day, thereby restricting this analysis to patients that had at least 30 days of follow-up after the consultation of interest. Finally, to align results with the other analyses of this project,[12,16,33,34] we only included data from a practice if the practice had complete data for the full year.

# Results

Among patients without comorbidity between 2013 and 2015, the most common consultations were for acute cough (573827), sore throat (386971), URTI (383847), LRTI (161065) and UTI (128566) (Table 1). In these conditions, the percentages of consultations resulting in an antibiotic prescription on the same day were 41%, 59%, 25%, 87%, and 91%, respectively (Table 1). Guidelines and expert elicitations indicate that antibiotic treatment is necessary in only a small proportion of patients without comorbidity consulting for sore throat, rhinosinusitis, acute cough, acute bronchitis and AOM.[15,16,18,20] Nevertheless, relatively high prescribing proportions were observed for these conditions (Table 1). The percentage of consultations resulting in an antibiotic prescription on the same day was especially high for AOM (actual 88% versus ideal 17% among children aged 2–18 years[16]), rhinosinusitis (actual 88% versus ideal 11%[16]) and acute bronchitis (actual 82% versus ideal 13%[16]). UTI consultations among females aged >14 years resulted in an antibiotic prescription in 92% of cases (ideal 75%[16]);

**Table 1.** Actual and 'ideal' antibiotic prescribing proportions among patients without comorbidities consulting at a general practice

| Condition | Consultations (*n*) | Proportion of consultations with a systemic antibiotic prescription (95% CI) | Ideal proportion of consultations resulting in systemic antibiotic prescriptions (IQR)[16] |
|---|---|---|---|
| Acne | 60959 | 0.43 (0.43–0.44) | 0.21 (0.10–0.35) |
| Acute bronchitis | 17084 | 0.82 (0.82–0.82) | 0.13 (0.06–0.22) |
| Acute cough | 573827 | 0.41 (0.41–0.41) | 0.10 (0.06–0.16) |
| Acute otitis media (age 0–1 year) | 14886 | 0.92 (0.91–0.92) | 0.19 (0.09–0.33) |
| Acute otitis media (age 2–18 years) | 39513 | 0.88 (0.88–0.89) | 0.17 (0.08–0.30) |
| Acute rhinosinusitis | 74359 | 0.88 (0.88–0.88) | 0.11 (0.05–0.18) |
| Acute sore throat | 386971 | 0.59 (0.58–0.59) | 0.13 (0.07–0.22) |
| Asthma exacerbation | 23292 | 0.47 (0.46–0.47) | –[c] |
| COPD exacerbation | 13840 | 0.73 (0.72–0.74) | 0.54 (0.31–0.78) |
| Gastroenteritis (age >2 years) | 114290 | 0.05 (0.05–0.05) | 0.09 (0.04–0.16) |
| Impetigo | 29809 | 0.53 (0.52–0.53) | 0.12 (0.06–0.53) |
| Influenza-like illness | 23787 | 0.18 (0.18–0.19) | –[c] |
| Lower respiratory tract infection[a] | 161065 | 0.87 (0.87–0.88) | –[c] |
| Upper respiratory tract infection[b] | 383847 | 0.25 (0.25–0.25) | –[c] |
| Urinary tract infection age (>14 years) | 128566 | 0.92 (0.91–0.92) | 0.75 (0.61–0.86) |

[a]Including non-specific LRTI, COPD exacerbations, acute bronchitis and pneumonia.
[b]Including non-specific URTI, common cold, laryngitis and tracheitis.
[c]Condition for which expert opinion on ideal prescribing proportions was not elicited.

however, when only UTI symptoms (and not diagnoses) were coded, only 24% (95% CI 23%–24%) of consultations resulted in an antibiotic prescription on the same day as the general practitioner visit. In 37% of first consultations with acne an oral oxytetracycline, tetracycline, doxycycline, lymecycline, minocycline or erythromycin was prescribed. Within 90 days of the consultations this percentage was 43% (Table 1).

There was considerable between-practice variation in prescribing proportions, even after accounting for differences in the number of consultations per practice (Figures 1–3 and Figures S1–S5, available as Supplementary data at *JAC* Online). Between-practice variation was larger than would be expected by chance alone, as indicated by the substantial amount of practices lying outside the 95% CI seen in the funnel plots.

It is often suggested that there may be a 'Friday effect' in antibiotic prescribing in the sense that GPs may prescribe more antibiotics on Friday, owing to a higher workload as a consequence of increased numbers of patients visiting their GP prior to the weekend. However, the proportion of patients receiving antibiotics for cough and sore throat consultations—the most common RTI consultations in primary care—was comparable to other days of the week (Tables S1 and S2). Moreover, patients consulted more frequently with cough or sore throat on Monday than on Friday (Tables S1 and S2).

### *Sensitivity analysis*

Prescribing proportions were generally higher among patients with one of the selected comorbidities and/or receiving at least two prescriptions of immunosuppressives or inhaled/systemic steroids in the year before the consultation (Table 2). The largest differences were observed for URTI (25% without comorbidities; 42% with comorbidities), ILI (18% without comorbidities; 28% with comorbidities), acute cough (41% without comorbidities; 54% with comorbidities) and asthma exacerbations (47% without comorbidities; 57% with comorbidities). A noticeable exception was sore throat, with a higher prescribing proportion among patients without one of the selected comorbidities and/or drug prescriptions than among patients with these comorbidities and/or drug prescriptions (59% versus 47%). This was not explained by higher prescribing in children compared with adults (the latter will typically more often have comorbidities), since this observation remained similar when restricting the analysis to patients aged 18 years and older (55% versus 45%).

Excluding consultations that were preceded by a consultation for a similar condition within the prior 180 days reduced the number of consultations, but did not alter the prescribing proportions (data not shown). The percentage of consultations that resulted in an antibiotic prescription within 30 days of the consultation was, as one would expect, higher than the percentage of consultations that resulted in same-day prescriptions (Table 3). For example, consultations for ILI resulted in an antibiotic prescription on the same day in 18% of the cases (Table 1), whereas within 30 days 29% of consultations were followed by an antibiotic prescription. Very similar results were found when we only included data from a practice if the practice had complete data for the full year (data not shown).

## Discussion

This study shows that the majority of practices in England prescribe considerably more antibiotics for several selected conditions than would be expected based on guidelines and expert

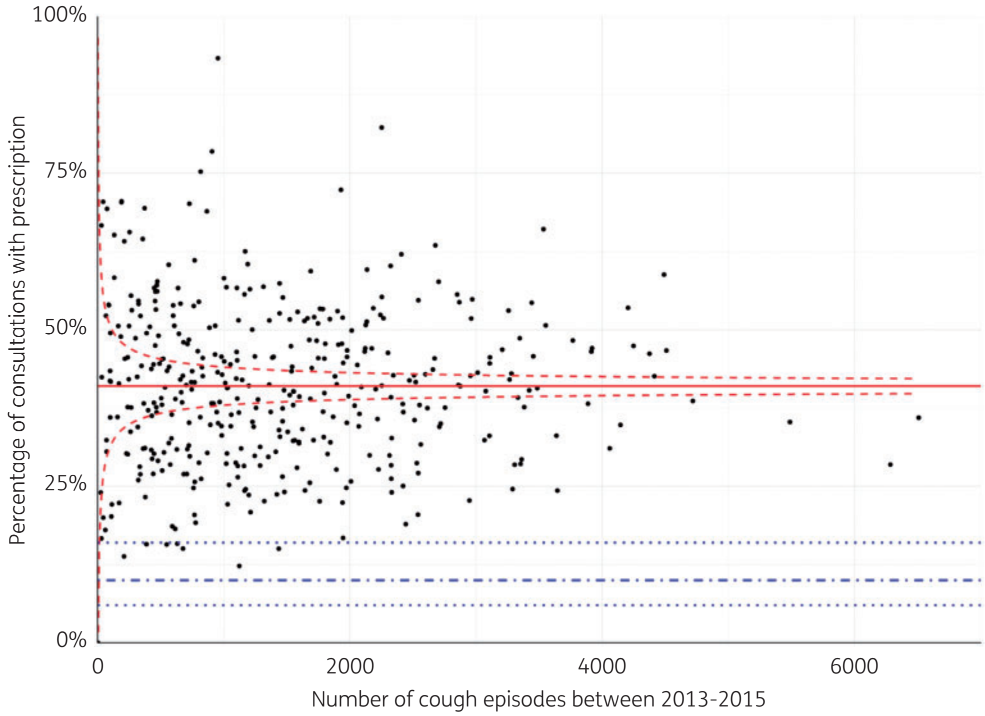


**Figure 1.** Proportion of acute cough consultations resulting in an antibiotic prescription on the same day among patients without comorbidity. Each dot represents a practice. The solid red line represents the weighted mean (41%) and the dashed red lines its 95% CI. The blue dotted/dashed line represents the ideal prescribing proportion based on the expert elicitation and the blue dotted lines its IQR.

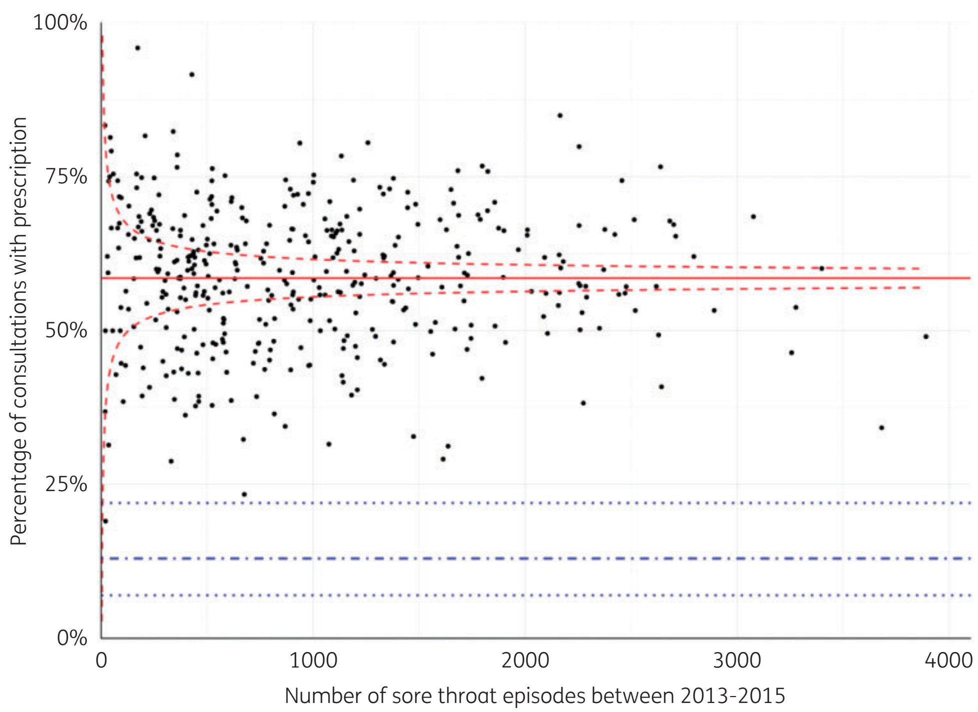


**Figure 2.** Proportion of sore throat consultations resulting in an antibiotic prescription on the same day among patients without comorbidity. Each dot represents a practice. The solid red line represents the weighted mean (59%) and the dashed red lines its 95% CI. The blue dotted/dashed line represents the ideal prescribing proportion based on the expert elicitation and the blue dotted lines its IQR.

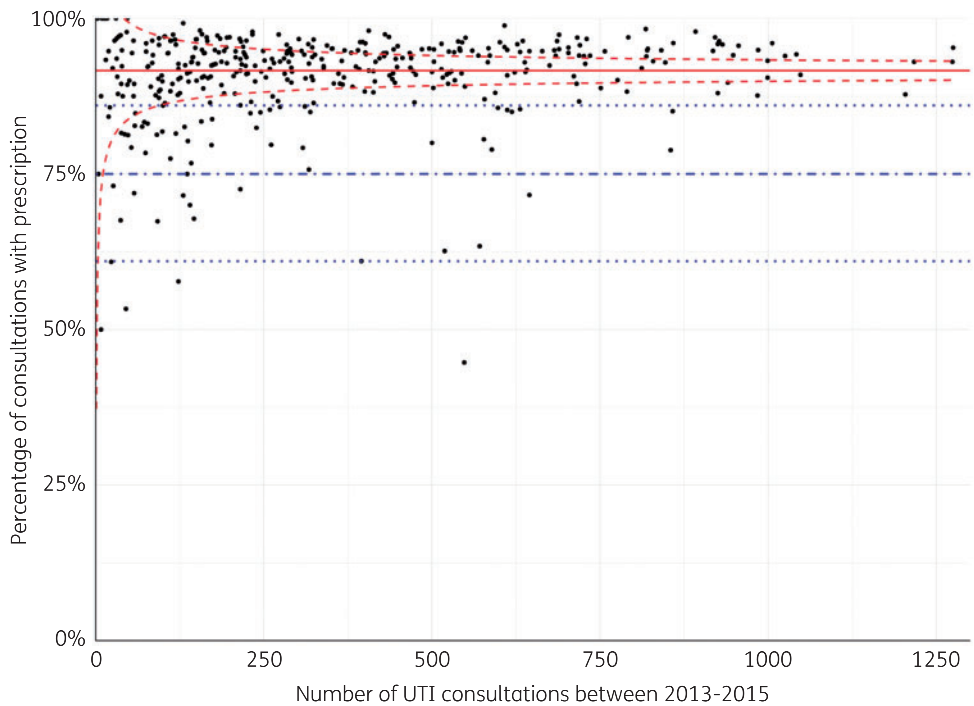


**Figure 3.** Proportion of urinary tract infection consultations resulting in an antibiotic prescription on the same day among female patients aged >14 years without comorbidity. Each dot represents a practice. The solid red line represents the weighted mean (92%) and the dashed red lines its 95% CI. The blue dotted/dashed line represents the ideal prescribing proportion based on the expert elicitation and the blue dotted lines its IQR.

**Table 2.** Actual antibiotic prescribing proportions among patients with comorbidities consulting at a general practice

| Condition | Consultations (*n*) | Proportion of consultations with a systemic antibiotic prescription (95% CI) |
|---|---|---|
| Acne | 6075 | 0.42 (0.41–0.44) |
| Acute bronchitis | 12024 | 0.87 (0.87–0.88) |
| Acute cough | 297388 | 0.54 (0.54–0.54) |
| Acute otitis media (age 0–1 year) | 422 | 0.93 (0.90–0.95) |
| Acute otitis media (age 2–18 years) | 3091 | 0.89 (0.88–0.90) |
| Acute rhinosinusitis | 25433 | 0.90 (0.90–0.90) |
| Acute sore throat | 71536 | 0.47 (0.47–0.48) |
| Asthma exacerbation[a] | 5237 | 0.57 (0.56–0.59) |
| COPD exacerbation[a] | 11670 | 0.71 (0.70–0.72) |
| Gastroenteritis (age >2 years) | 55862 | 0.07 (0.07–0.07) |
| Impetigo | 4161 | 0.54 (0.52–0.55) |
| Influenza-like illness | 5538 | 0.28 (0.26–0.29) |
| Lower respiratory tract infection | 165314[b] | 0.86 (0.85–0.86) |
| Upper respiratory tract infection | 80036[c] | 0.42 (0.42–0.43) |
| Urinary tract infection | 54286 | 0.90 (0.90–0.90) |

[a]Only comorbidities other than chronic respiratory and ignored steroids.
[b]Including non-specific LRTI, COPD exacerbations, acute bronchitis and pneumonia.
[c]Including non-specific URTI, common cold, laryngitis and tracheitis.

**Table 3.** Proportion of consultations followed by a systemic antibiotic prescription within 30 days

| Condition | Consultations (*n*) | Proportion of consultations followed by a systemic antibiotic within 30 days (95% CI) |
|---|---|---|
| Acute bronchitis | 16661 | 0.89 (0.89–0.90) |
| Acute cough | 555380 | 0.48 (0.48–0.48) |
| Acute otitis media (age 0–2 years) | 21050 | 0.93 (0.93–0.94) |
| Acute otitis media (age 3–18 years) | 31723 | 0.90 (0.89–0.90) |
| Acute rhinosinusitis | 72302 | 0.90 (0.89–0.90) |
| Acute sore throat | 375456 | 0.63 (0.63–0.64) |
| Gastroenteritis (age >2 years) | 110913 | 0.13 (0.12–0.13) |
| Impetigo | 28885 | 0.58 (0.58–0.59) |
| Influenza-like illness | 23065 | 0.29 (0.28–0.29) |
| Lower respiratory tract infection[a] | 155568 | 0.89 (0.89–0.90) |
| Upper respiratory tract infection[b] | 371627 | 0.34 (0.34–0.34) |
| Urinary tract infection | 133023 | 0.94 (0.94–0.94) |

[a]Including non-specific LRTI, COPD exacerbations, acute bronchitis and pneumonia.
[b]Including non-specific URTI, common cold, laryngitis and tracheitis.

opinion.[15,16,18,20] In particular, the proportions of patients receiving antibiotics for sore throat, otitis media and rhinosinusitis were much higher than primary care experts would consider appropriate levels of antibiotic prescribing. In line with expectations, the percentages of patients receiving antibiotics were generally higher among patients with comorbidities than among patients without comorbidities. This difference was especially prominent for URTI, ILI and acute cough.

The high proportion of patients receiving antibiotics for respiratory conditions that should, in the majority of cases, not result in an antibiotic prescription has been previously observed by others in the UK.[21,35,36] Using 1998–2001 data, Petersen *et al.*[35] observed antibiotic prescribing percentages of 64% for sore throat, 85% for rhinosinusitis and 44% for URTI. Between 2010 and 2012, among adults aged 18–59 years, Gulliford *et al.*[36] found median antibiotic prescribing percentages of 60% for sore throat, 91% for rhinosinusitis and 38% for colds and URTI. Hawker *et al.*[21] estimated the prescribing proportions in 2011 to be 62% for sore throat, 51% for cough/cold and 56% for URTI. Although there may be differences in the patient populations included, time periods included, definitions of respiratory conditions, and databases used, together these studies suggest that there is substantial overprescribing of antibiotics for several respiratory conditions. Our findings indicate that this has not improved substantially since these previous studies, with prescribing proportions of 41% for cough, 88% for rhinosinusitis and 59% for sore throat. The proportion of acne consultations with an antibiotic prescription (the same antibiotics we considered for acne) has been previously assessed using 2004–13 UK data.[26] Approximately 33%–34% of new acne consultations resulted in an oral antibiotic prescription on the same day.[26] Although that study was based on a different database and time period, estimates for new acne consultations are relatively close to our estimate (37%).

Similarly, Boggon *et al.*[14] previously assessed the proportion of COPD exacerbation cases being prescribed an antibiotic among patients aged $\geq$40 years between 2005 and 2010 in the UK. Of exacerbation cases, 61% were prescribed antibiotics.[14] When restricted to the same age category our data give a prescribing proportion of 72%. The higher estimate in our study may be explained by differences in Read codes used to select COPD exacerbations, databases used, study periods and the definition of new episodes of COPD exacerbations (no COPD exacerbation in the prior 30 days versus prior 28 days).

Although guidelines recommend against routine use of antibiotics to treat asthma attacks,[37] 47% of acute asthma exacerbations were treated with a systemic antibiotic. This prescribing proportion seems rather high; however, a recent randomized controlled trial evaluating the effect of azithromycin on acute asthma exacerbations among UK adults had to exclude a high number of patients because they were already receiving antibiotic therapy for their asthma exacerbation.[38] To our knowledge this is the first population-based study to confirm that in English primary care asthma exacerbations are frequently treated with antibiotics.

This study has several strengths. The current analyses are based on a large, representative sample of English general practices. Moreover, prescribing proportions were evaluated for various conditions, which allows identification of overprescribing for other conditions than the usual RTI conditions included in previous studies. Comparisons with appropriate levels of antibiotic prescribing estimated by primary care experts[15,16] make it possible to identify additional areas with a high propensity for overprescribing, and thus areas for future focus.

Furthermore, prescribing proportions were evaluated among patients with and without comorbidities. Several guidelines suggest that antibiotics may be appropriate for patients with comorbidities.[18–20] Hence, by restricting to patients without comorbidity who did not receive inhaled/systemic steroid or immunosuppressive prescriptions in the year before the consultation, low antibiotic prescribing proportions should be obtained for conditions where guidelines do not recommend antibiotics for most patients.

This study also has some limitations. First, we did not have reliable information about whether the prescriptions were intended as delayed prescriptions. Although there are Read codes to identify deferred antibiotic therapy, these codes are rarely used.[36] Nevertheless it is not likely that delayed prescribing would completely explain the observed high prescribing rates.[36,39]

Second, it is possible that general practitioners are more likely to code a diagnosis or symptom when they prescribe an antibiotic than when they decide not to prescribe. This would bias the prescribing proportions upwards. However, expected low prescribing proportions for conditions such as gastroenteritis indicate that seemingly high prescribing proportions for other conditions might be true and not substantially biased due to coding practices.

Third, in the primary analysis we focused on antibiotic prescriptions given on the same day as the consultation. When comparing with ideal prescribing proportions obtained via the expert elicitation,[16] one should take into account that these latter estimates included antibiotics prescribed during the entire episode of the condition. To assess potential prescriptions that are prescribed for the same episode at a subsequent consultation, antibiotic prescribing within 30 days of the first consultation was assessed. Although it is possible that some of these antibiotics were prescribed for other, unrelated conditions, the sensitivity analysis showed that antibiotic prescribing proportions would increase if the whole duration of the episode was taken into account. Related to this, to increase the likelihood that antibiotic prescriptions within 90 days of an acne consultation were actually issued for acne, we restricted analysis to a selected subset of systemic antibiotics.[26]

Fourth, the ideal prescribing proportions estimated by expert elicitation[16] may not be the true ideal prescribing proportions for the included practices. However, these estimates are in line with acceptable ranges of prescribing proportions estimated by European experts[15] and estimates obtained via an online survey among antibiotic prescribers in the UK.[16] The observation that there is substantial overprescribing for several conditions is further supported by guidelines and randomized controlled trials indicating that antibiotic treatment is necessary in only a small proportion of patients without comorbidity consulting for sore throat, rhinosinusitis, acute cough, acute bronchitis and AOM.[18–20,40–44]

## Conclusions

The results of this study show that the majority of English practices prescribe considerably more antibiotics than would be expected based on guidelines and expert opinion of ideal prescribing levels. The proportions of patients receiving antibiotics for sore throat, otitis media and rhinosinusitis were particularly high compared with expected 'ideal' proportions, especially given the fact that the current analyses were restricted to patients without comorbidities and without potential complicating factors. This research highlights that there is a large potential to lower antibiotic prescribing in English primary care.

## Acknowledgements

The authors are grateful for the support of a group of subject matter experts who formed a Modelling Oversight Group (MOG) that convened bimonthly to discuss and review this work. Group members are listed in another paper of this Supplement.[34] J. V. R. is affiliated with the National Institute for Health Research Health Protection Research Units (NIHR HPRU) in Healthcare Associated Infection and Antimicrobial Resistance at both Imperial College London and University of Oxford in partnership with PHE. Further, we thank Sandro Bösch for improving the figures presented in this paper.

## Funding

This paper was published as part of a Supplement supported and resourced by Public Health England (PHE). Only internal resources were used for this paper.

## Transparency declarations

J. V. R. is a co-opted member of the UK Government Advisory Committee on Antimicrobial Prescribing, Resistance and Healthcare Associated Infection (APRHAI). All other authors: none to declare.

## Supplementary data

Figures S1 to S5 and Tables S1 and S2 are available as Supplementary data at *JAC* Online.

## References

**1** Carter D, Charlett A, Conti S *et al*. A risk assessment of antibiotic pan-drug-resistance in the UK: Bayesian analysis of an expert elicitation study. *Antibiotics* 2017; **6**: 9.

**2** Public Health England. *English Surveillance Programme for Antimicrobial Utilisation and Resistance (ESPAUR)*. 2016. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/575626/ESPAUR_Report_2016.pdf.

**3** De Kraker MEA, Jarlier V, Monen JCM *et al*. The changing epidemiology of bacteraemias in Europe: trends from the European antimicrobial resistance surveillance system. *Clin Microbiol Infect* 2013; **19**: 860–8.

**4** Review on Antimicrobial Resistance. *Tackling Drug-Resistant Infections Globally*. https://amr-review.org/Publications.html.

**5** GOV.UK. *G7 2016 in Japan: PM Press Statement*. 2016. https://www.gov.uk/government/speeches/g7-2016-in-japan-pm-press-statement.

**6** Tyrstrup M, van der Velden A, Engstrom S *et al*. Antibiotic prescribing in relation to diagnoses and consultation rates in Belgium, the Netherlands and Sweden: use of European quality indicators. *Scand J Prim Health Care* 2017; **35**: 10–8.

**7** Kronman MP, Zhou C, Mangione-Smith R. Bacterial prevalence and antimicrobial prescribing trends for acute respiratory tract infections. *Pediatrics* 2014; **134**: e956–65.

**8** Fleming-Dutra KE, Hersh AL, Shapiro DJ *et al*. Prevalence of inappropriate antibiotic prescriptions among US ambulatory care visits, 2010-2011. *JAMA* 2016; **315**: 1864–73.

**9** Dekker ARJ, Verheij TJM, van der Velden AW. Inappropriate antibiotic prescription for respiratory tract indications: most prominent in adult patients. *Fam Pract* 2015; **32**: 401–7.

**10** Neumark T, Brudin L, Engström S *et al*. Trends in number of consultations and antibiotic prescriptions for respiratory tract infections between 1999 and 2005 in primary healthcare in Kalmar County, Southern Sweden. *Scand J Prim Health Care* 2009; **27**: 18–24.

**11** Neumark T, Brudin L, Mölstad S. Use of rapid diagnostic tests and choice of antibiotics in respiratory tract infections in primary healthcare—a 6-y follow-up study. *Scand J Infect Dis* 2010; **42**: 90–6.

**12** Pouwels KB, Dolk FCK, Smith DRM *et al*. Explaining variation in antibiotic prescribing between general practices in the UK. *J Antimicrob Chemother* 2018; **73** Suppl 2: ii27–35.

**13** Ashworth M, Charlton J, Ballard K *et al*. Variations in antibiotic prescribing and consultation rates for acute respiratory infection in UK general practices 1995-2000. *Br J Gen Pract* 2005; **55**: 603–8.

**14** Boggon R, Hubbard R, Smeeth L *et al*. Variability of antibiotic prescribing in patients with chronic obstructive pulmonary disease exacerbations: a cohort study. *BMC Pulm Med* 2013; **13**: 32.

**15** Adriaenssens N, Coenen S, Tonkin-Crine S *et al*. European Surveillance of Antimicrobial Consumption (ESAC): disease-specific quality indicators for outpatient antibiotic prescribing. *BMJ Qual Saf* 2011; **20**: 764–72.

**16** Smith DRM, Dolk FCK, Pouwels KB *et al*. Defining the appropriateness and inappropriateness of antibiotic prescribing in primary care. *J Antimicrob Chemother* 2018; **73** Suppl 2: ii11–8.

**17** OpenPrescribing. *BNF Section 5.1: Antibacterial Drugs*. https://openprescribing.net/bnf/0501/.

**18** NICE. *Clinical Knowledge Summaries (CKS)*. 2017. https://cks.nice.org.uk/#?char=A.

**19** NICE. *Respiratory Tract Infections (Self-Limiting): Prescribing Antibiotics. Guidance and Guidelines*. 2008. https://www.nice.org.uk/guidance/CG69.

**20** Public Health England. *Managing Common Infections: Guidance for Primary Care*. 2017. https://www.gov.uk/government/publications/managing-common-infections-guidance-for-primary-care.

**21** Hawker JI, Smith S, Smith GE *et al*. Trends in antibiotic prescribing in primary care for clinical syndromes subject to national recommendations to reduce antibiotic resistance, UK 1995-2011: analysis of a large database of primary care consultations. *J Antimicrob Chemother* 2014; **69**: 3423–30.

**22** Bourke A, Dattani H, Robinson M. Feasibility study and methodology to create a quality-evaluated database of primary care data. *Inform Prim Care* 2004; **12**: 171–7.

**23** Blak BT, Thompson M, Dattani H *et al*. Generalisability of The Health Improvement Network (THIN) database: demographics, chronic disease prevalence and mortality rates. *Inform Prim Care* 2011; **19**: 251–5.

**24** Maguire A, Blak BT, Thompson M. The importance of defining periods of complete mortality reporting for research using automated data from primary care. *Pharmacoepidemiol Drug Saf* 2009; **18**: 76–83.

**25** UCL. THIN Database. http://www.ucl.ac.uk/pcph/research-groups-themes/thin-pub/database.

**26** Francis NA, Entwistle K, Santer M *et al*. The management of acne vulgaris in primary care: a cohort study of consulting and prescribing patterns using the Clinical Practice Research Datalink. *Br J Dermatol* 2017; **176**: 107–15.

**27** Cope AL, Chestnutt IG, Wood F *et al*. Dental consultations in UK general practice and antibiotic prescribing rates: a retrospective cohort study. *Br J Gen Pract* 2016; **66**: e329–36.

**28** Berni E, Butler CC, Jenkins-Jones S *et al*. Comparative estimated effectiveness of antibiotic classes as initial and secondary treatments of respiratory tract infections: longitudinal analysis of routine data from UK primary care 1991-2012. *Curr Med Res Opin* 2016; **32**: 1023–32.

**29** Berni E, Scott L, Jenkins-Jones S *et al*. Non-response to antibiotic treatment in adolescents for four common infections in UK primary care 1991–2012: a retrospective, longitudinal study. *Antibiotics* 2016; **5**: 25.

**30** Currie CJ, Berni E, Jenkins-Jones S *et al*. Antibiotic treatment failure in four common infections in UK primary care 1991-2012: longitudinal analysis. *BMJ* 2014; **349**: g5493.

**31** GOV.UK. *Influenza: The Green Book, Chapter 19*. 2015. https://www.gov.uk/government/publications/influenza-the-green-book-chapter-19.

**32** NHS Employers Seasonal Influenza Vaccination Programme Read Codes Used for Payment. 2015. http://www.nhsemployers.org/~/media/Employers/Documents/Primary%20care%20contracts/V%20and%20I/V%20and%20I%20Home%20Page/15-16%20Seasonal%20flu%20at%20risk%20Read%20codes.xlsx.

**33** Dolk FCK, Pouwels KB, Smith DRM *et al*. Antibiotics in primary care in England: which antibiotics are prescribed and for which conditions? *J Antimicrob Chemother* 2018; **73** Suppl 2: ii2–10.

**34** Smieszek T, Pouwels KB, Dolk FCK *et al*. Potential for reducing inappropriate antibiotic prescribing in English primary care. *J Antimicrob Chemother* 2018; **73** Suppl 2: ii36–43.

**35** Petersen I, Hayward AC; SACAR Surveillance Subgroup. Antibacterial prescribing in primary care. *J Antimicrob Chemother* 2007; **60**: i43–7.

**36** Gulliford MC, Dregan A, Moore MV *et al*. Continued high rates of antibiotic prescribing to adults with respiratory tract infection: survey of 568 UK general practices. *BMJ Open* 2014; **4**: e006245.

**37** British Thoracic Society. *British Guideline on the Management of Asthma*. 2016. https://www.brit-thoracic.org.uk/document-library/clinical-information/asthma/btssign-asthma-guideline-2016/.

**38** Johnston SL, Szigeti M, Cross M *et al*. Azithromycin for acute exacerbations of asthma. *JAMA Intern Med* 2016; **176**: 1630–7.

**39** Little P, Stuart B, Hobbs FDR *et al*. Antibiotic prescription strategies for acute sore throat: a prospective observational cohort study. *Lancet Infect Dis* 2014; **14**: 213–9.

**40** Little P, Stuart B, Moore M *et al*. Amoxicillin for acute lower-respiratory-tract infection in primary care when pneumonia is not suspected: a 12-country, randomised, placebo-controlled trial. *Lancet Infect Dis* 2013; **13**: 123–9.

**41** Kenealy T, Arroll B. Antibiotics for the common cold and acute purulent rhinitis. *Cochrane Database Syst Rev* 2013; issue **6**: CD000247.

**42** Spinks A, Glasziou PP, Del Mar CB. Antibiotics for sore throat. *Cochrane Database Syst Rev* 2013; issue **11**: CD000023.

**43** Venekamp RP, Sanders SL, Glasziou PP *et al*. Antibiotics for acute otitis media in children. *Cochrane Database Syst Rev* 2015; issue **6**: CD000219.

**44** Lemiengre MB, van Driel ML, Merenstein D *et al*. Antibiotics for clinically diagnosed acute rhinosinusitis in adults. *Cochrane Database Syst Rev* 2014; issue **2**: CD000243.