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Late-career Physicians Prescribe Longer Courses of Antibiotics

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(See the Editorial Commentary by Wald-Dickler and Spellberg on pages 1476–9.)

Background. Antibiotic duration is often longer than necessary. Understanding the reasons for variability in antibiotic duration can inform interventions to reduce prolonged antibiotic use. We aim to describe patterns of interphysician variability in prescribed antibiotic treatment durations and determine physician predictors of prolonged antibiotic duration in the community setting.

Methods. We performed a retrospective cohort analysis of family physicians in Ontario, Canada, between 1 March 2016 and 28 February 2017, using the Xponent dataset from IQVIA. The primary outcome was proportion of prolonged antibiotic course prescribed, defined as >8 days of therapy. We used multivariable logistic regression models, with generalized estimating equations to account for physician-level clustering to evaluate predictors of prolonged antibiotic courses.

Results. There were 10 616 family physicians included in the study, prescribing 5.6 million antibiotic courses. There was substantial interphysician variability in the proportion of prolonged antibiotic courses (median, 33.3%; interdecile range, 13.5%–60.3%). In the multivariable regression model, later physician career stage, rural location, and a larger pediatric practice were significantly associated with greater use of prolonged courses. Prolonged courses were more likely to be prescribed by late-career physicians (adjusted odds ratio [aOR], 1.48; 95% confidence interval, 1.38–1.58) and mid-career physicians (aOR, 1.25; 1.16–1.34) when compared to early-career physicians.

Conclusions. We observed substantial variability in prescribed antibiotic duration across family physicians, with durations particularly long among late-career physicians. These findings highlight opportunities for community antimicrobial stewardship interventions to improve antibiotic use by addressing practice differences in later-career physicians.

Keywords. antibiotics; treatment duration; outpatient; antimicrobial stewardship.

For the last few decades, antibiotic-resistant organisms have steadily been emerging and spreading globally to become a serious worldwide public health concern. Due to the continuous increase in antimicrobial resistance and the scarcity of research and development of new antimicrobial agents, current efforts to reduce antimicrobial resistance focus on optimizing antibiotic use. In this context, antimicrobial stewardship, "a coherent set of actions which promote using antimicrobials responsibly" [1], has become an essential pillar in addressing antimicrobial resistance. The principles of antimicrobial stewardship include using antibiotics only when appropriate, selecting the optimal agent at the correct dose, and treating patients for the appropriate duration [2].

Evidence across healthcare sectors suggests that antibiotic duration is often longer than necessary [3], with shorter courses being equally effective as prolonged courses for many common bacterial infections with less adverse effects [4–8]. Excessive length of antibiotic treatment promotes antimicrobial resistance by increasing selective pressure on bacterial organisms, in turn, causing a more rapid adaptive response [9]. Furthermore, prolonged antibiotic therapy produces changes in the functionality of the intestinal microbiota, which facilitates colonization of antibiotic-resistant organisms [10]. Promoting shorter courses of antibiotics is a potential stewardship strategy that is likely safe and acceptable to physicians and reduces selective pressure by limiting the exposure time to antibiotics [9–11]. Understanding patterns of variability in prescribed antibiotic durations will support the utility of an intervention and help define subgroups of physicians who are most in need of practice improvement.

The large majority of all antibiotic prescriptions occurs in the outpatient setting, and family physicians prescribe generally the highest volume of antibiotic courses [12, 13]. If prolonged antibiotic duration in the community is associated with physician factors, antibiotic duration represents an important opportunity to manage antimicrobial stewardship activities and improve antibiotic use, in turn, contributing to the reduction in antimicrobial resistance [5, 14]. Thus, we aim to describe patterns of interphysician variability in prescribed antibiotic

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treatment durations and determine predictors of prolonged antibiotic duration in the community setting.

METHODS

Setting, Population, and Dataset

This study was conducted in Ontario, Canada's most populous province, with 14.2 million people and approximately 30 000 physicians [15]. We performed a retrospective cohort study of Ontario family physicians who prescribed oral antibiotics in the community between 1 March 2016 and 28 February 2017. This study used the Xponent dataset from IQVIA (formerly QuintilesIMS), which captures 61.3% of outpatient prescriptions dispensed in Ontario. IQVIA supplements this database with insurance claims and antibiotic sales data. IQVIA projects to 100% coverage of all prescriptions using a proprietary, routinely validated geospatial extrapolation algorithm to estimate prescriptions from the nonsample based on the volume of prescriptions from surrounding pharmacies and the geographical distance between the captured and noncaptured stores [16]. Therefore, these data are representative of all oral outpatient antibiotic courses dispensed in the community settings of Ontario during the study period. IQVIA uses the days supplied field to determine duration of antibiotic therapy. This methodology is routinely internally validated [13], and their hospital sales data have been previously validated [17]. Outpatient antibiotic data from IQVIA represent the most complete population-based source of data in many jurisdictions [12, 13] but, to our knowledge, has not been externally validated.

Inclusion Criteria, Definitions, and Outcomes

For the purposes of the study, we included only active family physician prescribers, defined as those physicians who prescribed >75 antibiotic courses during the study period. We excluded low-frequency prescribers for whom we were not able to obtain precise estimates of their prescribing behavior. This cutoff only represented 5% of all antibiotic courses. All dispensed antibiotics were prescribed via oral route and placed into the following classes and subclasses: penicillin with beta-lactamase inhibitor, penicillin without beta-lactamase inhibitor, first-generation cephalosporins, second- or third-generation cephalosporins, fluoroquinolones, extended-spectrum fluoroquinolones, macrolides, trimethoprim and/or sulfonamides, tetracyclines, lincosamides, nitrofurantoin, metronidazole, and others. We also applied a second classification to categorize antibiotics in 3 groups: "all" (encompassing all the classes and subclasses), "respiratory antibiotics" (penicillins with and without beta-lactamase inhibitor, cephalosporins, macrolides, extended-spectrum fluoroquinolones), and "urinary antibiotics" (fluoroquinolones, trimethoprim and/or sulfonamides, and nitrofurantoin) based on the most common indication for these agents (Supplementary Table S1). Antibiotic treatment duration was categorized in the following ranges: 1–4 days, 5–6 days, 7–8 days, 9–10 days, 11–14 days, 15–29 days, and ≥30 days. Antibiotic courses did not include refilled prescriptions. We conservatively defined prolonged duration of treatment as >8 days of therapy, as most common community bacterial infections can be effectively treated with antibiotic durations that do not exceed 8 days [4–8]. We selected this higher cutoff to include more potentially inappropriately prolonged courses of therapy since the dataset does not have indication for treatment. As a sensitivity analysis, we also analyzed the data using a cutoff of >6 days of therapy.

Exposures and Covariates

We examined whether physician, regional, and practice characteristics were predictors of prolonged antibiotic duration.

Physician Characteristics

We evaluated physician gender and career stage, defined as years since graduation from medical school: early, <11 years; mid, 11 to 24 years; or late, ≥25 years.

Regional Characteristics

We included variables of urban vs rural area of practice and community physician density (total number of physicians per 1000 population).

Practice Characteristics

We included practice size, that is, overall antibiotic and nonantibiotic prescription volume categorized in 4 levels as follows: low, <2740 prescriptions per year; medium, 2741–5174 prescriptions per year; high, 5175–9020 prescriptions per year; and very high, >9020 prescriptions per year; total antibiotic volume, that is, total prescribed antibiotic courses categorized as follows: low, 75–325 prescriptions per year; medium, 326–650 prescriptions per year; high, 651–1450 prescriptions per year; and very high, >1450 prescriptions per year; new patient volume, that is, the proportion of new patients' prescriptions per antibiotic course prescribed; and practice complexity score based on the patient Chronic Disease Score (CDS) [18, 19]. The CDS represents a measure of the burden of comorbid diseases, ranges from 1 to 21, and additionally informs about a patient's health service utilization. This index was transformed into a 3-level scale at the physician level (high, medium, and low level of practice complexity for scores ≤4, 5, and ≥6, respectively, based on the mean score of their patient population). The proportion of patients treated by each prescriber in different sex and age groups were also included as follows: male aged <18 years, female aged <18 years, male aged 18–64 years, female aged 18–64 years, male aged ≥65 years, and females aged ≥65 years.

Statistical Analyses

The unit of analysis was at the antibiotic prescription level. Variability in antibiotic treatment duration by prescriber was described as a mean proportion (%) of total antibiotic courses by duration range. We generated crude and adjusted multivariable logistic regression models, with generalized estimating equations to account for physician-level clustering, in order to estimate predictors of prolonged antibiotic treatment durations. All covariates were a priori included in the model based on their potential clinical significance to antibiotic duration. These variables were physician gender and career stage, geographic area of practice, community physician density, practice size, total antibiotic volume, new patient volume, practice complexity score, and patient age and sex (male aged <18 years, female aged <18 years, male aged 18–64 years, female aged 18–64 years, male aged ≥65 years, and females aged ≥65 years). Robust estimators and exchangeable correlation structure were used in all analyses. Sensitivity analyses were performed to evaluate predictors for prolonged durations for respiratory antibiotics only and for urinary antibiotics only using two definitions of prolonged treatment: >8 days of therapy and >6 days of therapy respectively. Spearman correlation coefficient was determined between physicians' use of prolonged durations for respiratory and urinary antibiotics. All analyses were performed using SPSS (v. 23.0) and R (version 3.4.2) with a 2-sided level of significance of $\alpha = .05$.

The Public Health Ontario Ethics Review Board approved the study.

RESULTS

Physician, Regional, and Practice Characteristics

During the 12-month study period, the cohort included 10 616 family physicians who prescribed a median of 295.1 (interquartile range [IQR], 117.6–610.8) antibiotic courses for a total of 5.6 million antibiotic courses. The studied physicians were 55.8% male, mostly at mid or late career (77.2%) with a median experience length of 23.0 (IQR, 12.0–33.0) years. Most medical practices were in urban areas (94.5%), and there was an average physician density of 5.3 (standard deviation, 0.8) physicians per 1000 population. Adult female patients received 56.8% of the antibiotic courses, adult males 29.6%, and children 13.5% (Table 1).

Table 1. Physician, Regional, and Practice Characteristics of the Ontarian Family Physician Active Antibiotic Prescribers (N = 10 616)

Characteristic	Results n (%)
Physician variables	
Gender	
Male	5922 (55.8)
Female	4694 (44.2)
Career Stage, median (interquartile range)[a]	23.0 (12.0–33.0)
Late career (>24 years)	4961 (46.7)
Mid-career (11–24 years)	3242 (30.5)
Early career (<11 years)	2413 (22.7)
Regional variables	
Geographic area	
Rural	581 (5.5)
Urban	10 035 (94.5)
Physicians per 1000 population, mean ± SD	5.27 ± 0.75
Practice variables	
Overall prescription volume (antibiotic and nonantibiotic)	
Very high	1112 (10.5)
High	2246 (21.2)
Medium	3524 (33.2)
Low	3734 (35.2)
Total antibiotic volume, mean ± SD[b]	529.80 ± 660.74
Very high	647 (6.1)
High	1686 (15.9)
Medium	2463 (23.2)
Low	5820 (54.8)
New patient volume[c]	
Very high	2081 (19.6)
High	3277 (30.9)
Medium	3329 (31.4)
Low	1929 (18.2)
Physician practice complexity[d]	
High score (≥6 points)	4514 (42.5)
Medium score (5 points)	4424 (41.7)
Low score (≤4 points)	1678 (15.8)
Patient sex and age, percent ± SD	
Male <18 years	6.7% ± 5.6
Female <18 years	6.8% ± 5.6
Male 18–64 years	19.5% ± 9.8
Female 18–64 years	38.9% ± 13.8
Male ≥65 years	10.1% ± 7.9
Female ≥65 years	17.9% ± 12.0

Abbreviation: SD, standard deviation.
[a]Years since graduation from medical school.
[b]Total prescribed antibiotic courses.
[c]Proportion of new patients' prescriptions per antibiotic course prescribed.
[d]Index based on the patient Chronic Disease Score.

Treatment Durations

The treatment length most commonly selected by the family physicians was 7–8 days (median, 38.4%; IQR, 26.3%–51.3%), followed by 9–10 days (25.2%; IQR, 14.8%–38.2%), and 5–6 days (17.5%; IQR, 5.4%–25.5%; Figure 1). Overall, physicians prescribed an average of 35.4% of antibiotic courses for durations that exceeded 8 days.

Antibiotic Classes

Treatment durations varied across the classes and subclasses of antibiotic agents. The largest proportion of prolonged treatment duration was seen for tetracyclines (78.3%) followed by penicillins without beta-lactamase inhibitor (51.4%) and penicillins with beta-lactamase inhibitor (48.4%). Nitrofurantoin (15.3%) and macrolides (19.6%) were the lowest proportion of prolonged treatment duration (Supplementary Table S2).

Interphysician Variability in Prolonged Treatment Duration

There was substantial interphysician variability in the proportion of prolonged antibiotic courses (median, 33.3%; IQR,

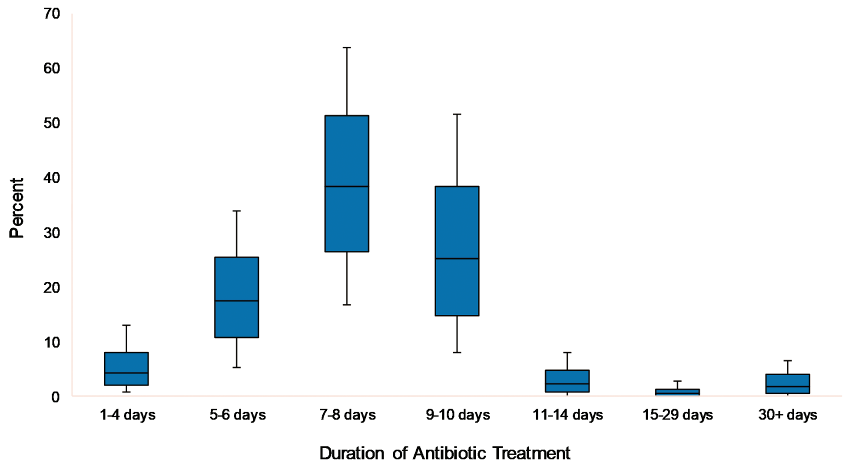

Figure 1. Distribution of prescriber antibiotic durations. The box plots represent the average antibiotic durations prescribed by family physicians in Ontario (N = 10 616). The black lines represent the median prescribed antibiotic duration, and the whiskers represent the 10th and 90th percentiles. Family physicians prescribed 35% of antibiotic courses for a prolonged duration using our definition of >8 days representing a prolonged course.

21.9%–47.2%; interdecile range, 13.5%–60.3%), especially for those in late-career stage. Figure 2 graphically demonstrates this variability between the most active family physician prescribers of the cohort (N = 2333) who accounted for 50% of all antibiotic use. Physicians' use of prolonged durations for respiratory antibiotics was correlated with their use of prolonged durations of urinary antibiotics (Figure 2; Spearman rho = 0.44; $P < .001$).

Predictors of Prolonged Antibiotic Courses

The bivariate analysis showed that family physicians at late-, mid-, and early-career stages prescribed prolonged antibiotic courses for 38.6%, 34.4%, and 30.5%, respectively (Table 2). This association persisted after multivariable adjustment (late-career stage: adjusted odds ratio [aOR], 1.48; 95% confidence interval [CI], 1.38–1.58; mid-career stage: aOR, 1.25; 95% CI, 1.16–1.34 compared to early-career stage). The multivariable model also revealed that physicians in rural locations were more likely to select prolonged duration treatment than those in urban areas (aOR, 1.15; 95% CI, 1.01–1.30). Additionally, prolonged antibiotic courses were more likely to be prescribed by physicians with more comorbid patients (aOR, 1.06; 95% CI, 1.01–1.12 per 1-point increase in CDS). Family physicians who saw proportionally more children were also significantly more likely to prescribe prolonged durations (males aged <18 years, 1.20; 95% CI, 1.16–1.25, and females aged <18 years, 1.12; 95% CI 1.08–1.16; Table 2).

Sensitivity Analyses

To test the robustness of our findings, we evaluated predictors of prolonged durations separately for the subgroups of respiratory and urinary antibiotics. Physician career stage was consistently significantly associated with a higher likelihood of prolonged antibiotic duration for >8 days (Table 3) and for >6 days (Supplementary Table S3).

DISCUSSION

In this cohort study of more than 10 000 Ontario family physicians, our results revealed substantial interphysician variability in the proportion of prolonged antibiotic treatment durations. We found that more than one third of the antibiotic courses prescribed by family physicians were prolonged beyond 8 days. After adjustment for several variables (physician, regional, and practice

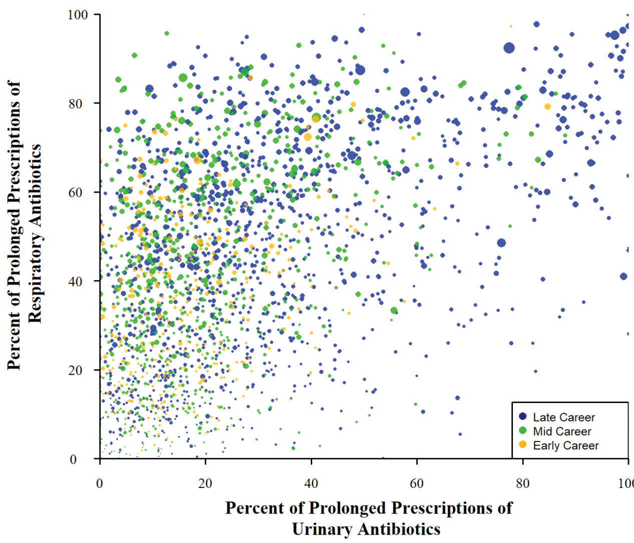

Figure 2. Correlations of prolonged courses of respiratory antibiotics vs prolonged courses of urinary antibiotics. The scatterplot represents the most active family doctor prescribers (>650 antibiotic courses per year), which accounts for 50% of all antibiotic use. Each prescriber (n = 2333) is represented by a color dot according their career stage (early, <11 years; mid, 11–24 years; and late, >24 years), with dot size proportional to antibiotic volume. Comparisons between career stage groups were significant ($P < .001$). Respiratory antibiotics were defined as penicillin with and without beta-lactamase inhibitor, second- or third-generation cephalosporins, extended-spectrum fluoroquinolones, and macrolides. Urinary antibiotics were defined as fluoroquinolones, trimethoprim and/or sulfonamides, and nitrofurantoin.

Table 2. Bivariate and Multivariable Logistic Regression Models Using Generalized Estimating Equation Evaluating Predictors of Prolonged Antibiotic Courses

		Bivariate Analyses		Multivariate Logistic Regression	
Variables	Proportion of Prolonged Antibiotic Courses (Mean ± Standard Deviation)	Crude OR	95% CI	Adjusted OR	95% CI
Physician variables (N = 10 616)					
Gender					
Male	36.7% ± 19.3%	**1.13**	(1.09–1.16)	1.02	(0.96–1.08)
Female	34.0% ± 16.5%	Ref.	Ref.	Ref.	Ref.
Career stage					
Late career (>24 years)	38.6% ± 19.8%	**1.44**	(1.39–1.49)	**1.48**	(1.38–1.58)
Mid-career (11–24 years)	34.4% ± 17.2%	**1.19**	(1.15–1.24)	**1.25**	(1.16–1.34)
Early career (<11 years)	30.5% ± 13.9%	Ref.	Ref.	Ref.	Ref.
Regional variables					
Geographic area					
Rural	38.0% ± 17.8%	**1.12**	(1.05–1.19)	**1.15**	(1.01–1.30)
Urban	35.3% ± 18.1%	Ref.	Ref.	Ref.	Ref.
Physicians per 1000 population	…	**1.04**	(1.02–1.06)	1.04	(0.99–1.08)
Practice variables					
Overall prescription volume (antibiotic and nonantibiotic)					
Very high	37.5% ± 22.3%	**1.21**	(1.14–1.28)	1.10	(0.96–1.28)
High	37.5% ± 20.2%	**1.21**	(1.16–1.27)	1.01	(0.93–1.10)
Medium	35.9% ± 17.9%	**1.13**	(1.09–1.17)	**1.05**	(1.01–1.09)
Low	33.2% ± 20.0	Ref.	Ref.	Ref.	Ref.
Total antibiotic volume					
Very high	37.4% ± 22.3%	**1.13**	(1.05–1.22)	0.90	(0.78–1.03)
High	37.4% ± 22.2%	**1.13**	(1.08–1.18)	**0.93**	(0.87–0.99)
Medium	35.7% ± 17.9%	**1.05**	(1.01–1.09)	0.97	(0.94–1.01)
Low	34.6% ± 17.0%	Ref.	Ref.	Ref.	Ref.
New patient volume					
Very high	36.1% ± 17.0%	1.03	(0.98–1.09)	1.00	(0.96–1.04)
High	36.4% ± 17.4%	1.05	(1.00–1.10)	1.01	(0.98–1.04)
Medium	34.2% ± 17.7%	0.95	(0.91–1.00)	1.01	(0.97–1.04)
Low	35.4% ± 20.9%	Ref.	Ref.	Ref.	Ref.
Physician practice complexity					
High score (≥6 points)	35.0% ± 17.8%	**1.05**	(1.01–1.10)	**1.06**	(1.01–1.12)
Medium score (5 points)	36.6% ± 18.3%	**1.13**	(1.08–1.18)	**1.08**	(1.05–1.12)
Low score (≤4 points)	33.8% ± 18.4%	Ref.	Ref.	Ref.	Ref.
Patient sex and age					
Male <18 years	45.8% ± 31.6%	**1.15**	(1.12–1.17)	**1.20**	(1.16–1.25)
Female <18 years	43.3% ± 30.3%	**1.03**	(1.01–1.06)	**1.12**	(1.08–1.16)
Male 18–64 years	32.8% ± 18.6%	**0.67**	(0.66–0.68)	**0.70**	(0.69–0.72)
Female 18–64 years	37.7% ± 25.1%	**0.83**	(0.81–0.84)	**0.87**	(0.83–0.92)
Male ≥65 years	28.4% ± 20.1%	**0.54**	(0.53–0.55)	**0.58**	(0.55–0.61)
Female ≥65 years	42.2% ± 23.2%	Ref.	Ref.	Ref.	Ref.

Bold values are statistically significant at *P* values <.05.

Abbreviations: CI, confidence interval; OR, odds ratio; Ref., reference.

characteristics), we found that later physician career stage was significantly associated with prolonged antibiotic treatment.

Multiple studies have demonstrated that shorter courses of antibiotics are as effective as longer courses to treat the majority of common infections [4–8]. Decreasing unnecessary antibiotic consumption through shorter durations of therapy is a potentially effective strategy to reduce bacterial resistance [5, 14]. Dawson-Hahn et al [20] reviewed prior systematic reviews of randomized, controlled trials performed in children and adults with bacterial infections commonly treated in outpatient or

Table 3. Bivariate and Multivariable Logistic Regression Models Using Generalized Estimating Equation for Prolonged Courses of Respiratory and Urinary Antibiotics

Variables	Respiratory Drugs (n = 10 608 Physicians)			Urinary Drugs (n = 10 585 Physicians)		
	Proportion of Prolonged Antibiotic Courses (mean ± SD)	Crude OR (95% CI)	Adjusted OR (95% CI)	Proportion of Prolonged Antibiotic Courses (mean ± SD)	Crude OR (95% CI)	Adjusted OR (95% CI)
Physician variables						
Gender						
Male	40.9% ± 22.8%	**1.04** (1.01–1.08)	0.98 (0.92–1.06)	28.4% ± 21.2%	**1.44** (1.38–1.50)	**1.15** (1.08–1.23)
Female	39.9% ± 21.3%	Ref.	Ref.	21.6% ± 17.7%	Ref.	Ref.
Career stage						
Late career (>24 years)	43.8% ± 23.1%	**1.54** (1.48–1.61)	**1.40** (1.28–1.52)	30.6% ± 23.0%	**1.80** (1.71–1.88)	**1.91** (1.77–2.06)
Mid-career (11–24 years)	40.3% ± 22.0%	**1.33** (1.27–1.40)	**1.27** (1.15–1.40)	21.7% ± 16.5%	**1.13** (1.07–1.18)	**1.22** (1.12–1.31)
Early career (<11 years)	33.6% ± 18.3%	Ref.	Ref.	19.7% ± 14.4%	Ref.	Ref.
Regional variables						
Geographic area						
Rural	42.1% ± 22.1%	1.08 (1.00–1.16)	**1.16** (1.02–1.33)	29.4% ± 20.3%	**1.24** (1.14–1.34)	**1.20** (1.03–1.40)
Urban	40.3% ± 22.1%	Ref.	Ref.	25.2% ± 20.0%	Ref.	Ref.
Physicians per 1000 population		1.01 (0.99–1.03)	1.02 (0.97–1.08)		**1.04** (1.02–1.07)	1.03 (0.99–1.08)
Practice variables						
Overall prescription volume (antibiotic and nonantibiotic)						
Very high	42.7% ± 23.7%	**1.26** (1.18–1.34)	1.01 (0.86–1.18)	30.4% ± 22.5%	**1.49** (1.39–1.60)	**1.52** (1.19–1.95)
High	43.2% ± 22.3%	**1.28** (1.22–1.35)	1.01 (0.92–1.11)	28.5% ± 21.1%	**1.36** (1.29–1.44)	1.09 (0.94–1.25)
Medium	41.4% ± 21.3%	**1.20** (1.15–1.25)	**1.06** (1.01–1.12)	24.7% ± 19.0%	**1.12** (1.07–1.18)	1.16 (0.99–1.14)
Low	37.2% ± 22.0%	Ref.	Ref.	22.7% ± 19.0%	Ref.	Ref.
Total antibiotic volume						
Very high	45.0%± 24.3%	**1.29** (1.20–1.40)	1.07 (0.91–1.26)	23.6% ± 21.3%	0.93 (0.85–1.03)	**0.62** (0.48–0.81)
High	43.6% ± 23.0%	**1.22** (1.16–1.28)	1.01 (0.93–1.09)	27.2%± 21.6%	**1.13** (1.07–1.20)	**0.77** (0.68–0.86)
Medium	40.9%± 21.5%	**1.09** (1.05–1.14)	1.03 (0.99–1.07)	25.9% ± 19.4%	**1.06** (1.01–1.11)	**0.89** (0.83–0.96)
Low	38.8%± 21.7%	Ref.	Ref.	24.9% ± 19.6%	Ref.	Ref.
New patient volume						
Very high	41.0% ± 21.4%	1.07 (1.00–1.13)	**1.07** (1.02–1.12)	24.1% ± 17.8%	**0.85** (0.80–0.91)	**0.85** (0.80–0.91)
High	42.3% ± 21.5%	**1.12** (1.06–1.19)	**1.05** (1.02–1.09)	24.7% ± 18.0%	**0.88** (0.83–0.94)	**0.90** (0.86–0.95)
Medium	38.8% ± 21.9%	0.97 (0.92–1.03)	1.04 (1.00–1.08)	25.8% ± 20.6%	**0.93** (0.87–0.99)	0.96 (0.91–1.02)
Low	39.5% ± 24.1%	Ref.	Ref.	27.2% ± 24.1%	Ref.	Ref.
Physician practice complexity						
High score (≥6 points)	38.1% ± 21.5%	**0.88** (0.83–0.92)	1.03 (0.96–1.09)	26.5% ± 19.5%	**1.38** (1.30–1.47)	**1.22** (1.13–1.31)
Medium score (5 points)	42.5% ± 22.4%	**1.06** (1.01–1.11)	1.03 (0.99–1.08)	26.1% ± 20.5%	**1.35** (1.27–1.44)	**1.12** (1.06–1.19)
Low Score (≤4 points)	41.2% ± 22.4%	Ref.	Ref.	20.7% ± 19.4%	Ref.	Ref.
Patient sex and age						
Male <18 years	43.4% ± 32.7%	**1.40** (1.36–1.44)	**1.26** (1.17–1.36)	31.8% ± 44.0%	**1.73** (1.58–1.90)	**2.13** (1.84–2.47)
Female <18 years	42.1% ± 32.3%	**1.32** (1.28–1.36)	**1.18** (1.10–1.26)	16.2% ± 32.1%	**0.75** (0.70–0.80)	0.91 (0.81–1.01)
Male 18–64 years	42.3% ± 27.2%	**1.36** (1.34–1.39)	**1.29** (1.22–1.37)	43.2% ± 35.0%	**2.89** (2.79–2.99)	**3.20** (2.97–3.45)
Female 18–64 years	41.0% ± 24.9%	**1.29** (1.27–1.32)	**1.24** (1.17–1.30)	19.7% ± 21.8%	**0.94** (0.91–0.96)	1.04 (0.97–1.10)
Male ≥65 years	36.7% ± 29.5%	**1.08** (1.06–1.11)	**1.09** (1.07–1.12)	38.8% ± 34.6%	**2.39** (2.31–2.47)	**2.29** (2.21–2.37)
Female ≥65 years	34.9% ± 27.1%	Ref.	Ref.	20.8% ± 23.9%	Ref	Ref

Respiratory antibiotics: penicillin with and without beta-lactamase inhibitor, second- or third-generation cephalosporins, extended-spectrum fluoroquinolones, and macrolides. Urinary antibiotics: fluoroquinolones, trimethoprim and/or sulfonamides, and nitrofurantoin. Bold values are statistically significant at *P* values <.05.

Abbreviations: CI, confidence interval; OR, odds ratio; SD, standard deviation.

primary care settings to evaluate evidence of short courses vs long courses of oral antibiotics. The results of the review revealed no significant difference in the rates of clinical cure for adults and children with uncomplicated urinary tract infections and community acquired pneumonia, adults treated for acute sinusitis and acute pyelonephritis, and children treated for tonsillopharyngitis and acute otitis media when comparing shorter courses of antibiotics to longer courses. Additionally, shorter courses of antibiotics were associated with lower rates of adverse effects. Hence, given the lack of benefit and potential harm of prolonged antibiotic duration, some experts have argued to abandon the concept of a fixed antibiotic course in favor of patient-centered decision-making and increased dialogue about the harms of antibiotic overuse [21].

A study of antibiotic treatment duration in long-term care facilities found that 45% were for >7 days [22]. This is similar but slightly less than our rate of 35% since we defined prolonged duration more conservatively and long-term care residents are usually more complex than outpatients. Moreover, our study corroborates the high variability of prolonged antibiotic treatment durations across prescribers. At the physician level, our findings are in line with prior literature that found time in practice to be associated with differences in antibiotic prescribing [23, 24] and, in particular, differences in appropriateness of antibiotic prescribing [25, 26]. Prescriber tendencies to start antibiotics, prolonged treatment durations, and drug selection follow historical patterns of practice [27]. Hence, differences in antibiotic prescribing and prolonged antibiotic prescribing at different career stages may have an "educational-timing" explanation. Current late-career physicians received medical training in a period when there was limited knowledge about required lengths of therapy for most infectious diseases, with less evidence about the long-term consequences of antibiotic misuse and overuse on the community. This may explain in part the higher rate of inappropriate antibiotic initiation, selection, dosing, and duration [28]. Medical training of the current mid-career physicians occurred in an educational environment characterized by a global rising awareness of antimicrobial resistance in which quality and rational prescribing became more significant [29, 30]. The current early-career physicians have been trained in a newer prescribing culture based on the general principles of antimicrobial stewardship [31] with more evidence-based guidelines for implementation [2]. This premise is additionally supported by a previous study that identified lower individual knowledge of the implications of antibiotic overuse among later-career practitioners [32]. It is expected that late-career physicians are more likely to have older and more comorbid patients; however, our findings persisted after adjusting for these practice differences. Therefore, differences in educational background may explain the high interphysician variability in the selection of antibiotic duration treatments found in this study as well as the significant prescribing differences among late-, mid-, and early-career physicians.

Based on this, targeting later-career physicians may represent an important opportunity for antimicrobial stewardship interventions in community settings in order to reduce the proportion of prolonged antibiotic courses. Recently, Macheda et al [33] found that two-thirds of infectious diseases physicians were not routinely recommending evidenced-based short-course regimens, suggesting that education and stewardship on optimal antibiotic durations should also be directed to infectious diseases physicians. There are multiple opportunities for antimicrobial stewardship activities in the community. Lack of knowledge of recommended durations may make a physician more likely to prescribe longer antibiotic courses than necessary [34]. Hence, educational materials on appropriate durations for community infections are an important approach to reducing prolonged antibiotic regimens. Audit and feedback of prolonged prescribing data show physicians how they are performing compared to their peers in order to identify inappropriate habits related to their prescribing behavior. Therefore, peer-comparison interventions, aimed to compare prescribing data on antibiotic duration, may be another potential antimicrobial stewardship approach. The interphysician variability observed in this study supports the potential utility of this type of intervention. Effective interventions should have a multifaceted approach and involve principles of implementation science to maximize effectiveness [35, 36].

Most current and past antimicrobial stewardship interventions have focused on changing behavior after postgraduate education, once poor prescribing behavior is established. However, breaking long-standing repetitive habits such as prescribing is challenging and often requires multiple strategies [37]. While age and experience may sharpen some skills, for example, surgery performance [38], it may just harden other preferences into habits. Hence, the training stage in medical school is a crucial period for shaping behavior in prescribing as it provides the basic education for future professionals before they acquire habits. Despite this, some studies have identified gaps between skills and knowledge needed in practice and those gained at the undergraduate level, with an important proportion of students demanding more prescribing education [39, 40]. Therefore, improving antimicrobial prescribing education in undergraduate curricula may be an effective approach to prevent the development of poor habits over the course of years of practice and be a more efficient strategy for fostering rational prescribing.

Our study has some limitations. First, the Xponent dataset is based on a percentage of the total antibiotic courses dispensed. However, IQVIA supplements this data with insurance claims and sales data and applies a routinely validated geospatial projection algorithm to project the antibiotic data to 100% of the population [13, 16]. It is possible that there are some geographic differences in the extrapolated data in underserviced areas that we attempted to adjust for in the models. In addition, we only included active prescribers and excluded those prescribers who wrote fewer than 75 antibiotic courses in a community setting during the study period. Consequently, our insights may not be generalizable to occasional prescribers. However, we feel the study population is relevant to the group that should be targeted by antimicrobial stewardship programs. We categorized antibiotics as "respiratory" and "urinary" based on the most common indication for those agents; however, there will be overlap in the use of these antibiotics for different conditions. We used the definition of >8 days as our definition of a prolonged course since most infectious diseases treated with oral antibiotics can be effectively treated in less time. As a result, extrapolation of the data may be somewhat limited in certain therapies because the appropriateness of each treatment course varies by type of infection and antibiotic used. The Xponent database does not have clinical information, and we could not differentiate appropriate from inappropriate prolonged durations.

CONCLUSIONS

The use of prolonged antibiotic treatments in outpatient settings is common, particularly among those family physicians in late-career stages. Moreover, there is meaningful interphysician variability in the selection of prolonged antibiotic durations, highlighting the need for multifaceted antimicrobial stewardship interventions. Future research should evaluate the optimal community-based interventions to improve prescribing behaviors.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Author contributions. C. F. L., the primary author, was involved in design of the study, performed the data analysis and interpretation, and drafted the manuscript. K. A. B. was involved with study conception and design, assisted in data analysis and interpretation, and provided critical edits to the manuscript. B. L. was involved with study conception, design, and data interpretation and provided critical edits to the manuscript. N. D. was involved with study conception and design and data interpretation and provided critical edits to the manuscript. G. G. was involved with study conception and design, study oversight, and data interpretation and provided critical edits to the manuscript. K. L. S. was the senior author involved with study conception and design, study oversight, and data interpretation and assisted with drafting the manuscript and providing critical edits to the manuscript.

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