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TITLE PAGE

TITLE: Predictors of Potentially Suboptimal Treatment of Urinary Tract Infections (UTIs) in Long-Term Care Facilities

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RUNNING TITLE: Suboptimal UTI Treatment Predictors VA CLCs

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SUMMARY

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BACKGROUND: Suboptimal antibiotic treatment of urinary tract infection (UTI) is high in long-term care facilities (LTCFs) and likely varies between facilities, but large-scale evaluations have not been conducted.

AIM: To identify facility-level predictors of potentially suboptimal treatment of UTI in Veterans Affairs (VA) LTCFs and to quantify variation across facilities.

METHODS: We conducted a retrospective cohort study in 21,938 residents of 120 VA LTCFs (2013-2018) known as Community Living Centers (CLCs). Potentially suboptimal treatment was assessed from drug choice, dose frequency, and/or treatment duration. To identify facility characteristics predictive of suboptimal UTI treatment, we compared LTCFs with higher and lower rates of suboptimal treatment (\geq median, $<$ median) using unconditional logistic regression models. Joinpoint regression models were used to quantify the average percent difference across facilities. Multilevel logistic regression models were used to quantify variation across facilities.

FINDINGS: The rate of potentially suboptimal antibiotic treatment varied from 1.7 -34.2 per 10,000 bed days across LTCFs. The average percent difference in rates across facilities was 2.5% (95% confidence interval [CI] 2.4%-2.7%). The only facility characteristic predictive of suboptimal treatment was the incident rate of UTI per 10,000 bed days (odds ratio 4.9, 95% CI 2.3-10.3). Multilevel models demonstrated that 94% of the variation in potentially suboptimal treatment between facilities was unexplained after controlling for resident and CLC characteristics.

CONCLUSION: Potentially suboptimal UTI treatment was variable across VA LTCFs. However, most of the variation across LTCFs was unexplained. Future research should continue to investigate factors that are driving suboptimal antibiotic treatment in LTCFs.

TEXT

COUNT: 3,230

INTRODUCTION

Antibiotic stewardship, or coordinated interventions to improve and measure the appropriate use of antibiotics, is increasingly being required in all healthcare settings, including long-term care facilities (LTCFs).¹⁻⁴ There are several recommendations available for approaches to antibiotic stewardship, however unfortunately there is no “one-size fits all” approach and it remains a challenge for many facilities to implement successful antibiotic stewardship strategies, such as educational materials or meetings and treatment guidelines.^{1, 2, 5-7} Challenges for LTCFs include limited resources as compared to acute care facilities, and providers who are often off-site and have to split their time between multiple facilities.^{7, 8} Tailored approaches to antibiotic stewardship might be needed as the decision-making process surrounding antibiotic use is complex and varies widely between facilities due to many factors such as facility size and type, resources available, staffing characteristics, resident populations, and local antibiograms.⁶ Previous work has found that antibiotic use is highly variable across LTCFs as are the antibiotic stewardship strategies used.^{9, 10} Inappropriate antibiotic treatment also likely varies across facilities, but large-scale evaluations have not yet been conducted.

Quantification of the variation in inappropriate antibiotic treatment across facilities could be helpful in identifying which facilities could benefit from additional antibiotic stewardship education or activities and in identifying facility characteristics associated with higher rates of inappropriate antibiotic treatment. This information could be helpful in developing tailored interventions for facilities to improve their antibiotic use. In LTCFs, suspected urinary tract infections (UTIs) are the leading driver of overall antibiotic use, including inappropriate antibiotic use.¹¹⁻¹⁴ As such, we sought to evaluate the variation in suboptimal treatment of UTIs across VA long-term care units (known as Community Living centers or CLCs). We did not assess whether the antibiotic treatment residents received was necessary or not, but rather whether the antibiotic treatment received was suboptimal with regards to antibiotic drug choice, dose frequency, and duration. The objectives of our work were to describe the facility-level rate of potentially suboptimal treatment of residents with UTI, identify facility characteristics predictive of suboptimal treatment, and to quantify the extent of variation across CLC facilities.

METHODS

Study population.

We used a cohort of residents with a suspected incident UTI treated in a VA CLC between 2013-2018. We have previously described methods used to identify our national VA study population.^{15, 16} Briefly, suspected UTIs required collection of a urine culture and an antibiotic given on the culture collection date or within 3 days after culture collection.^{15, 16} Our definition of UTI was based on guidelines of the Infectious Diseases Society of America (IDSA) guidelines which require bacteriuria and symptoms for a UTI diagnosis.^{17, 18} An incident UTI was defined as the first UTI per resident identified during the study period with no UTIs treated in a VA CLC in the year prior. We excluded female residents of childbearing age and residents with a urologic procedure within 2 weeks of the index date in order to exclude residents potentially treated appropriately for asymptomatic bacteriuria.^{16, 18} Additionally, we excluded residents with other positive cultures from other non-urine sources to exclude those treated for another potential infection. We also excluded residents treated with antibiotics over 30 days and those treated with any non-UTI or uncommon antibiotics.¹⁶

Exposure to potentially suboptimal antibiotic treatment.

Individual-Level Resident Exposure

We assessed exposure to potentially suboptimal antibiotic treatment at the individual resident level. We have previously defined potentially suboptimal antibiotic treatment and subtypes of potentially suboptimal antibiotic treatment.¹⁶ Briefly, potentially suboptimal antibiotic treatment was defined as use of a suboptimal 1) initial antibiotic drug choice 2) dose frequency, and/or 3) excessive treatment duration. Initial antibiotic drug choice was suboptimal if resistance to the antibiotics used was detected from urine culture and susceptibility (C&S) results in the prior 180 days.¹⁹ If there were no 180-day urine C&S results, initial antibiotic drug choice was suboptimal if antibiotics used provided insufficient coverage (percent susceptibility <80%) based on the local CLC urine antibiogram from the year prior.¹⁹ Dose frequency was suboptimal if it did not agree with recommendations for dosing based on renal function.¹² Duration of therapy greater than 14 days was suboptimal.^{20, 21}

Aggregate Facility-Level CLC Exposure

We assigned and aggregated individual residents to the single CLC where the first urine culture during UTI treatment was obtained. We summarized initial treatment choice and rate of antibiotic use in days of therapy per 10,000 bed days (DOT/10,000 bed days) by antibiotic class. We also summarized the rate of residents receiving potentially suboptimal antibiotic treatment per 10,000 bed days across CLCs. We ranked CLCs by this rate from those with the lowest rates to those with the highest rates. We then grouped CLCs into suboptimal (those with rates at or above the median) and optimal CLCs (those with rates below the median). In sensitivity analyses, we used unique residents as the denominator and summarized and ranked CLCs based on the frequency of residents receiving potentially suboptimal treatment.

Potential independent predictors of potentially suboptimal antibiotic use.

Potential independent predictors of potentially suboptimal antibiotic treatment were selected a priori based on clinical relevance and/or previous work.²²⁻²⁷ In previous work, we identified several resident characteristics that were predictive of potentially suboptimal antibiotic treatment at the individual resident level.¹⁶ In this current study, we assessed and identified CLC characteristics predictive of potentially suboptimal antibiotic treatment at the aggregate CLC facility-level. We aggregated individual residents to the facility-level to determine average demographic characteristics, such as average age, and CLC rate of incident UTIs per 10,000 bed days. We considered CLC size (average daily census of more than 100 or not).²⁸ We assessed location (defined as urban or rural), geographic region (defined as Midwest, South, West, or Northeast), and proximity of the CLC to a main VA medical center (VAMC) campus (defined as similar campuses, distinct campuses, or other/unknown) as potentially predictors. We also considered several staffing and quality measures available from the VA Strategic Analytics for Improvement Learning Model (SAIL) and the VA CLC Compare data.^{29, 30} SAIL staffing measures are based on the average number of hours of care provided to each resident per day by nursing staff (including registered nurses, licensed practical nurses/ vocational nurses, and nurses aids).³¹ Quality measures used were developed from the Minimum Data Set (MDS) and Medicare claims data.³¹ Quality measures assess health status, physical functioning, mental status, general well-being and other information about the physical and clinical needs of the resident.³¹ Nursing homes are provided an overall 5 star quality rating, where nursing homes with a 5 star rating are considered much above average and those with a 1 star rating are considered much below average.³²

Analytic approach.

We described the CLC rate of potentially suboptimal antibiotic treatment (as defined above). We also described the CLC rate of use of subtypes of potentially suboptimal antibiotic drug choice, dose frequency, and excessive duration. We graphically displayed the distribution of facility-level aggregate rates across all CLCs. Joinpoint regression models were used to quantify the average percent difference across CLCs. Differences in CLC characteristics between groups (suboptimal vs. optimal CLCs) were analyzed using chi-square or Fisher's exact tests for categorical data and Student's *t* test or the Wilcoxon rank sum test for continuous data, as appropriate. We identified CLC characteristics predictive of potentially suboptimal antibiotic treatment using backwards, manual, stepwise unconditional logistic regression models.³³ In univariate analysis, we identified variables with a p-value of <0.10 and included these variables in subsequent multivariable analysis. Next we removed variables one at a time from the multivariable model until variables in the final model demonstrated statistical significance (p-value <0.05).³³

We built three multilevel logistic regression models with random intercepts for each CLC to examine variation in potentially suboptimal antibiotic treatment among residents with UTIs across CLCs. Two level random intercept models were estimated among individual residents with UTIs (level 1) nested within CLCs (level 2). In these models the probability of potentially suboptimal antibiotic treatment was allowed to vary across CLCs but the effect of resident characteristics was fixed for all CLCs.³⁴ The null model was the empty model which only incorporated CLC-specific random intercepts and did not contain any resident or CLC characteristics. The first model included resident characteristics identified as independent predictors of potentially suboptimal antibiotic treatment (identified from our previous work) and CLC-specific random intercepts.¹⁶ Resident-level predictors that were potentially correlated with the random effects were removed from the multilevel models, as the random effects are assumed to be independent of the model covariates.³⁵ The second model included CLC characteristics identified as independent predictors of potentially suboptimal antibiotic treatment (from our predictive analyses) and CLC-specific random intercepts. The third model included both resident characteristics and CLC characteristics identified as independent predictors and CLC-specific random intercepts. We included year as a fixed effect in all three models.

We calculated the intraclass correlation coefficient (ICC) to measure components of variance. To calculate the ICC, we used the latent variable approach which assumes that the dichotomous dependent variable comes from an unknown latent continuous variable with a residual that follows a logistic distribution with a mean of 0 and a variance of 3.29.³⁶ We determined the percentages of additional variance explained by comparing each model to the null model.^{34, 37} We calculated the median odds ratio (MOR) to quantify the heterogeneity between CLCs.^{35, 38} We performed analyses with SAS versions 9.2 and 9.4 and Joinpoint Regression Program version 4.6.0.0.

RESULTS

Between 2013-2018, 21,938 residents with an incident UTI were treated in 120 VA CLCs. The median average daily census of CLCs ranged from 5-248 (median 67). The average percentage of residents that were male in each CLC was 95.9% and the median average age of residents was 75.2 years. The rate of incident UTI ranged from 2.9-51.3 per 10,000 bed days (median 10.3 per 10,000 bed days) across CLCs. The total rate of incident UTI antibiotic use ranged from 21.7-578.2 DOT per 10,000 bed days across CLCs (median 92.6 DOT/ per 10,000 bed days, *supplemental Figure 1*). The CLCs at the minimum and maximum used fluoroquinolones as initial treatment in 5.2% and 54.2% of residents with incident UTIs, respectively (median 34.3%, *supplemental Figure 2*).

In **Figure 1**, the rate of residents receiving potentially suboptimal antibiotic treatment and subtypes of potentially suboptimal antibiotic treatment per 10,000 bed days are presented across VA CLCs and ranked from CLCs with the lowest to highest rates. In the CLC at the median, the rate was 6.8 per 10,000 bed days. In the CLC at the minimum, the rate of potentially suboptimal antibiotic treatment was 1.7 per 10,000 bed days. In the CLC at the maximum, the rate was 34.2 per 10,000 bed days. The average percent difference in rates from lowest to highest CLC was 2.5% (95% confidence interval [CI] 2.4%-2.7%), **Figure 2**. The rate of potentially suboptimal initial drug choice ranged from 1.2-27.2 per 10,000 bed days (median 4.7 per 10,000 bed days), potentially suboptimal dose frequency ranged from 0.8-22.5 per 10,000 bed days (median 2.8 per 10,000 bed days), and excessive duration ranged from 0.2-10.4 per 10,000 bed days (median 1.3 per 10,000

bed days) for the CLCs at the minimum and maximum, respectively. Similar results were observed when assessing frequency of potentially suboptimal treatment and subtypes of potentially suboptimal treatment (*supplemental Table I and Figure 1*).

Table I presents a comparison of CLC characteristics for suboptimal (those with rates of potentially suboptimal antibiotic treatment at or above the median, ≥ 6.8 per 10,000 bed days) vs optimal CLCs (those with rates below the median, ≤ 6.8 per 10,000 bed days). Suboptimal CLCs were more likely to have higher incident UTI rates (median incident UTI rate [interquartile range]: 15.9 [12.4–19.2] vs. 7.6 [6.3–8.9] per 10,000 bed days, $p < 0.001$). The only CLC characteristic predictive of higher suboptimal antibiotic treatment was the incident UTI rate. The odds of being a CLC with higher rates of potentially suboptimal antibiotic treatment increased by 4.9 times (95% CI 2.3-10.3) with each unit increase in the incident UTI rate. No CLC characteristics were identified as independent predictors of higher suboptimal antibiotic treatment in multivariable sensitivity analyses (*supplemental Table II*).

The null multilevel model demonstrated that the between CLC variation in potentially suboptimal antibiotic treatment was 3.42% (**Table II**). Together resident characteristics and CLC characteristics reduced the CLC-level variance by 0.20%, and thereby explained 5.98% of the observed CLC-level variance in potentially suboptimal antibiotic treatment. The median odds ratio for the full model was 1.37.

DISCUSSION

Our study is the first to demonstrate significant variation in potentially suboptimal antibiotic treatment of incident UTIs across a large nationwide group of LTCFs.

Our results are supported by previous studies which have consistently found variation in antibiotic usage among LTCFs.^{9, 10, 39-41} Among 73 nursing homes in 4 US states, mean facility antibiotic use ranged from 0.4-23.5 courses per 1,000 resident days.⁹ Among 607 nursing homes in Canada, antibiotic use ranged from 20.4-192.9 antibiotic-days per 1,000 resident-days.¹⁰ In these prior studies, UTI was generally among the most common conditions for which antibiotics were prescribed.^{9, 41} While prior studies did not assess antibiotic

appropriateness or focus specifically on the treatment of UTIs, it is reasonable to expect that the inter-facility variations in antibiotic use observed may have been related at least in part to variations in the appropriate use of antibiotics for UTI.

Another key finding of our study was that the only CLC characteristic that was predictive of higher rates of potentially suboptimal antibiotic treatment was incident UTI rate. Thus, it may be important to focus antibiotic stewardship strategies in CLCs with higher incidence UTI rates. Example strategies that may be helpful include implementation of facility-specific antibiotic guides and/or educational sessions and materials with specific recommendations to optimize drug choice, dose, and duration for residents with UTI based on national guidelines and local urinary antibiograms.^{42, 43} A cluster randomized trial among 8 public LTCFs in Canada found that mailing an antibiotic guide to physicians was associated with a 20.5% reduction in inappropriate antibiotic prescriptions in intervention facilities as compared to a reduction of only 5.1% in the control facilities.⁴² The antibiotic guide was targeted to common infections, including UTI, and had recommendations for empiric treatment including recommendations for antibiotic choice, dose, frequency, and duration. Disseminating treatment guidelines with education to facilities could reduce heterogeneity and may represent an easy approach to improve the treatment of UTI across VA CLCs.^{42, 43} Development of “peer comparison” tools that display the interfacility variation in potentially suboptimal antibiotic treatment may also decrease variability across facilities.⁴⁴ By seeing a visual display of interfacility variation in potentially suboptimal antibiotic treatment, LTCFs could see where they rank compared to other facilities and use this information to improve antibiotic use at their facility.⁴⁵ As misdiagnosis and unnecessary treatment of UTI is another well-known problem in LTCFs, antibiotic stewardship strategies should address both suboptimal and unnecessary UTI treatment.^{12, 14}

We also found that a large amount of the variation in potentially suboptimal antibiotic treatment remained unexplained even after adjusting for resident and CLC characteristics, and thus there may be other factors driving the variation. There is a great need to continue to investigate factors, to explain the variation in potentially suboptimal antibiotic treatment across LTCFs. Several potentially important measures of CLC performance were not included in our retrospective analysis, such as nurse staffing levels, admission rates into

the CLC vs. long stay prevalence, hospitalization rates, and whether CLC attendings also attended in acute care settings, since these are not readily measured. There also may be other factors that are not typically available in large electronics datasets which were not included, such as knowledge and practice of health care professionals, the context of the facility including the complexity of the resident population and access to doctors and diagnostic tests, and the social interaction between nurses, residents' families and doctors.⁴⁶ Other factors that might drive variations observed include differences in resident and family expectations, the use of antibiotics near the end of life, and the medical and nursing staff caring for residents life.⁴⁷ Physician preferences, which refers to prescribing practices that are based on non-clinical factors such as time of the day, staff biases, or fear or liability concerns, may also account for some of the some of the unexplained variation we observed.⁴⁸

Our findings may also support the need for tailored interventions in each CLC since the driving factors of potentially suboptimal treatment might vary by CLC .⁶ Additionally the median odds ratio for the full model was 1.37 which suggests that between two identical residents with UTIs (with the same covariate patterns) treated at two randomly chosen CLCs, in one of the residents potentially suboptimal antibiotic treatment would be 37% more likely than in the other resident just because of the CLC in which the resident was treated. This suggests the need for facilities to focus on targeted interventions based on characteristics that may be unique to each facility. Therefore, while individual CLC site visits are time consuming and labor intensive, they may be helpful in determining which factors might be driving potentially suboptimal UTI treatment at each CLC.

There are limitations to this study. First, despite considering a large set of potential predictors, approximately 94% of the variation in use of potentially suboptimal antibiotics remained unexplained. As such, there likely were other important unmeasured characteristics. There could have also been measurement error in the included characteristics. We were not able to capture the presence/extent of existing antibiotic stewardship services in place at each facility which may explain some of the variation. Comprehensive surveys of the antibiotic stewardship strategies at each CLC are warranted to investigate the impact of these factors in future work. Second, we only captured residents with a suspected UTI in which a urine culture was collected and was treated with antibiotics in a VA CLC. We thus did not capture residents in whom a urine sample was not

collected or available such as those with poor urine output, or urinary incontinence. Third, there are no established definitions for suboptimal antibiotic treatment of residents with UTI and as such our definitions were based on best available guidelines and expert opinion. In clinical practice determining the most optimal treatment is complex and based on a number of factors such as previous allergies and adverse drug events, comorbidities, and concomitant medications. Thus, despite meeting our definition for potentially suboptimal treatment, the antibiotics used may have represented the most optimal treatment for the resident. Moreover, there is no established definitions for high suboptimal antibiotic treatment rates at the facility-level, which is why we utilized the median level. Fourth, we did not assess prescriber or provider characteristics which may influence potentially suboptimal antibiotic use, such as provider type, specialty, knowledge or previous experience. Fifth, the generalizability of findings to non-VA LTCF populations may be limited, as the CLC populations generally include more males and residents with more complex medical needs than community LTCFs. Moreover, each VA CLC is part of the nation's largest integrated healthcare system, and findings may not be generalizable to stand alone community LTCFs with more limited resources.

CONCLUSIONS

In this large national study of almost 22,000 residents with an incident UTI treated in 120 VA CLCs, potentially suboptimal antibiotic treatment was highly variable across CLCs. The only CLC characteristic of predictive of suboptimal antibiotic use was the incident UTI rate. Despite findings, most of the variation across CLCs remained unexplained. Future research should continue to investigate factors that are predictive of suboptimal antibiotic treatment.

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CONFLICTS OF INTEREST

Haley Appaneal is supported in part by a Career Development Award, Department of Veterans Affairs and has received research funding from Shionogi.

Aisling Caffrey has received research funding from Pfizer, Merck, and Shionogi.

Vrishali Lopes has no conflicts.

David Dosa has no conflicts.

Vincent Mor Chairs the Scientific Advisory Committee for naviHealth, a post-acute care convener serving MA plans and hospital systems.

Kerry LaPlante has received research funding or acted as a scientific advisor for Merck, Ocean Spray, Pfizer, Allergan, Nabriva, Paratek, and Shionogi.

Theresa Shireman has no conflicts.

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Table I. Comparison of CLC characteristics between suboptimal and optimal CLCs

CLC Characteristic	Suboptimal CLCs (those with rates of potentially suboptimal antibiotic treatment at or above the median, ≥ 6.8 per 10,000 bed days, n =60)	Optimal CLCs (those with rates of potentially suboptimal antibiotic treatment below the median, < 6.8 per 10,000 bed days, n =60)	P value
Median Average Resident Age (IQR)	75.0 (73.2-76.5)	75.5 (74.2-77.1)	0.103
Average percent male, (+/- SD)	95.7% (2.3%)	96.1% (2.1%)	0.268
Average percent white, (+/- SD)	77.5% (15.6%)	73.8% (17.3%)	0.237
Average percent Hispanic, (+/- SD)	4.4% (12.8%)	2.7% (4.2%)	0.710
Average percent married, (+/- SD)	41.4% (7.3%)	42.3% (8.9%)	0.548
Incident UTI rate per 10,000 bed days, median (IQR)	15.9 (12.4-19.2)	7.6 (6.3-8.9)	<0.001
Region, n(%)			0.074
South	18 (30.0)	20 (33.3)	
Midwest	20 (33.3)	11 (18.3)	
Northeast	8 (13.3)	18 (30.0)	
West	14 (23.3)	11 (18.3)	
Proximity to acute care facility, n(%)			0.40
Same campus	43 (71.7)	37 (61.7)	

Remote	10 (16.7)	16 (26.7)	
Other	7 (11.7)	7 (11.7)	
Rural campus, n(%)	10 (16.7)	10 (16.7)	1.0
Average daily census size greater than 100, n(%)*	8 (13.3)	21 (35)	<0.001
Staffing**			
RN hours per resident day, median (IQR)	3.2 (2.5 - 4.0)	2.3 (1.9 - 3.3)	<0.001
LPN hours per resident day, median (IQR)	1.7 (1.2 - 2.4)	1.5 (0.9 - 2.0)	0.068
Nurse aide hours per resident day, median (IQR)	3.0 (2.4 - 4.0)	3.3 (2.7 - 3.8)	0.285
Total nurse staff hours per resident day, median (IQR)	8.1 (7.0 - 9.6)	7.4 (6.2 - 8.6)	0.008
Quality Ratings***			
Overall star rating median (IQR)	4.0 (3.0 - 5.0)	4.0 (3.0 - 5.0)	0.447
Survey rating, median (IQR)	4.0 (2.0 - 4.0)	3.0 (2.0 - 4.0)	0.078
Staffing rating, median (IQR)	5.0 (5.0 - 5.0)	5.0 (5.0 - 5.0)	1.0
Quality rating, median (IQR)	3.0 (2.0 - 4.0)	4.0 (3.0 - 5.0)	0.02
Quality Measures*****			

Percentage of short stay residents with a newly received antipsychotic medication, median (IQR)*	2.1 (1.2 - 3.3)	1.3 (0.7 - 2.4)	0.013
Percentage of short stay residents with moderate or severe pain, median (IQR)*	27.8 (19.2 - 39.0)	23.6 (16.9 - 32.5)	0.074
Percentage of short stay residents with a new or worse pressure ulcer, median (IQR)*	0.5 (0 - 1.2)	0.4 (0.0 - 1.1)	0.91
Percentage of short stay residents with improvement in function, median (IQR)	72.9 (65.7 - 78.0)	68.9 (57.6 - 76.6)	0.077
Percentage of short stay residents with a high-risk resident pressure ulcer, median (IQR)	9.2 (5.1 - 13.7)	7.1 (4.5 - 10.0)	0.084
Percentage of long stay residents with one or more falls with major injury, median (IQR)	2.2 (0.7 - 3.6)	2.1 (1.0 - 3.7)	0.704

Percentage of long stay residents with a catheter left in bladder, median (IQR)	2.4 (0.5 - 4.9)	2.0 (0.6 - 3.0)	0.299
Percentage of long stay residents with a newly received antipsychotic medication, median (IQR)	13.7 (8.8 - 16.6)	15.0 (10.0 - 21.0)	0.210
Percentage of long stay residents with moderate or severe pain, median (IQR)	34.5 (20.6 - 49.5)	30.4 (15.5 - 43.9)	0.096
Percentage of long stay residents who need help in activities of daily living, median (IQR)	13.7 (10.0 - 18.0)	13.0 (9.8 - 17.4)	0.379
Percentage of long stay residents with a UTI, median (IQR)	2.3 (1.6 - 4.0)	2.1 (1.2 - 3.5)	0.222
Percentage of long stay residents with ability to move independently, median (IQR)	13.0 (9.4 - 16.4)	11.7 (8.1 - 15.5)	0.605

CLC= Community Living Center; IQR= Interquartile range; LPN= Licensed practical nurse; RN= Registered nurse; SD= Standard deviation; UTI= Urinary tract infection; VA= Veterans Affairs

Individual residents with UTIs were aggregated to the single CLC in which the first urine culture during the UTI treatment period was obtained. We aggregated 21,938 individual residents with an incident UTI between 2013-2018 to 120 separate VA CLCs. We compared suboptimal and optimal CLCs (rates of potentially suboptimal antibiotic treatment at the median or above; rates below the median).

*We defined CLC size based on average daily census from 2015-2018.

**Staffing measures are based on the average number of hours of care provided to each resident per day by nursing staff (including registered nurses, licensed practical nurses/ vocational nurses, and nurses aids)

***Quality ratings are based on health surveys, staffing, and quality of resident care measures. VA CLCs are given a rating between 1 and 5 stars on each of these three domains and also assigned an overall star rating. 5 star ratings are considered much above average and 1 star ratings are considered much below average.

**** Quality measures are assessed separately for short stay residents, those who spend 100 days or less in the nursing home) and long stay residents (who spend more than 100 days in the nursing home).

Table II. Variance components and median odds ratios from multilevel logistic regression models

	Variance at the CLC level	Median odds ratio
Null model	3.42%	1.38
Model 1: Resident characteristics included	3.35%	1.38
Model 2: CLC characteristics included	3.24%	1.37
Model 3 (full model): Resident and CLC characteristics included	3.22%	1.37

CLC= Community Living Center; UTI= Urinary tract infection

Table 2 presents components of variance in potentially suboptimal antibiotic treatment attributed to the CLC-level. The null model variance component indicates that approximately 3.42% of the variability in the underlying propensity for potentially suboptimal antibiotic treatment of residents with incident UTIs is accounted for by the CLCs, leaving 96.58% of the variability to be accounted for by the systematic differences between the individual residents.

The null model was the empty model which only included random intercepts for each CLC.

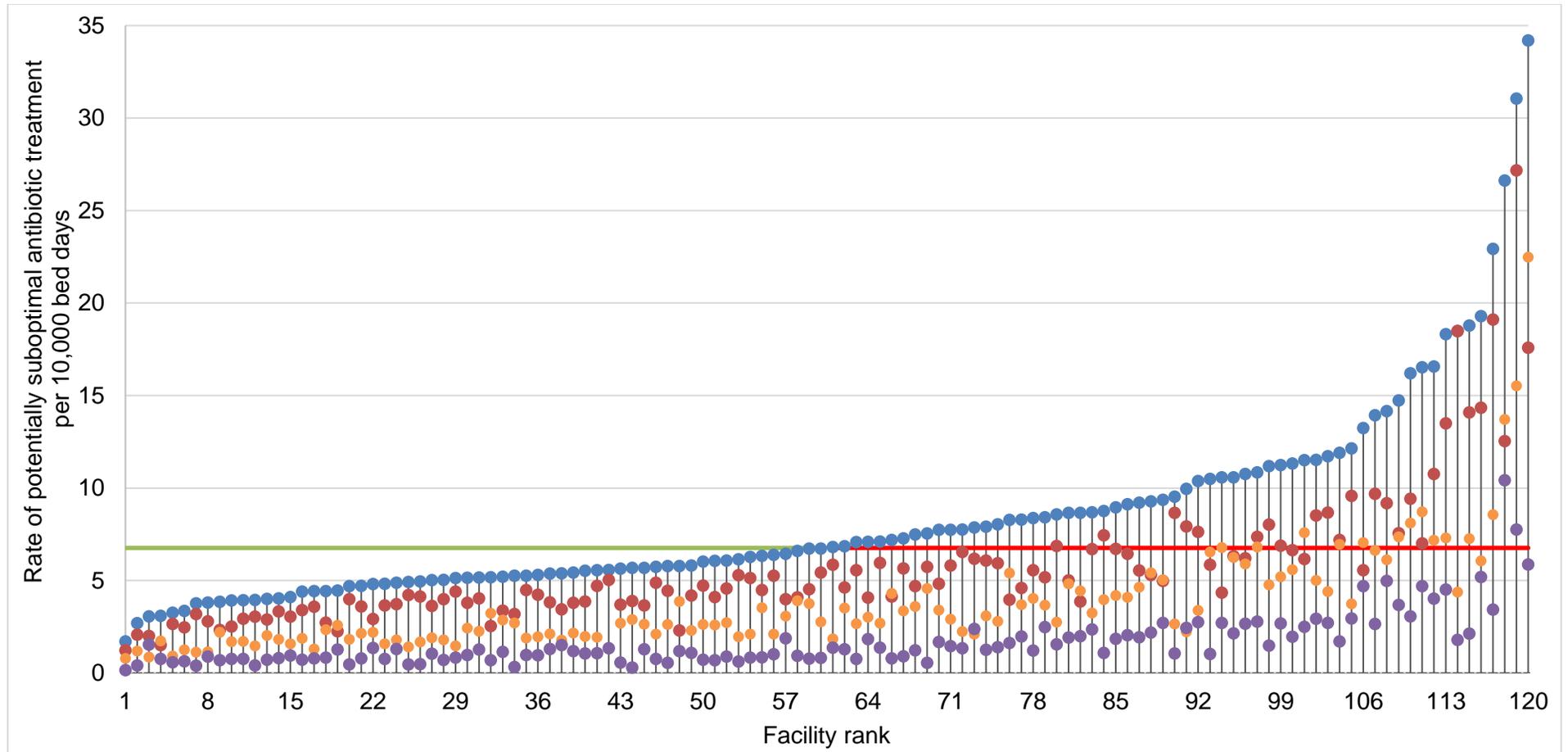
Model 1 included random intercepts for each CLC and adjusted for resident characteristics (cardiopulmonary comorbidity, renal disease comorbidity, genitourinary disorder comorbidity, recent high white blood cell count, age, prior fluoroquinolone exposure, prior skin infection, prior hospitalization) and year.

Models 2 included random intercepts for each CLC and adjusted for CLC characteristics (CLC rate of incident UTI) and year.

Models 3 included random intercepts for each CLC and adjusted for resident characteristics included in Model 1 and CLC characteristics included in Model 2 and year.

Not presented in table, model which included random intercepts for each CLC and adjusted for year reduced the variance by 0.03 and explained only 0.83% of the variance in potentially suboptimal antibiotic treatment.

Figure 1. Ranking of 120 CLCs based on rate of residents receiving potentially suboptimal antibiotic treatment for suspected incident UTIs and subtypes of potentially suboptimal antibiotic treatment



CLC= Community Living Center

- Potentially suboptimal antibiotic use*
- Potentially suboptimal antibiotic drug choice**
- Potentially suboptimal antibiotic dose frequency***
- Potentially suboptimal antibiotic duration****

 Median rate of potentially suboptimal antibiotic treatment, facilities below this line have lower rates of potentially suboptimal antibiotic treatment

 Median rate of potentially suboptimal antibiotic treatment, facilities below this line have higher rates of potentially suboptimal antibiotic treatment

Individual residents with UTIs were aggregated to the single CLC in which the first urine culture during the UTI treatment period was obtained. We aggregated 21,938 individual residents with an incident UTI between 2013-2018 to 120 separate VA CLCs. The rate of residents receiving potentially suboptimal antibiotic treatment and subtypes potentially suboptimal antibiotic treatment per 10,000 bed days are presented across VA CLCs. VA CLCs were ranked from those with the lowest to highest rate of potentially suboptimal antibiotic treatment. VA facilities below the green line are facilities with rates of potentially suboptimal antibiotic treatment below the median (CLCs with lower rates of potentially suboptimal antibiotic treatment). VA facilities above the red line are facilities with rates of potentially suboptimal antibiotic treatment above the median (CLCs with higher rates of potentially suboptimal antibiotic treatment).

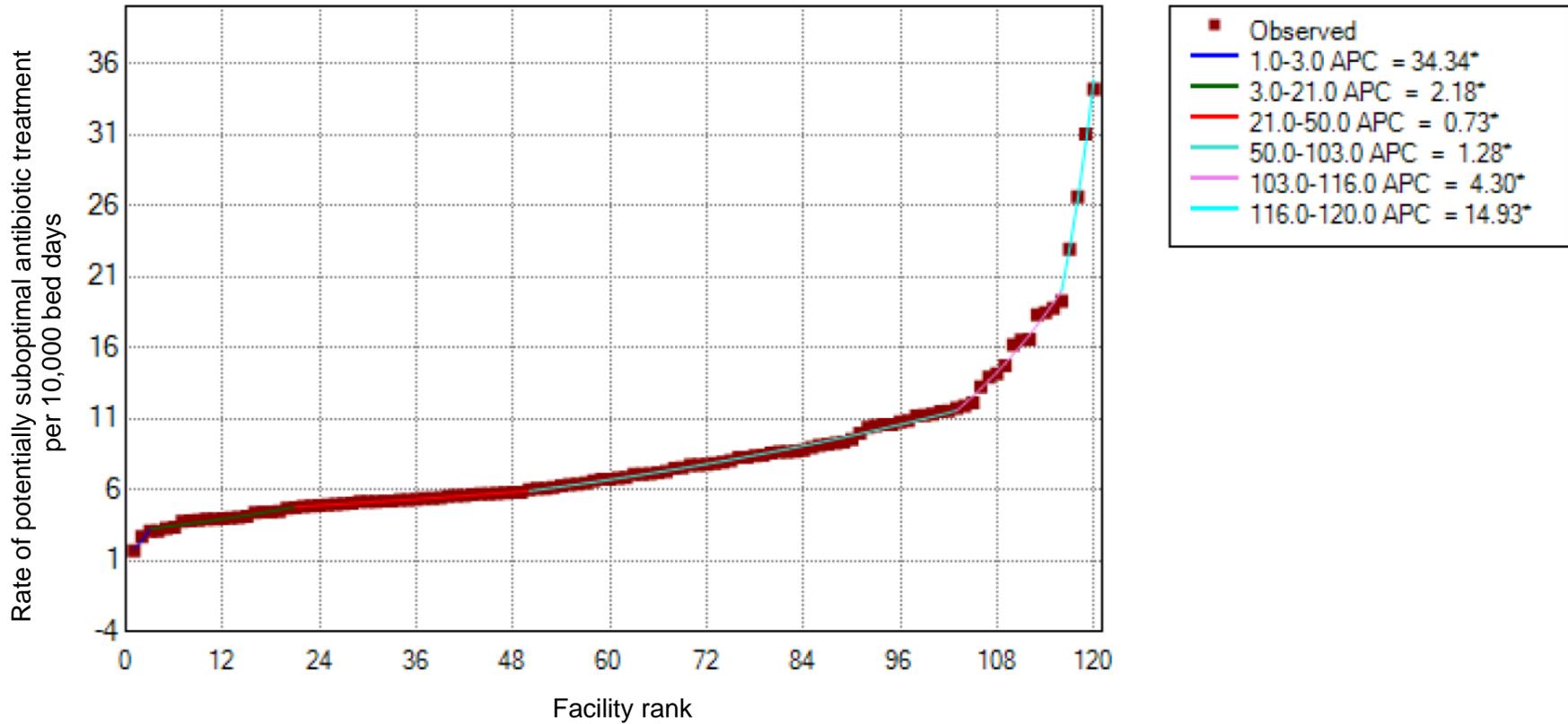
*Potentially suboptimal antibiotic treatment was defined as exposure to any of subtype of potentially suboptimal antibiotic treatment (drug, dose frequency dose frequency, and/or duration).

**Potentially suboptimal initial drug choice was defined based on previous urine cultures and susceptibilities or local CLC urine antibiogram. Initial treatment was defined as antibiotics given on the first day of the UTI treatment period.

***Potentially suboptimal dose frequency was defined based on renal function.

****Potentially suboptimal antibiotic duration was defined as an excessive treatment duration greater than 14 days.

Figure 2. Average percent difference in rate of residents receiving potentially suboptimal antibiotic treatment across CLCs from Joinpoint analyses



*Indicates that the Average Percent Change (APC) is significantly different from zero at the alpha of 0.05 level. Final model included 5 Joinpoints.

Supplemental Table 1. Frequency of suboptimal antibiotic use and subtypes of suboptimal antibiotic use across CLCs

	Potentially suboptimal antibiotic use*	Potentially suboptimal antibiotic drug choice**	Potentially suboptimal antibiotic dose frequency***	Potentially suboptimal antibiotic duration****
Minimum	36.8%	22.4%	13.6%	3.1%
Quartile 1	61.1%	36.9%	23.2%	9.4%
Median	66.3%	48.6%	28.2%	12.2%
Quartile 3	71.0%	54.7%	31.8%	15.4%
Maximum	100.0%	100.0%	47.5%	37.2%

Individual residents with UTIs were aggregated to the single CLC in which the first urine culture during the UTI treatment period was obtained. We aggregated 21,938 individual residents with an incident UTI between 2013-2018 to 120 separate VA CLCs. The frequency of residents receiving potentially suboptimal antibiotic treatment and subtypes potentially suboptimal antibiotic treatment (unique resident as the denominator) are presented across VA CLCs.

*Potentially suboptimal antibiotic treatment was defined as exposure to any of subtype of potentially suboptimal antibiotic treatment (drug, dose frequency dose frequency, and/or duration).

**Potentially suboptimal initial drug choice was defined based on previous urine cultures and susceptibilities or local CLC urine antibiogram. Initial treatment was defined as antibiotics given on the first day of the UTI treatment period.

***Potentially suboptimal dose frequency was defined based on renal function.

****Potentially suboptimal antibiotic duration was defined as an excessive treatment duration greater than 14 days.

Supplemental Table 2. Comparison of CLC characteristics between suboptimal and optimal CLCs

CLC Characteristic	Suboptimal CLCs (those with frequencies of potentially suboptimal antibiotic treatment at or above the median, n =60)	Optimal CLCs (those with frequencies of potentially suboptimal antibiotic treatment below the median, n =60)	P value
Median Resident Age (IQR)	75.4 (74.2-76.8)	75.0 (73.1-76.7)	0.187
Average percent male, (+/- SD)	96.1% (2.2%)	95.8% (2.2%)	0.438
Average percent white, (+/- SD)	75.1% (16.7%)	76.2% (16.5%)	0.713
Average percent Hispanic, (+/- SD)	4.2% (12.5%)	3.0% (5.1%)	0.484
Average percent married, (+/- SD)	42.1% (7.2%)	41.6% (9.0%)	0.765
Incident UTI rate per 10,000 bed days, median (IQR)	9.0 (7.0-12.9)	11.9 (8.3-17.3)	0.014
Region, n(%)			0.954
South	20 (33.3)	18 (30)	
Midwest	16 (26.7)	15 (25)	
Northeast	12 (20)	14 (23.3)	
West	12 (20)	13 (21.7)	
Proximity to acute care facility, n(%)			0.846
Same campus	39 (65.0)	41 (68.3)	
Remote	13 (21.7)	13 (21.7)	
Other	8 (13.3)	6 (10)	
Rural campus, n(%)	13 (21.7)	7 (11.7)	0.142

Average daily census size			
greater than 100, n(%)*	12 (20)	17 (28.3)	0.286
Staffing**			
RN hours per resident day,			
median (IQR)	2.8 (2.0 - 3.8)	2.6 (2.1 - 3.7)	0.682
LPN hours per resident day,			
median (IQR)	1.7 (1.1 - 2.3)	1.5 (1.1 - 2.0)	0.322
Nurse aide hours per			
resident day, median (IQR)	3.3 (2.5 - 3.9)	3.2 (2.7 - 4.0)	0.840
Total nurse staff hours per			
resident day, median (IQR)	8.9 (6.5 - 9.2)	7.6 (6.6 - 8.9)	0.949
Quality Ratings***			
Overall star rating median			
(IQR)	4.0 (3.0 - 5.0)	4.0 (3.0 - 5.0)	0.541
Survey rating, median (IQR)	3.0 (2.0 - 4.0)	3.0 (2.0 - 4.0)	0.714
Staffing rating, median			
(IQR)	5.0 (5.0 - 5.0)	5.0 (5.0 - 5.0)	1.0
Quality rating, median (IQR)	3.0 (2.0 - 4.5)	3.0 (3.0 - 4.0)	0.758
Quality Measures*****			
Percentage of short stay			
residents with a newly			
received antipsychotic			
medication, median (IQR)*	1.5 (0.9 - 2.4)	2.2 (1.0 - 4.0)	0.039
Percentage of short stay			
residents with moderate or			
severe pain, median (IQR)*	25.1 (18.5 - 37.5)	25.0 (16.0 - 38.0)	0.953

Percentage of short stay residents with a new or worse pressure ulcer, median (IQR)*	0.3 (0 - 1.2)	0.5 (0.0 - 1.2)	0.89
Percentage of short stay residents with improvement in function, median (IQR)	71.7 (62.8 - 77.0)	71.1 (61.5 - 76.7)	0.823
Percentage of short stay residents with a high-risk resident pressure ulcer, median (IQR)	8.3 (5.3 - 13.5)	7.1 (4.2 - 12.2)	0.162
Percentage of long stay residents with one or more falls with major injury, median (IQR)	2.2 (0.4 - 3.4)	2.1 (1.0 - 3.6)	0.833
Percentage of long stay residents with a catheter left in bladder, median (IQR)	2.2 (0.5 - 3.4)	2.2 (0.1 - 4.8)	0.914
Percentage of long stay residents with a newly received antipsychotic medication, median (IQR)	14.4 (7.8 - 18.6)	13.9 (10.3 - 18.2)	0.612
Percentage of long stay residents with moderate or severe pain, median (IQR)	32.1 (16.2 - 45.6)	31.9 (17.5 - 44.3)	0.876
Percentage of long stay residents who need help in activities of daily living, median (IQR)	13.6 (10.0 - 18.4)	13.0 (9.7 - 17.6)	0.503

Percentage of long stay residents with a UTI, median (IQR)	2.1 (1.1 - 3.7)	2.3 (1.6 - 3.6)	0.385
Percentage of long stay residents with ability to move independently, median (IQR)	12.6 (9.6 - 16.4)	11.5 (7.2 - 16.2)	0.433

CLC= Community Living Center; IQR= Interquartile range; LPN= Licensed practical nurse; RN= Registered nurse; SD= Standard deviation; UTI= Urinary tract infection; VA= Veterans Affairs

In multivariable analysis, no CLC characteristics were identified as independent predictors of suboptimal UTI treatment.

Individual residents with UTIs were aggregated to the single CLC in which the first urine culture during the UTI treatment period was obtained. We aggregated 21,938 individual residents with an incident UTI between 2013-2018 to 120 separate VA CLCs. VA CLCs were ranked from those with the lowest to highest frequency of potentially suboptimal antibiotic treatment. We compared suboptimal and optimal CLCs (defined as CLCs with frequencies of potentially suboptimal antibiotic treatment at the median or above; and those with frequencies below the median).

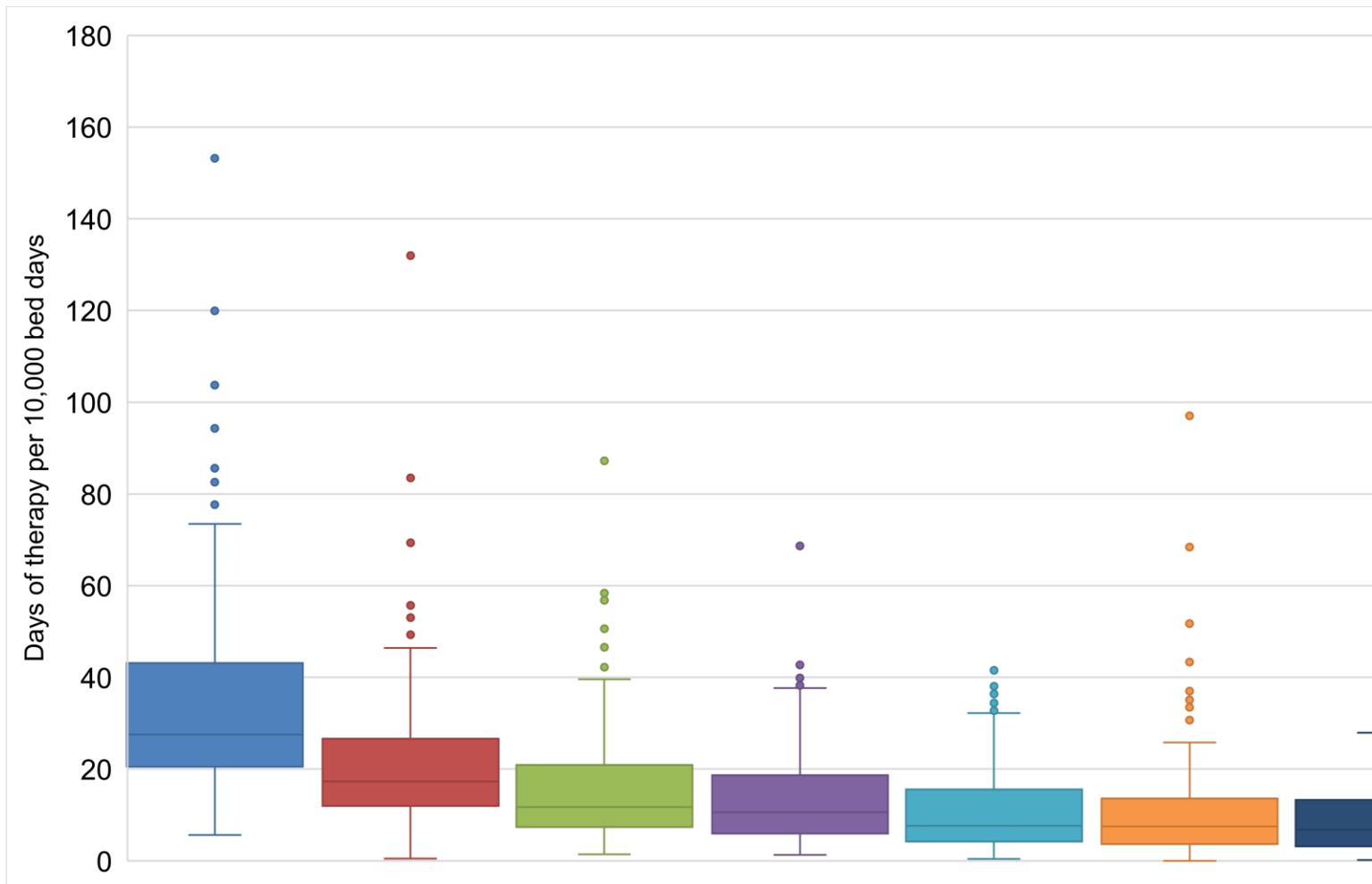
*We defined CLC size based on average daily census from 2015-2018.

**Staffing measures are based on the average number of hours of care provided to each resident per day by nursing staff (including registered nurses, licensed partitional nurses/ vocational nurses, and nurses aids)

***Quality ratings are based on health surveys, staffing, and quality of resident care measures. VA CLCs are given a rating between 1 and 5 stars on each of these three domains and also assigned an overall star rating. 5 star ratings are considered much above average and 1 star ratings are considered much below average.

**** Quality measures are assessed separately for short stay residents, those who spend 100 days or less in the nursing home) and long stay residents (who spend more than 100 days in the nursing home).

Supplemental Figure 1. Rate of incident UTI antibiotic use by antibiotic class across VA CLCs

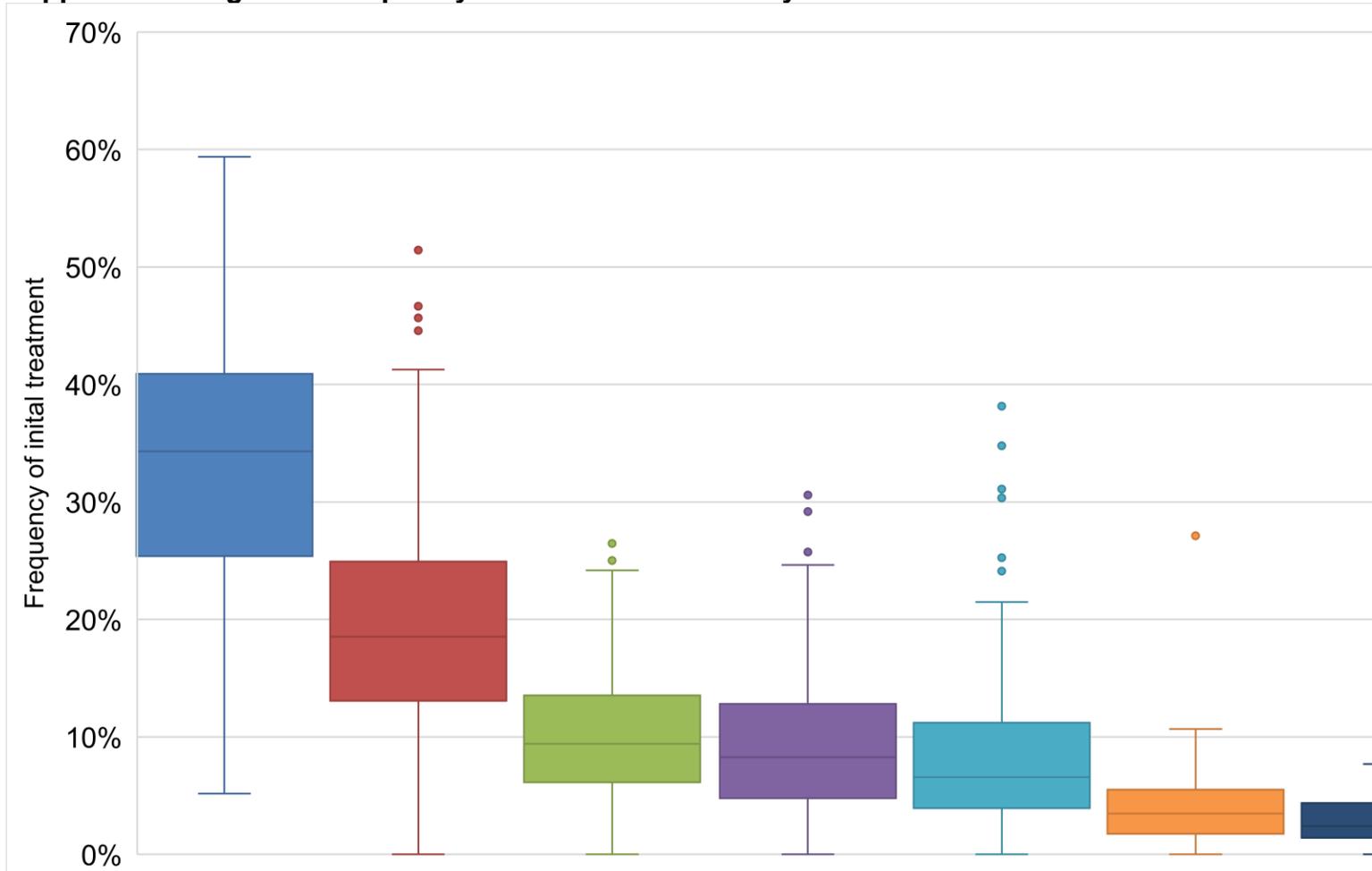


	Fluoro-quinolone	Genito-urinary tract agent	Amino-penicillin	3 rd /4 th gen cephalosporin	1 st /2 nd gen cephalosporin	Carbapenem/piperacillin-tazobactam	Anti-Age
Min	5.6	0.5	1.4	1.3	0.4	0.0	
Q 1	20.6	12.0	7.4	6.0	4.3	3.7	
Median	27.5	17.3	11.7	10.6	7.6	7.5	
Q3	42.9	26.5	20.0	18.4	15.5	13.4	
Max	153.2	131.9	87.2	68.6	42.7	97.0	

CLC= Community Living Center; Max= Maximum; Min= Minimum; MRSA= Methicillin-resistant *Staphylococcus aureus*; Q1= Quartile 1; Q3=Quartile 3; UTI= Urinary Tract Infection; VA= Veterans' Affairs

We identified suspected incident UTIs among residents in VA CLCs from 2013-2018. We aggregated individual UTIs to the facility-level and summarized antibiotic use rates in days of therapy per 10,000 bed days by antibiotic class.

Supplemental Figure 2. Frequency of initial UTI treatment by antibiotic class across VA CLCs



	Fluoro-quinolone	Genito-urinary tract agent	Amino-penicillin	3 rd /4 th gen cephalosporin	1 st /2 nd gen cephalosporin	Carbapenem/piperacillin-tazobactam	Anti-Ager
Min	5.2%	0.0%	0.0%	0.0%	0.0%	0.0%	
Q1	25.5%	13.1%	6.3%	4.8%	4.0%	1.9%	
Median	34.3%	18.5%	9.4%	8.3%	6.6%	3.5%	
Q3	40.5%	24.6%	13.5%	12.7%	11.2%	5.3%	
Max	54.2%	51.4%	27.0%	30.6%	38.2%	27.1%	

CLC= Community Living Center; Max= Maximum; Min= Minimum; MRSA= Methicillin-resistant *Staphylococcus aureus*; Q1= Quartile 1; Q3=Quartile 3; UTI= Urinary Tract Infection; VA= Veterans' Affairs

We identified suspected incident UTIs among residents in VA CLCs from 2013-2018. We aggregated individual UTIs to the facility-level and summarized the frequency of initial treatment choice by antibiotic class.