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Leveraging the McGeer Criteria to Estimate Frequency of Inappropriate Antibiotic Prescribing for Urinary and Respiratory Tract Infections Relative to the Onset of the COVID-19 Pandemic at a Skilled Nursing Facility

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Abstract: Background/Objectives: The COVID-19 pandemic affected antimicrobial stewardship in healthcare, including Skilled Nursing Facilities (SNFs). This study aimed to (1) assess the appropriateness of antibiotic prescriptions for urinary tract infections (UTIs) and respiratory tract infections (RTIs), and identify predictors of inappropriate use, and (2) analyze changes in prescribing practices relative to the pandemic's onset. **Methods**: A retrospective review of electronic medical records from a 300-bed SNF (March 2019 - March 2021) identified suspected UTIs and RTIs based on laboratory tests and antibiotic requests. Antibiotic prescription appropriateness was defined by clinical and microbiological alignment with the McGeer criteria, which are standardized infection definitions for long-term care residents, for UTI and RTI. Logistic regression models identified predictors of inappropriate prescribing, and an interrupted time-series analysis (ITS) examined trends relative to the pandemic onset (March 11, 2020) in Arizona. **Results**: Among 370 antibiotic prescriptions, 77% of UTI and 61% of RTI prescriptions were inappropriate per the McGeer criteria. Acute dysuria and increased urgency were associated with lower odds of inappropriate UTI prescribing. For RTIs, a positive COVID-19 test increased odds of inappropriate prescribing, while fever and acute functional decline lowered them. UTI prescriptions and inappropriateness overall increased during the pandemic, but no significant ITS trends emerged. For RTIs, no significant changes in prescribing or inappropriateness relative to the pandemic were observed. **Conclusions**: Over two-thirds of antibiotics prescribed for UTI and RTI were inappropriate, with these trends persisting during the pandemic. Findings emphasize the need for robust antimicrobial stewardship during and after public health emergencies.

Keywords: antimicrobial stewardship; COVID-19; skilled nursing facility; antibiotic prescribing; McGeer criteria

1. Introduction

Long-term care (LTC) settings, including Skilled Nursing Facilities (SNF), are prone to the overuse of antibiotics due to concerns about infection spread in congregate living environments, the high susceptibility of immunosuppressed residents, and resource limitations, such as limited diagnostic tools [1]. The magnitude of antibiotic consumption in SNFs is a well-documented phenomenon, with an estimated 49% to 79% of residents prescribed at least one antibiotic during

their stay [2]. In addition to high prescription rates, the majority (40-70%) of antibiotics used in these settings have been determined inappropriate or unnecessary [3]. As a result of frequent and often prolonged antibiotic usage, these settings also perpetuate transmission of multidrug-resistant organisms (MDRO) pathogens, with an estimated 35% of residents colonized [4]. The overprescribing of antibiotics in LTC settings significantly contributes to antimicrobial resistance (AMR), which has been consistently named a top global public health threat due to the increasing emergence of MDROs [5]. Inappropriate antibiotic use accelerates the development of resistant strains, making infections harder to treat and increasing the risk of disease spread, severe illness, and death [6]. The revised McGeer criteria, developed to standardize infection definitions for surveillance purposes in LTC populations, were designed specifically to address the unique clinical and microbiologic criteria in LTC residents [7]. While clinical discretion lies with the treating provider in individual cases, these criteria offer surveillance definitions to define to approximate true infections from non-infectious symptoms common in elderly populations in aggregate.

The COVID-19 pandemic hindered efforts to combat AMR, including inhibiting antimicrobial stewardship (AMS) interventions in clinical practice [8]. A 2022 report produced by the Centers for Disease Control and Prevention (CDC) highlighted significant losses in progress toward established AMS and AMR goals due to the burden of COVID-19 on the United States healthcare system [9]. Considerable reductions in AMR data collection and AMS programs, coupled with increases in antimicrobial use and subsequent MDRO infections have been attributed to the pandemic. A 2021 meta-analysis revealed that as many as 75% of COVID-19 patients received antibiotics, with higher prescription rates among older individuals or those on mechanical ventilation [10]. This finding was supported by a 2023 systematic review which revealed that among hospitalized individuals, antibiotics were prescribed to 78% of COVID-19 patients, regardless of condition severity [11]. These trends in prescribing persist despite the low incidence of bacterial co-infection in COVID-19 cases [12]. Amid these shifts in prescribing trends, LTC facilities faced distinct challenges.

Confronting pre-existing resource limitations, LTC faced compounded challenges during the COVID-19 pandemic. These included staffing shortages and a critical scarcity of personal protective equipment, while simultaneously caring for a population highly vulnerable to the virus [13]. SNF residents faced high mortality and morbidity as a result of the pandemic, resulting in decreases in resident census counts for many facilities due to increases in case counts and a subsequent fear of contracting the virus [14]. However, despite a history of consistent overuse of antibiotics in these settings, existing literature presents fluctuations in prescribing behaviors throughout the pandemic's progression [8]. Studies in LTC have described a decrease in antibiotic prescribing overall compared to pre-pandemic estimates [8,15,16]. Conversely, there were significant increases in specific antibiotic usage (e.g., azithromycin and ceftriaxone) [16,17].

Collectively, studies have not established a clear relationship between the COVID-19 pandemic and antibiotic prescribing in LTC. Our study objectives were to (1) assess the appropriateness of antibiotic prescriptions for suspected urinary (UTI) and respiratory tract infections (RTI) using the revised McGeer criteria standardized infection definitions and identify predictors of inappropriate antibiotic use, and (2) analyze changes in prescribing practices relative to the onset of the COVID-19 pandemic within electronic medical records (EMR) from a large, Arizona-based SNF.

2. Results

2.1. Suspected Events & Demographic Characteristics

Between March 2019 – March 2021, 775 suspected UTI and RTI infection events were abstracted; 5 duplicate records and any suspected infection that did not result in the prescription of an antibiotic was removed (n = 400). Per the McGeer criteria, UTI infections were separated by presence or absence of an indwelling catheter or non-indwelling during urine collection. Both suprapubic and foley catheters were considered "indwelling". The final sample consisted of 208 UTI (indwelling n = 53, non-indwelling n = 155) and 162 RTI suspected infections that resulted antibiotic events (Figure 1).
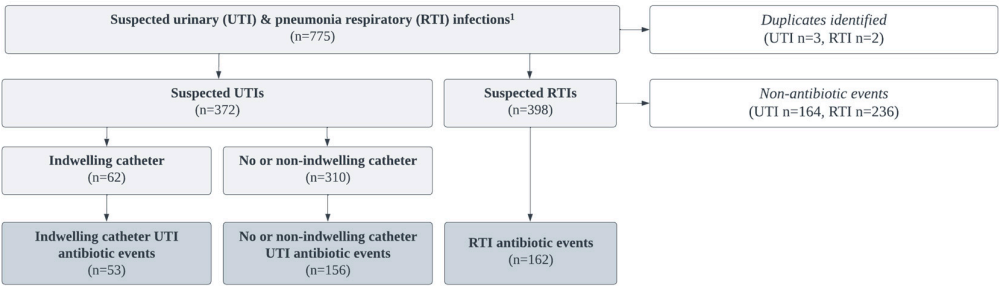
Figure 1. Flow diagram to demonstrate electronic medical record abstraction analysis inclusion and exclusion criteria. [1] A suspected infection was defined as a laboratory order (e.g., urine analysis, chest x-ray), or an antibiotic prescription.

Overall, 770 suspected UTI or RTI infections were attributed to 294 residents. On average, there were 2.6 suspected infections, and 1.5 antibiotic prescribed for each resident. Our sample consisted, on average, of older (mean = 75.6, sd = 11.3), female (62.1%, n = 175), and largely white (90.1%, n = 254) residents. 18.0% (n = 50) of individuals were classified in the EMR as being of Hispanic origin and most spoke English as their preferred language (93.3%, n = 263). Prior to their stay at this facility, the majority of residents previously resided in Pima county (Table 1).

Table 1. Demographic characteristics of residents comprising suspected infections receiving an antibiotic prescribing within an Arizona-based Skilled Nursing Facility between March 2019 - 2021, n=163[1].

	mean	*sd*	*range*
Age	75.9	11.5	37.0 – 103.0
Resident Census (days per month)	3,854.5	864.9	2,382.0 – 5,197.0
Suspected Infections per Resident	2.6	2.6	1 - 17
Antibiotic Prescriptions per Resident	2.0	1.0	0 - 13
	n (%)		
Sex			
Male	64 (39.3)		
Female	99 (60.7)		
Race			
White	145 (89.0)		
Black or African American	8 (4.9)		
American Indian / Alaska Native	3 (1.8)		
Unknown	7 (4.3)		
Ethnicity			
Not of Hispanic origin	128 (78.5)		
Hispanic	29 (17.8)		
Unknown	6 (3.7)		
Preferred language			
English	152 (93.3)		
Spanish	11 (6.8)		

4

County previously resided in

Pima	271 (92.2)
Other	23 (7.8)

[1]370, non-duplicate antibiotic events for suspected UTI and RTIs were attributed to 163 residents.

2.2. Antibiotic Appropriateness & Predictors

Our kappa reliability assessment to assess consistency of arrival at the same McGeer criteria designation (e.g., whether an antibiotic event met or did not meet the McGeer criteria for an infection) yielded an agreement rate of 96.1% (kappa statistic = 0.81). Across the study period, 77% of antibiotic prescriptions for UTIs and 61% for RTIs were deemed inappropriate.

In examining UTIs, those with acute dysuria had 92% lower odds of receiving inappropriate antibiotic prescriptions compared to those without acute dysuria (OR 0.08, 95% CI: 0.03 - 0.23). Similarly, individuals with a new or marked increase in urgency had 98% lower odds of receiving inappropriate antibiotic prescriptions compared to those without this symptom (OR 0.02, 95% CI: 0.04 - 0.78). Although gross hematuria was considered a potential predictor, it did not reach statistical significance (95% CI: 0.13-1.10) (Table 2a).

Table 2. a. Unadjusted generalized estimating equations (GEE) to model predictors of inappropriate antibiotic prescribing for urinary tract infections (UTI) without an indwelling catheter[1] between March 2019 – 2021 (n = 156).

	UTI			
	% Inappropriate	% Appropriate	OR (95% CI)	p
Acute dysuria	9.8	60.9	0.08 (0.03-0.23)	**<0.0001**
Acute pain, swelling, or tenderness of the testes, epididymis, or prostate	1.5	4.4	0.27 (0.02-3.16)	0.30
Fever or leukocytosis	49.0	43.5	1.57 (0.91 2.71)	0.11
Acute costovertebral angle pain or tenderness	omitted due to small sample sizes			
Suprapubic pain	omitted due to small sample size			
Gross hematuria	3.8	26.1	0.38 (0.13-1.10)	0.08
New or marked increase of incontinence	12.0	21.7	0.92 (0.33-2.55)	0.87
New or marked increase of urgency	0.8	8.7	0.18 (0.04-0.78)	**0.02**
New or marked increase of frequency	0.8	13.0	0.43 (0.09-2.13)	0.304
Acute change in mental status from baseline	8.3	13.0	1.31 (0.32-5.36)	0.70
Acute functional decline	9.0	8.7	0.72 (0.26-2.09)	0.54
Foul-smelling urine	11.3	13.0	0.97 (0.39-2.42)	0.95
Dark urine	20.3	26.1	1.80 (0.84-3.85)	0.13
Presence of ESBL	24	8.7	1.52 (0.45-5.19)	0.50

[1]suspected infections for patients with an indwelling catheter were excluded due to small sample sizes.

For RTIs, the presence of fever was associated with 89% lower odds of receiving inappropriate antibiotics compared to those without fever (OR 0.11, 95% CI: 0.05-0.24). Testing positive for COVID-19 in the interval of one week prior to and one week following the suspected infection increased the odds of inappropriate prescribing for UTIs by 50% (OR 1.50, 95% CI: 1.05 - 2.18). Acute functional decline presented an OR (0.18), but did not meet statistical significance (Table 2b).

Table 2. b. Unadjusted generalized estimating equations (GEE) to model predictors of inappropriate antibiotic prescribing for respiratory tract infections (RTI) between March 2019 – 2021 (n = 162).

	RTI			
	% Inappropriate	% Appropriate	OR (95% CI)	p
New or increased cough	58.6	52.4	1.15 (0.64-2.09)	0.64
New or increased sputum production	30.3	19.1	1.36 (0.69-2.70)	0.38
O2 saturation < 94% on room air or a reduction in O2 saturation of >3% from baseline	77.8	84.1	0.70 (0.32-1.54)	0.38
New or changed lung examination abnormalities	61.6	65.1	0.91 (0.48-1.70)	0.76
Pleuritic chest pain	2.0	1.6	0.80 (0.11-6.15)	0.83
Respiratory rate of >= 25 breaths/min	2.0	6.4	0.50 (0.11-2.33)	0.38
Fever	44.4	90.5	0.11 (0.05-0.24)	**<0.01**
Leukocytosis	15.2	28.6	0.55 (0.26-1.14)	0.11
Acute change in mental status from baseline	2.0	4.8	0.59 (0.11-3.15)	0.54
Acute functional decline	2.0	9.5	0.18 (0.03-0.99)	0.05
COVID-19 positive test[1]	37.5	16.7	1.65 (1.07-2.56)	**0.02**
Influenza	0	9.1	1.40 (0.88-2.24)	0.16

[1]The COVID-19 positive test model included only antibiotic prescriptions for suspected RTIs following the onset of the COVID-19 pandemic using the World Health Organization pandemic declaration (March 11, 2020).

2.3. Changes in Antibiotic Prescribing Practices Relative to the Onset of the COVID-19 Pandemic

The proportion of prescriptions that did not meet the McGeer criteria fluctuated between March 2019 and March 2021. Notably, 100% of antibiotic prescriptions for suspected bacterial infections in December 2019 and 94% in March 2020 were classified as inappropriate. Resident days per month in

the SNF steadily declined from approximately 5,000 in March 2019 to around 3,000 by March 2021 (Figure 2).

Prior to the pandemic's onset, 60.0% of suspected UTIs in patients with indwelling catheters and 87.3% of those without catheters did not meet the McGeer criteria for appropriate antibiotic use. Similarly, 65.6% of RTI cases were classified as inappropriate for antibiotic treatment. However, there was a reduction in the rate of inappropriate antibiotic prescriptions following the pandemic onset. For UTIs in patients with indwelling catheters, there was a 13.6% decrease in observed inappropriate prescriptions. For those without catheters, the decrease was 3.4%. In the case of RTIs, there was a 10.0% reduction in inappropriate prescriptions post-pandemic declaration.
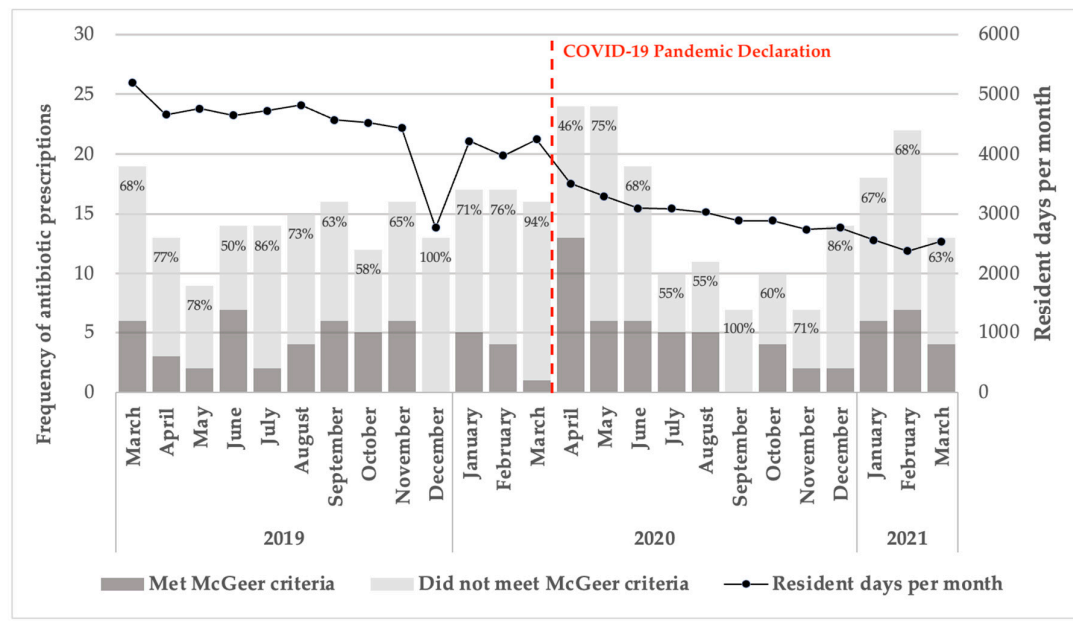

Figure 2. Antibiotic prescription accordance with McGeer criteria from March 2019 – 2021. <u>Note</u>: The frequency of antibiotic prescriptions, categorized based on adherence to McGeer criteria, is shown across the study period.

Prior to the pandemic's onset, there was an average of 5.75 inappropriate antibiotic prescriptions for UTIs per month, which increased to 7.07 per month following the onset. Similarly, the total number of antibiotic prescriptions for UTIs rose from an average of 7.33 per month prior to the pandemic to 9.23 per month after the pandemic's onset.

We used a Generalized Linear Model (GLM) to evaluate the impact of the COVID-19 pandemic on prescribing practices by comparing the pooled pre-pandemic period with the pooled post-pandemic period. The model adjusted for resident days per 1000 per month to account for differences in facility occupancy over time, allowing us to assess the overall effect of the pandemic's onset on prescribing patterns across the entire pre- and post-period. The model showed that the incidence rate of inappropriate UTI prescriptions was 3.25 times higher after the onset of the pandemic compared to before (IRR = 3.25, p = 0.007). For total UTI prescriptions, the incidence rate was 4.63 times higher after the pandemic began (IRR = 4.63, p = 0.002).

In contrast, this trend was not observed for RTIs. Before the pandemic, there were 4.75 inappropriate RTI prescriptions per month, which decreased to 3.23 per month after the pandemic onset. Similarly, total RTI prescriptions declined from 7.33 per month before the pandemic to 5.69 per month during the pandemic. GLM models for RTIs, adjusting for 1000 resident days per month, showed that these changes were not statistically significant.

2.4. Interrupted Time Series Analysis

The analysis indicated no statistically significant changes in total or inappropriate UTI antibiotic prescriptions per 1000 resident days per month relative to the onset COVID-19 pandemic. While there were increases observed, none of these changes reached statistical significance (Table 3, Figure 3).

Table 3. Interrupted time-series analysis using generalized linear models (GLM) to model the impact of COVID-19 on inappropriate and total antibiotic prescribing practices for UTI between March 2019 – 2021.

Parameter	Variable(s)	Coefficient(s)	Total UTI Antibiotic Prescriptions*			Inappropriate UTI Antibiotic Prescriptions**		
			IRR (95% CI)	% Change	p	IRR (95% CI)	% Change	p
Intercept	*Constant*	β_0	…	…	…	…	…	…
Pre-COVID trend	*T*	β_1	1.04 (0.95 – 1.13)	3.7	0.39	1.04 (0.99 – 1.10)	4.2	0.11
Immediate COVID impact	*I*	β_2	3.42 (0.40 – 29.13)	242.2	0.25	1.66 (0.31 – 8.99)	66.1	0.54
Change during-COVID trend	*TSI*	β_3	0.98 (0.74 – 1.29)	-2.4	0.86	1.03 (0.853 – 1.269)	2.8	0.83
Persistence of trend during-COVID	*T + TSI*	$\beta_1 + \beta_3$	1.01 (0.78 – 1.32)	1.2	0.93	1.07 (0.925 – 1.309)	7.0	0.58

Note: In this equation modeling monthly rates of antibiotic prescribing outcomes, T represents the trend before the pandemic onset, I reflects the immediate impact of the pandemic's onset, TSI captures the difference between the post-pandemic and pre-pandemic trends, and T + TSI represents the overall post-pandemic trend. ***** Modelling the total number of antibiotics (both inappropriate and appropriate) prescribed for suspected UTIs per 1000 resident facility days per month, COVID-19 pandemic, study time by month, and an interaction term between two time-varying covariates: study time by month and pandemic variable (pre COVID-19: March 01, 2019 - March 11, 2020, during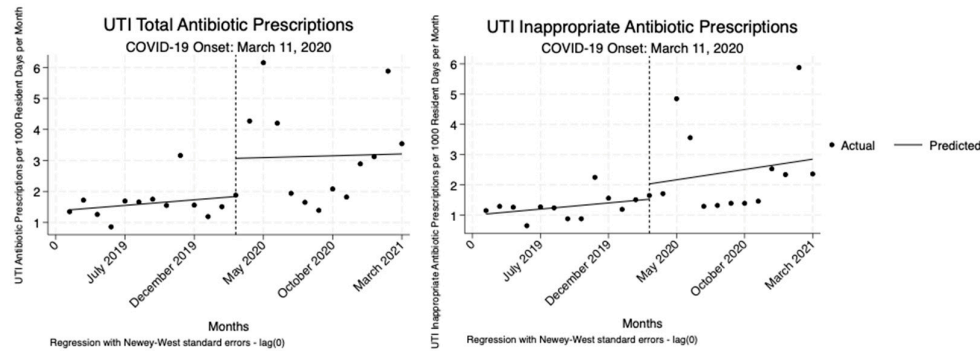 COVID-19: March 11, 2020 - March 31, 2021). ******Modelling the number of inappropriate antibiotic prescriptions for suspected UTIs per 1000 resident facility days per month, COVID-19 pandemic, study time by month, and an interaction term between two time-varying covariates: study time by month and pandemic variable (pre COVID-19: March 01, 2019 - March 11, 2020, during COVID-19: March 11, 2020 - March 31, 2021).

Figure 3. Interrupted time series analysis to assess changes in the total and inappropriate UTI antibiotic prescribing trends before and during the COVID-19 pandemic.

For RTIs, we also observed no significant changes in either total or inappropriate antibiotic prescriptions following the onset of the COVID-19 pandemic or throughout the pandemic period. Though there were slight decreases and increases in prescribing rates, none of these shifts were statistically significant (Table 4, Figure 4).

Table 4. Interrupted time-series analysis using generalized linear models (GLM) to understand the impact of COVID-19 on inappropriate and total antibiotic prescribing practices for RTIs between March 2019 – 2021.

Parameter	Variable(s)	Coefficient(s)	Total RTI Antibiotic Prescriptions*			Inappropriate RTI Antibiotic Prescriptions**		
			IRR (95% CI)	% Change	p	IRR (95% CI)	% Change	p
Intercept	*Constant*	β_0	…	…	…	…	…	…
Pre-COVID trend	*T*	β_1	1.07 (0.91 – 1.24)	6.7	0.39	1.05 (0.96 – 1.15)	5.4	0.23
Immediate COVID impact	*I*	β_2	0.63 (0.17 – 2.34)	-37.1	0.47	0.75 (0.28 – 1.85)	-27.6	0.48
Change during-COVID trend	*TSI*	β_3	1.00 (0.82 – 1.21)	-0.5	0.96	0.95 (0.82 – 1.09)	-5.1	0.44
Persistence of trend during-COVID	*T + TSI*	$\beta_1 + \beta_3$	1.06 (0.94 – 1.20)	6.2	0.33	1.00 (0.90 – 1.11)	-0.1	0.99

Note: In this equation modeling monthly rates of antibiotic prescribing outcomes, T represents the trend before the pandemic onset, I reflects the immediate impact of the pandemic's onset, TSI captures the difference between the post-pandemic and pre-pandemic trends, and T + TSI represents the overall post-pandemic trend. ***** Modelling the total number of antibiotics (both inappropriate and appropriate) prescribed for suspected RTIs per 1000 resident facility days per month, COVID-19 pandemic, study time by month, and an interaction term between two time-varying covariates: study time by month and pandemic variable (pre COVID-19: March 01,

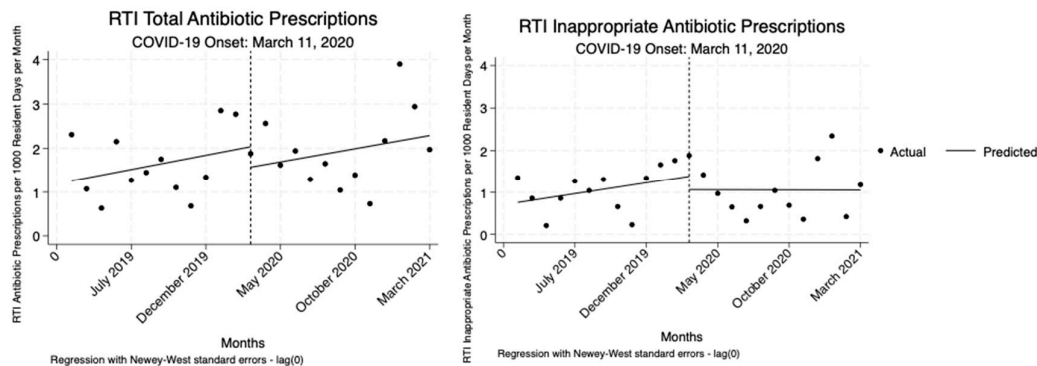2019 - March 11, 2020, during COVID-19: March 11, 2020 - March 31, 2021). **Modelling the number of inappropriate antibiotic prescriptions for suspected RTIs per 1000 resident facility days per month, COVID-19 pandemic, study time by month, and an interaction term between two time-varying covariates: study time by month and pandemic variable (pre COVID-19: March 01, 2019 - March 11, 2020, during COVID-19: March 11, 2020 - March 31, 2021).

Figure 4. Interrupted time series analysis to assess changes in the total and inappropriate RTI antibiotic prescribing trends before and during the COVID-19 pandemic.

3. Discussion

Using the McGeer criteria to assess the appropriateness of antibiotic prescriptions, our findings show that prescribing antibiotics consistent with standardized definitions of UTI and RTI in LTC was consistently low throughout the study period, particularly among residents with UTIs. This underscores the critical importance of standardized infection definitions in guiding antimicrobial stewardship, especially in LTC settings where the risk of inappropriate antibiotic use is high.[7]

Our analysis identified acute dysuria and new or marked increase in urgency as significant predictors of appropriate antibiotic use for UTIs. These symptoms were strongly associated with adherence to the McGeer criteria, indicating their relevance in distinguishing bacterial infections that warrant antibiotic treatment. For RTIs, the presence of fever and acute functional decline were significant predictors of appropriate antibiotic prescribing. Conversely, a positive COVID-19 status emerged as a significant predictor of inappropriate antibiotic prescribing, reflecting a possible overcaution in treatment practices during the pandemic. This pattern aligns with research in nursing homes where an increase in prescribing antibiotics such as azithromycin and ceftriaxone was observed despite a lack of bacterial co-infection, often driven by COVID-19-related concerns [16].

Our observed data demonstrated a fluctuating pattern of antibiotic prescribing during the COVID-19 pandemic. This aligns with findings from Canadian LTC, where Alberta facilities experienced significant reductions in overall antibiotic prescribing rates, while Ontario facilities saw decreases in specific antibiotic classes, particularly for RTIs, without a uniform decline in overall antibiotic use [18]. Our study found that while there was a noticeable decrease in the absolute percentage of inappropriate antibiotic prescriptions for both UTIs and RTIs, the overall volume of antibiotic prescribing did not uniformly decrease. This finding is consistent with other research in LTC settings, which reports a reduction in overall antibiotic prescribing compared to pre-pandemic levels [8,15,16]. After adjusting for resident census, regression analysis revealed a significant reduction in inappropriate prescribing rates for UTIs, but not for RTIs. Across both RTIs and UTIs, there were no statistically significant immediate or persistent changes in total or inappropriate antibiotic prescriptions relative to the onset of the COVID-19 pandemic. However, when we assessed the pooled pre-and post-COVID months, we found significant increases in inappropriate and total UTI prescriptions after adjusting for resident census, but no significant change for RTIs. This suggests a temporary disruption in UTI prescribing driven by early pandemic uncertainty. The simpler pre/post model captured short-term disruptions, which may explain the significant increase in UTI

prescriptions. Since the prescribing changes for UTIs were likely short-lived as a result of the pandemic onset, they did not persist enough to be detected in the ITS analysis.

3.1. Strengths

A key strength of our study is the detailed data collection within an SNF, a setting often underrepresented in research compared to acute care hospitals. The use of McGeer criteria provided a standardized and robust framework for assessing antibiotic appropriateness, enhancing the validity of our findings. The comprehensive examination of EMRs, including clinician notes, pharmacy orders, and diagnostic reports, allowed for an in-depth analysis of each suspected infection case. The high agreement rate in data abstraction further underscores the methodological rigor and reliability of our research. Additionally, examining antibiotic prescribing patterns relative to the onset of the COVID-19 pandemic provided critical insights into the practices of antimicrobial stewardship during a global health crisis.

3.2. Limitations

There are a few points to consider when interpreting these findings. The study's focus on a single SNF in Arizona may limit the generalizability of the findings to other regions or settings. The study relied on available EMR data and laboratory results, and any information not captured in these sources was not included in the analysis. UTIs and RTIs, while common in SNFs, do not fully represent the complete scope of antibiotic prescribing practices in these settings.

The revised McGeer criteria, commonly used in infection surveillance for LTC also come with several limitations. First, lower sensitivity for UTIs suggest the criteria may underestimate infection rates compared to clinical diagnoses [19]. Second, accurately distinguishing new infections from chronic or baseline symptoms—such as persistent cough or urinary urgency common in elderly residents—can be challenging. Third, many LTC facilities face resource limitations, with restricted access to diagnostics like radiology or laboratory testing, which can limit accurate application of the criteria. These criteria are not intended as clinical prescribing guidelines for benchmarking prescribing practices. In this paper, we have used these definitions to estimate "inappropriate prescribing."

Further research is warranted to explore the long-term impacts of the COVID-19 pandemic on antimicrobial prescribing patterns across various healthcare settings. The findings from this study can inform the development of more resilient healthcare policies, especially in enhancing AMS programs in LTC facilities.

Our study reveals largely consistent inappropriate prescribing patterns for antibiotics within an SNF during the COVID-19 pandemic. These patterns underscore the challenges faced by healthcare providers in maintaining appropriate antibiotic use amidst the pandemic, despite emphasis on AMS programs in the pre-pandemic period [20,21]. These findings highlight the need for effective AMS interventions that are sustainable during public health emergencies.

4. Materials and Methods

4.1. Study Design & Setting

In this retrospective cohort study, EMR from a cohort of SNF residents with suspected UTI or RTI, were systematically reviewed for the period March 2019 to March 2021. The study site was a 300-bed Arizona SNF with an AMS program in place.

4.2. Study Sample

Data was abstracted from the SNF's EMR system between the study period of March 2019 to March 2021 for suspected case(s) of UTIs or RTIs that resulted in an antibiotic prescription. Suspected UTIs and RTIs, defined by either healthcare provider requests for laboratory testing (e.g., a chest x-ray and/or urinary analysis) or the initiation of antibiotic therapy, were flagged within the facility EMR. Resident data was excluded if suspected infections (1) were duplicate records for the same

suspect infection occurring within one week of the index suspect infection event for the same resident (in these instances, the first record was used), (2) did not result in an antibiotic prescription, or (3) the resident had an admittance period shorter than one day (Figure 1).

4.3. Electronic Medical Record Abstraction

We designed our data abstraction protocol based on the elements needed to apply the McGeer criteria, a standardized set of infection definitions employed for surveillance purposes within LTC settings [7]. for UTIs (both indwelling and non-indwelling), and pneumonia-associated RTIs. Following suspected infection identification, we used a Research Electronic Data Capture (REDCap) EMR abstraction tool to extract McGeer components for each suspected infection type [22,23]. Three abstractors were assigned a random selection of EMRs. They each conducted a thorough review of clinician progress notes, microbiology information from laboratory reports, pharmacy orders, and vital statistics, to gather comprehensive data on each suspected infection. Patient demographic characteristics were also collected.

EMR documents were reviewed during the time frame extending one week prior to and one following the date of either a laboratory report or antibiotic prescription – whichever occurred first. This included laboratory reports sourced from the SNF's diagnostic testing facility, including bacterial counts in urine culture reports and chest x-ray results. In instances where more than one antibiotic or multiple types of laboratory testing (e.g., both urine culture and chest x-ray) were ordered within one week prior to and one week following a suspected infection, we created separate records to accurately reflect each distinct suspected infection event. For suspected RTIs, we also incorporated data from influenza and COVID-19 tests (following March 11, 2020, the COVID-19 onset-period) and influenza tests.

4.4. Statistical Analyses

4.4.1. Variables

Resident EMR data from the REDCap database was used to create a binary outcome variable based on the McGeer criteria. This variable consisted of both clinical and microbiological information, including colony forming units for UTIs (see McGeer, LTC-specific infection criteria in Supplementary Materials). For the purposes of our analyses, the outcome variable was the appropriateness of an antibiotic prescription. A prescription was deemed "appropriate" if the abstracted data for a suspected infection met the McGeer criteria, and "inappropriate" if the infection-specific criteria were not met. The infection types, as categorized in the criteria, included UTIs with or without indwelling catheters and RTIs. Individual covariates were created to identify the presence or absence of each McGeer-defined clinical symptom (e.g., fever, acute dysuria, cough, etc.) and microbiological criteria (e.g., presence of an ESBL, positive COVID-19 or influenza test). In total, 14 and 12 individual clinical and symptom criteria variables were created for UTI and RTIs, respectively.

A binary variable was also generated to identify the onset of the COVID-19 pandemic. A binary variable was created to identify trends relative to the onset of the COVID-19 pandemic in Arizona. The period before the pandemic's onset includes events from March 1, 2019, to March 10, 2020, while the period following the onset spans from March 11, 2020, to March 31, 2021, based on the World Health Organization's declaration of the pandemic on March 11, 2020. To account for changes in the SNF census over the study period, a variable consisting of the number of days per month residents remained in the facility was created using internal facility reports. Residents with an admittance period shorter than one day were excluded from the census. A variable consisting of study time in months (1-25) was also created.

4.4.2. Analyses

We assessed consistency of arrival at the same McGeer Criteria designation for suspected infections with antibiotic use (e.g., whether suspected infection met or did not meet the McGeer criteria for an infection) across abstractors and any remaining discrepancies were resolved by the

principal investigator. A kappa statistic was calculated to assess the level of agreement beyond chance.

To evaluate the appropriateness of antibiotic prescriptions from March 1, 2019, to March 31, 2021, we calculated the frequency and proportion of suspected infection events leading to antibiotic prescriptions. We then evaluated the binary outcome of antibiotic prescription appropriateness for each suspected infection, as defined by the McGeer criteria. We included all cases of suspected UTI (e.g., cultured with no catheter, non-indwelling catheter, or indwelling catheter). We then analyzed key predictors of inappropriate antibiotic prescriptions. To achieve this, we applied GEE to independently model the appropriateness of antibiotic prescriptions in relation to each specific clinical symptoms outlined in the criteria for UTIs (n=14) (Table 2a) and RTIs (n=11) (Table 2b) separately.

Our second objective assessed changes in antibiotic prescribing practices relative to the onset of the pandemic. We conducted an ITS to determine whether prescribing patterns differed following the onset of the COVID-19 pandemic in Arizona [24]. Two separate models were run for UTIs and RTIs. The first of which modeled the number of inappropriate antibiotic prescriptions and the second modeled the total number of antibiotic prescriptions (appropriate and inappropriate). The outcome was the number of inappropriate or total prescriptions per 1000 resident days and the onset of the pandemic was March 2020. Study time in months (1-25) was used to set the data. The equation representing this model is shown below [25].

$$Log(\mu_t) = \beta_0 + \beta_1 T(time_t) + \beta_2 I_t(pandemic_t) + \beta_3 TSI_t(time_t \times pandemic_t) + \beta_4(T_t + TSI_t)$$

In this equation modeling monthly rates of antibiotic prescribing outcomes, T represents the trend before the pandemic onset, I reflects the immediate impact of the pandemic's onset, TSI captures the difference between the post-pandemic and pre-pandemic trends, and T + TSI represents the overall post-pandemic trend.

All data analyses were performed using Stata 18 software, including use of the "itsa" package for ITS analyses. Grammarly was employed to enhance clarity and conciseness of the writing and ChatGPT was infrequently used to refine word choice during manuscript preparation. All AI-assisted suggestions were thoroughly reviewed by the authors to ensure scientific accuracy.

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