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Antibiotic prescribing for urinary tract infections at three nursing homes following implementation of an antibiotic stewardship program: A quantitative evaluation of the Emory Antibiotic Stewardship in Long Term Care (EASIL) Initiative

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Abstract

Antibiotic prescribing for urinary tract infections at three nursing homes following implementation of an antibiotic stewardship program: A quantitative evaluation of the Emory Antibiotic Stewardship in Long Term Care (EASIL) Initiative

By Andrea Cool

Introduction: Unnecessary use of antibiotics is common in nursing homes and can contribute to the emergence of antibiotic resistant organisms and increased rates of associated adverse events, such as *C. difficile* infections. As of November 2017, nursing homes are required to implement antibiotic stewardship programs to improve antibiotic prescribing practices. Three independent nursing homes collaborated with the Emory Antibiotic Stewardship in Long Term Care (EASIL) Initiative Team to start activities to reduce unnecessary antibiotic use for presumed urinary tract infections (UTIs). Activities included a stewardship gap analysis, launch of best practice guidance for UTI antibiotic prescribing shared with prescribing staff, and start of a data feedback system.

Objective/Aim: This study examines changes in antibiotic prescribing metrics for UTIs over the course of an antibiotic stewardship intervention in 3 Atlanta-based nursing homes enrolled in the EASIL Initiative.

Methods: Quantitative methods were used to analyze antibiotic prescribing for UTIs over the course of the intervention by comparing antibiotic prescribing metrics between a peri-intervention period to an early intervention and late intervention period. Comparative metrics included facility-specific proportions of UTI antibiotic prescriptions over the recommended duration and days of therapy (DOT) per 1,000 resident days (RD).

Results: Average monthly RD at the three nursing homes ranged from 3,535 to 5,981. During the peri-intervention period, 96 (28.2%) antibiotic prescriptions were for UTIs, of which, 51 (53.1%) were new antibiotic starts. Metrics did not differ significantly between peri- and early intervention periods; however, one facility reported a significant reduction in new UTI prescriptions over recommended duration in late-intervention compared to peri-intervention period (Risk Ratio = 0.35, 95% CI 0.13-0.93, $p = 0.033$), while the other two reported non-significant declines. One facility reported a significant reduction in DOT/1000 RD between late-intervention period compared to peri-intervention period (Rate Ratio = 0.52, 95% CI 0.40-0.67, $p < .001$), while another experienced a significant increase in DOT/1,000 RD (Rate Ratio = 2.05, 95% CI 1.52-2.76, $p < .001$).

Conclusion: While this study found some significant improvements in antibiotic prescribing metrics over the study period, changes were inconsistent across facilities. Exploring how effects of the intervention may vary due to differences in implementation or facility staffing between facilities is warranted.

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Abbreviations

ADE	Adverse drug event
ASB	Asymptomatic bacteriuria
CDC	Centers for Disease Control and Prevention
CDI	*Clostridioides difficile* Infection
CI	Confidence Interval
CMS	Centers for Medicare and Medicaid Services
DOT	Days of Therapy
EASIL	Emory Antibiotic Stewardship in Long Term Care
IDSA	Infectious Disease Society of America
IRB	Institutional Review Board
IRR	Incidence Rate Ratio
JAMDA	Journal of the American Medical Directors Association
KFF	Kaiser Family Foundation
RD	Resident Days
RR	Risk Ratio
SBAR	Situation-Background-Assessment-Recommendation
TDF	Theoretical Domains Framework
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action
UTI	Urinary tract infection

INTRODUCTION

Introduction and Rationale

The unnecessary use of antibiotics is a growing public health challenge due to the rapid emergence of multi-drug resistant organisms across the globe (Klein, Tseng, Pant, & Laxminarayan, 2019; Klein et al., 2018). The issue of antibiotic resistance is of particular concern in nursing homes, as antibiotics are one of the most commonly prescribed medications in this setting, and an estimated 25% to 75% of these prescriptions may be inappropriately or unnecessarily prescribed (van Buul et al., 2012). The unnecessary use of antibiotics in this population can lead to increased rates of adverse side effects, such as *Clostridioides difficile* infections (CDI); increased costs; and can further contribute to antibiotic resistance (Frentzel et al., 2015; van Buul et al., 2012).

Ensuring accurate and appropriate prescribing of antibiotics in nursing homes is particularly challenging, as nursing home residents commonly present with symptoms that are difficult to diagnose due to comorbidities and cognitive impairment (Scales et al., 2017). Additionally, nursing home residents are prescribed antibiotics more frequently due to increased risk of infection and sepsis due to frequent comorbid conditions, including immunosuppression, malnutrition, functional impairments, and the use of devices such as catheters (Girard, 2005; Stone, 2018).

In order to reduce the overuse of antibiotics in healthcare settings, in 2014 the Centers for Disease Control and Prevention (CDC) released guidelines for developing and implementing antibiotic stewardship programs that incorporate seven core elements: leadership, accountability, drug expertise, action, tracking, reporting, and education (CDC, 2015). These guidelines provide nursing homes with practical ways to initiate antibiotic stewardship activities aimed at improving antibiotic use, reducing adverse events, and preventing the emergence of antibiotic resistance.

Additionally, in response to the growing emphasis on antibiotic stewardship in nursing homes, as of November 28, 2017, the Centers for Medicare and Medicaid Services (CMS) began requiring that nursing homes implement an antibiotic stewardship program that includes antibiotic use protocols and a system to monitor antibiotic use (CMS, 2017). Despite these new requirements, many nursing homes still do not have comprehensive antibiotic stewardship programs that incorporate all of the CDC Core Elements (Fu, Mantell, Stone, & Agarwal, 2020; Palms et al., 2019; Stone, 2018).

Problem Statement

Due to the frequent occurrence of potentially unnecessary antibiotic prescribing in nursing homes, there is a critical need to examine existing antibiotic stewardship programs to understand the impact of stewardship activities on antibiotic prescribing and to identify gaps in programs that may inform future antibiotic stewardship program implementation. Additionally, due to the relatively limited research on the implementation of antibiotic stewardship programs in nursing homes, there is a need for further evaluation of the effectiveness of antibiotic stewardship program implementation in this setting as well as the facilitators and barriers to implementation (Crnich, Jump, Trautner, Sloane, & Mody, 2015).

Theoretical Framework

This study is informed by behavioral change theory to understand antibiotic prescribing behavior and the barriers and facilitators to implementing antibiotic stewardship programs. The constructs of the Theory of Planned Behavior (TPB), behavioral intention, attitudes, subjective norms, and perceived behavioral control, have been applied to understand antibiotic prescribing behaviors across healthcare settings and how to influence these behaviors (Ajzen, 1991). Additionally, the Theoretical Domains Framework (TDF), a framework that draws on behavioral change theories to help identify and examine influences on healthcare professional behaviors, has been used to identify key facilitators and barriers to the implementation of antibiotic stewardship programs in long-term care settings (Michie et al., 2005).

Purpose Statement

The purpose of this study is to examine the impact of a quality improvement initiative designed by the Emory Antibiotic Stewardship in Long Term Care (EASIL) Initiative team to support the antibiotic stewardship programs of three Atlanta-based nursing home facilities. The initiative was designed to fill critical gaps in the participating facilities' antibiotic stewardship programs identified through a gap analysis at each facility.

Research Question

This study is designed to answer the following research questions: (1) What is the estimated effect of the implementation of an antibiotic stewardship intervention on urinary tract infection (UTI) antibiotic prescribing metrics in three Atlanta-based nursing homes over the duration of the intervention? (2) How do changes in UTI antibiotic prescribing metrics over the course of the intervention vary across facilities?

Significance Statement

This research will help to inform future directions for developing, implementing, and evaluating antibiotic stewardship programs and policies to improve antibiotic prescribing and ensure patient safety in nursing homes.

Definition of Terms

The following definitions from the CDC will be used when referring to key terms throughout this report (CDC, 2019):

- Antibiotic resistance occurs when bacteria develop the ability to defeat the drugs designed to kill them.
- An antibiotic is a type of drug that treats infections caused by bacteria (e.g., strep throat, foodborne illness).
- Multi-drug resistant organisms are bacteria resistant to multiple antibiotics available for treatment.
- Antibiotic stewardship refers to improving the way antibiotics are prescribed and used.
- An adverse drug event (ADE) is a harm resulting from the use of medication and includes allergic reactions, side effects, overmedication, and medication errors.

LITERATURE REVIEW

Antibiotic Resistance

Antibiotic resistance is a rapidly growing threat to public health, as more than 2.8 million antibiotic-resistant infections occur in the United States annually (CDC, 2019). Antibiotic-resistant infections are often difficult, and sometimes even impossible to treat, thus resulting in more than 35,000 deaths each year (CDC, 2019). These infections not only cause a physical toll, but also pose an economic burden on the U.S. healthcare system, with increased hospital stays and follow-up visits as well as the utilization of costly treatments (CDC, 2019). The CDC has identified five organisms that are currently considered urgent threats to human health: carbapenem-resistant *Acinetobacter*, *Candida auris*, *Clostridioides difficile* (*C. difficile*), carbapenem-resistant Enterobacteriaceae, and drug-resistant *Neisseria gonorrhoeae* (CDC, 2019).

Clostridioides difficile

Of the five antibiotic-resistant organisms categorized as urgent threats, *C. difficile* poses a unique and significant challenge, as *C. difficile* is associated with the use of antibiotics that drive antibiotic resistance (CDC, 2019). According to the CDC, in 2017, nearly 223,900 people in the United States required hospital care for CDI and more than 12,800 people died from the infection (CDC, 2019). Symptoms of CDI include severe diarrhea, fever, stomach tenderness, loss of appetite, and nausea (CDC, n.d.-a). CDI is a particular concern for long-term care residents as *CDI*s tend to be more common and more severe in older patients (CDC, 2019). Major risk factors for CDI include being 65 years or older, a recent stay at a hospital or nursing home, a weakened immune system, and previous infection with or exposure to *C. diff* (CDC, n.d.-a).

Antibiotic Stewardship

When a patient requires an antibiotic to treat an infection, the benefits of prescribing the antibiotic typically outweigh any potential risks (CDC 2019). However, while antibiotics can be important life-saving treatments, they are not risk-free, and should thus only be used when recommended. The unnecessary or inappropriate prescribing of antibiotics can unnecessarily expose patients to a higher risk of ADEs, including allergic reactions, toxicity, or CDI (CDC, 2019). Unnecessary use of antibiotics is defined as antibiotic treatment in the absence of clear indication for an antibiotic according to clinical guidelines, while inappropriate prescribing of antibiotics refers to antibiotic therapy that does not adhere to the guidelines for correct dose, duration, or antibiotic agent (Doron & Davidson, 2011). In an effort to promote and measure appropriate antibiotic prescribing, the CDC developed its Core Elements of Antibiotic Stewardship, which offers healthcare providers and facilities with the key principles and activities to guide improvements in antibiotic use (CDC, 2014).

Dose, Duration, Indication

A key component of the CDC's Core Elements of Antibiotic Stewardship is the documentation of antibiotic prescribing elements, including dose, duration of antibiotic treatment, and indication (i.e., rationale and treatment site) for every course of antibiotics (CDC, 2014). Clear documentation of these elements for each course of treatment is necessary to ensure that antibiotics are modified or discontinued as needed to optimize treatment. Optimal antibiotic therapy requires treating patients with the most appropriate, properly dosed, and least harmful antibiotic agent according to treatment guidelines (Doron & Davidson, 2011). Duration of antibiotic course is another important element of antibiotic therapy, as shorter antibiotic courses have been found to be nearly as effective as longer courses in eliminating the infecting organism (Wilson, Daveson, & Del Mar, 2019). Furthermore, the longer the antibiotic exposure, the greater the risk of selection pressure for antibiotic resistant bacteria, such as *C. difficile*, that may cause serious infection (Wilson et al., 2019).

Antibiotic Prescribing in Nursing Homes

According to the Kaiser Family Foundation (KFF), as of 2019, approximately 15,000 nursing homes currently serve over 1,200,000 residents in the United States (KFF, 2019a, 2019b). Antibiotic resistance is of particular concern among nursing home residents, as antibiotics are the most commonly prescribed medications in this setting, with annual prevalence rates of antibiotic use in nursing homes ranging from 47% to 79% (van Buul et al., 2012). Additionally, nursing home residents experience greater risk of antibiotic resistance due to factors such as prior antibiotic use, use of invasive devices, including urinary catheters and feeding tubes, and reduced functional status (van Buul et al., 2012). As previously mentioned, antibiotic resistance is a significant threat to nursing home populations, as older adults living in nursing homes are at highest risk of contracting CDI (CDC, n.d.-a; Jump & Donskey, 2015). The high incidence of CDI in nursing homes is driven by the alarming rates of inappropriate or unnecessary antibiotic prescriptions in this setting, as it is estimated that 25-75% of these prescriptions are either inappropriate or unnecessary (Frentzel et al., 2015; Jump & Donskey, 2015).

Estimates of antibiotic use in nursing homes have found that, while antibiotic use overall has not changed, antibiotic use has increased in recent years among residents with UTIs (Cohen et al., 2020). Historically, UTIs are the most common indication for starting antibiotics among nursing home residents, with over one third of all antibiotics prescribed in this setting targeting UTIs (Crnich et al., 2015; Jump & Donskey, 2015; Thompson et al., 2016; Thompson et al., 2020). However, studies have found that residents are often inappropriately treated with antibiotics for UTIs. Studies of antibiotic prescriptions for UTIs suggest that antibiotics are often used in the absence of clinical evidence of infection, with one study finding that over one third of antibiotic prescriptions for UTIs started before a laboratory test was even performed (Eke-Usim et al., 2016; Kistler et al., 2017). These studies also found that the use of antibiotics for UTIs often continues for prolonged durations, despite negative laboratory tests (e.g., urinalysis, urine culture, blood culture) (Eke-Usim et al., 2016; Kistler et al., 2017).

The overuse of antibiotics for UTIs may be driven by the unnecessary treatment of asymptomatic bacteriuria (ASB) (Crnich et al., 2015). According to the CDC, ASB refers to the "isolation of bacteria in urine culture from a patient without signs or symptoms of [UTI]" (CDC, n.d.-b). A positive urine culture, without the necessary signs or symptoms of UTI, does not sufficiently meet the criteria for initiation of antibiotics (CDC, n.d.-b). However, research has found that over 80% of antibiotic prescriptions for catheterized residents were written for ASB rather than UTI (Phillips et al., 2012). Furthermore, for those without a catheter, more than half of antibiotic prescriptions for suspected UTI were administered to residents with no documented UTI symptoms (Phillips et al., 2012). These inaccurate diagnoses may be a result of insufficient provider and nurse education on ASB and UTI, as while providers may be able to recognize the definition of ASB, many have demonstrated difficulty distinguishing between UTI and ASB in practice (Trautner et al., 2017).

Additional challenges to antibiotic prescribing unique to this setting that may contribute to the high rates of unnecessary prescriptions for nursing home residents include the increased prevalence of comorbidities and cognitive impairments among this population that create difficulties in diagnosis (Crnich et al., 2015). Studies focused on the perceptions of nursing home providers have also found that significant barriers to improving antibiotic use in nursing homes include facility and staff factors (e.g., facility resources, staffing ratios, staff knowledge), as well as patient and family factors (e.g., pressure from family members to prescribe antibiotics) (Crnich et al., 2015; Langford, Quirk, Carey, Daneman, & Garber, 2019; Scales et al., 2017).

Antibiotic Stewardship in Nursing Homes

Due to the over prescription of antibiotics in nursing homes as well as the unique challenges of antibiotic prescribing in nursing home populations, the CDC adapted the original Core Elements of Hospital Antibiotic Stewardship to develop setting-specific guidance: The Core Elements of Antibiotic Stewardship in Nursing Homes (CDC, 2015). These guidelines outline practical methods nursing homes can employ to initiate or expand antibiotic stewardship activities. These methods are categorized by seven core elements of antibiotic stewardship in nursing homes: leadership commitment, accountability, drug expertise, action, tracking, reporting, and education (CDC, 2015). The CDC encourages nursing home leadership to implement the activities described in the guidance in a stepwise fashion, suggesting that even minor actions taken to improve antibiotic use will ultimately help to reduce ADEs, prevent antibiotic resistance, and result in improved resident outcomes (CDC, 2015).

Since the release of the Core Elements, many nursing homes (approximately 33%) have improved their antibiotic stewardship practices by requiring the use of antibiotic prescribing guidelines and protocols, enforcing policies to restrict antibiotic use, reviewing of cases for antibiotic appropriateness, and providing feedback to clinicians on antibiotic prescribing (Agarwal, Dick, Sorbero, Mody, & Stone, 2020). Furthermore, in their mixed-methods pilot study, Carter et al., found that nursing homes with leadership that was more supportive of antibiotic stewardship were characterized by practice patterns grounded in diagnostic criteria, proactive infection control and prevention, and open communication among staff (Carter, Montpetite, & Jump, 2017).

In a national cross-sectional survey of nursing homes, Herzig et al. found a wide variation in the antibiotic stewardship processes and practices implemented across the U.S. (Herzig et al., 2016). Among facilities that have implemented comprehensive antibiotic stewardship programs, many have reported improvements in various antibiotic prescribing metrics, including reductions in antibiotic prescriptions, shorter lengths of antibiotic therapy, and lower overall antibiotic use (Carter et al., 2017; Feldstein, Sloane, & Feltner, 2018). Additionally, antibiotic stewardship programs have been found to be associated with improved resident outcomes, such as reduced rates of positive CDI tests (Cheatham, Leriger, Pinon, & Wack, 2018; Jump & Donskey, 2015).

In order to further promote the implementation of antibiotic stewardship programs in nursing homes, as of November 28, 2017, CMS began requiring that nursing homes have an antibiotic stewardship program in place that includes antibiotic use protocols and a system to monitor antibiotic use and that nursing homes employ a trained infection preventionist (CMS, 2017). According to the revised CMS Requirements of Participation, facilities that do not have a sufficient antibiotic stewardship program in place, as determined by a state surveyor, are subject to an infection control deficiency citation as well as a financial penalty (CMS, 2017).

Despite these new requirements, many nursing homes continue to have limited or inadequate antibiotic stewardship programs that do not meet the criteria required by CMS (Fu et al., 2020; Palms et al., 2019; Stone, 2018). According to several national studies, over one third of nursing homes have received infection control deficiency citations due to inadequate antibiotic stewardship programs (Herzig et al., 2016; Stone, 2018). Additionally, many antibiotic stewardship programs continue to lack important components from the CDC's guidelines, with only 40% of nursing homes meeting all seven of the Core Elements for Antibiotic Stewardship in Nursing Homes (Palms et al., 2019; Stone, 2018). Furthermore, in a national survey of U.S. nursing homes, only 33% of facilities were found to have "comprehensive" antibiotic stewardship policies, with data collection on antibiotic use reported as the most common stewardship activity implemented, and restriction of antibiotic use the least reported (Fu et al., 2020).

While deficiencies in antibiotic stewardship programs in nursing homes persist, nursing home staff and leadership continue to report a demonstrated commitment to changing antibiotic prescribing practices (Sloane et al., 2020). Therefore, nursing homes that want to improve antibiotic prescribing may benefit from additional support to effectively implement stewardship policies and activities. Preliminary research has found that nursing homes that receive support from antibiotic stewardship experts, such as hospital-based teams or medical director advisory groups, experience improvements in antibiotic prescribing metrics, including decreased rates of systemic antibiotic prescriptions and decreased rates of fluroquinolone days of therapy (DOT) per 1,000 resident days (Felsen et al., 2020; Sloane et al., 2020).

Documentation and Standardized Criteria

A key antibiotic stewardship practice recommended by the CDC and other infectious disease experts is the documentation of clinical assessments to monitor signs and symptoms that indicate a need for antibiotics (CDC, 2015). However, many antibiotics, particularly those for suspected UTIs, continue to be administered in the absence of documented symptoms (Phillips et al., 2012). To reduce unnecessary antibiotic prescriptions and improve resident outcomes, it is recommended that providers use a standardized diagnostic tool to identify cases where a resident's clinical status indicates a need for an antibiotic (CDC, 2015). One such tool, the Loeb's Minimum Criteria, was developed in 2001 through a consensus conference to outline the minimum standards for initiation of antibiotics in long-term care settings based on infection signs and symptoms (Armbruster, Prenovost, Mobley, & Mody, 2017; Loeb et al., 2001; Olsho et al., 2013).

However, studies have found very low rates of adherence to the Loeb's Minimum Criteria in nursing homes. For example, in their 2017 study of 247 nursing home residents treated for suspected UTI, Kistler et al. observed that only 60% had documented signs and symptoms of UTI and only 15% met Loeb's Minimum Criteria (Kistler et al., 2017). Additionally, results from a cross-sectional analysis of resident-level antibiotic prescriptions found that only 12.7% of all prescriptions and 10.2% of prescriptions for UTI were classified as adherent to Loeb's Minimum Criteria (Olsho et al., 2013).

Furthermore, among clinically diagnosed catheter associated UTIs (CAUTI), only 40% met Loeb's Minimum Criteria (Armbruster et al., 2017).

Education and Best Practices

One of the core elements of antibiotic stewardship, education, is defined by the CDC as the provision of "resources to clinicians, nursing staff, residents and families about antibiotic resistance and opportunities for improving antibiotic use" (CDC, 2015). Studies has shown that effective education of nurses, providers, and families can help to improve adherence to antibiotic prescribing guidelines, and thus improve resident outcomes (Crnich et al., 2015; Felsen et al., 2020). Furthermore, education on standardized best practices for antibiotic prescribing is important to ensure that antibiotics are only prescribed when necessary and appropriate (Felsen et al., 2020). Results from a study using a human factors engineering approach suggest that this education is most effective when incorporated into the workflow of nurses and providers, in the form of reference pocket cards or decision-making guides (Katz et al., 2017). McMaughan et al.'s study on the impact of decision-making aids for suspected UTIs supports this recommendation, as the study found that the odds of an antibiotic prescription being written for ASB decreased significantly in nursing homes that succeeded in implementing a decision-making aid (Odds Ratio = 0.35, 95 % Confidence Interval = [0.16–0.76]) compared to a control group (McMaughan et al., 2016).

Communication and Coordination

Effective communication between nursing staff and prescribers is essential to improving antibiotic use, as prescribers are often physicians who spend only a fraction of time in nursing home facilities. Therefore, physicians must rely on the information that is communicated to them from nursing staff about a resident's symptoms and clinical status to inform decisions regarding treatment (Renz, Boltz, Wagner, Capezuti, & Lawrence, 2013). Communication continues to be a challenge in long-term care facilities, as many providers report receiving limited information about resident cases, creating challenges in making antibiotic decisions (Kistler et al., 2017). In an effort to improve nurse-physician communication, staff at Kaiser Permanente developed the Situation-Background-Assessment-Recommendation (SBAR) tool which provides a framework for communicating about a patient's condition (Haig, Sutton, & Whittington, 2006; IHI, n.d.). While the SBAR is commonly used across healthcare settings, the technique has been found to be particularly useful for nurses in long-term care settings, as the tool allows nurses to organize information before sharing it with providers and provides cues on what information to communicate (Renz et al., 2013). However, some nurses have expressed challenges with using the tool, including limited time to complete the SBAR and additional communication barriers that are not addressed by the tool (Renz et al., 2013).

Acute Care vs. Long-Term Care

While guidelines on the implementation of antibiotic stewardship programs have been published, these recommendations have mostly targeted acute care, with limited evaluation of their impact in other settings (Agarwal et al., 2020; Barlam et al., 2016). As previously described, the unique characteristics of long-term care settings pose distinct challenges to implementing antibiotic stewardship programs compared with acute care. For instance, limited physician oversight in nursing homes and reliance on communication between nurses and prescribers may impact clinical decision making in this setting (Crnich et al., 2015; Kistler et al., 2017). Additionally, the high rates of comorbidities and cognitive impairment among nursing home residents may hinder accurate diagnoses and lead to higher levels of risk aversion among nursing home providers (Crnich et al., 2015; Kistler et al., 2017; Scales et al., 2017). Finally, as facility characteristics (e.g., bed size, staffing ratios, ownership) vary significantly across nursing homes in the U.S., it is difficult to develop defined antibiotic stewardship guidelines that apply to all nursing homes (CMS, 2015).

Due to the unique characteristics of nursing homes and the complexity of nursing home resident populations, these facilities may require additional support to effectively adopt antibiotic stewardship practices. Furthermore, as metrics for evaluating the impact of antibiotic stewardship programs have been predominantly studied in acute care settings, additional research is needed to determine the most reliable and valid metrics for assessing these programs in nursing homes due to the different structural and environmental factors that may impact implementation in this setting (Agarwal et al., 2020; Barlam et al., 2016).

Theoretical Framework

The development of antibiotic stewardship programs is often informed by behavioral science theory used to understand antibiotic prescribing behavior and the barriers and facilitators to implementing antibiotic stewardship programs. The TPB can help to better understand the underlying factors associated with intention to prescribe antibiotics. Originally developed in 1991 as an extension of the Theory of Reasoned Action (TRA), the TPB postulates that an individual's performance of a behavior is determined by their intention to engage in the behavior and their perception that the behavior is within their control (Ajzen, 1991). In a systematic review on healthcare professionals' intentions and behaviors, Godin et al. (2008) demonstrated that the TPB is an appropriate theory to predict antibiotic prescribing behavior, as antibiotic prescribing is influenced by both the behavioral intentions and perceived behavioral control of healthcare providers (Godin, Belanger-Gravel, Eccles, & Grimshaw, 2008).

According to the TPB, a healthcare provider's behavioral intention to prescribe antibiotics is informed by their attitudes towards antibiotic prescribing as well as subjective norms related to antibiotic prescribing (Ajzen, 1991). Attitudes are defined as a person's degree of favorability towards the behavior, while subjective norms are defined as a person's perceived social pressure to either perform or not perform the behavior (Ajzen, 1991; Liabsuetrakul, Chonsuvivatwong, Lumbiganon, & Lindmark, 2003; Liu et al., 2019). Studies examining antibiotic prescribing using the TPB framework have found that providers' perceptions of the usefulness, appropriateness, and effectiveness of antibiotics has a significant influence on their intention to prescribe (Eccles et al., 2007; Liu et al., 2019; Walker, Grimshaw, & Armstrong, 2001). Additionally, those who perceive greater social pressure to prescribe antibiotics and perceive weaker control over their prescribing practices, have been found to have lower intention to reduce antibiotic prescribing (Eccles et al., 2007; Liu et al., 2019; Walker et al., 2001).

While the majority of studies that apply the TPB to antibiotic prescribing have focused on acute-care or outpatient settings, the TPB constructs can be used to understand influences on antibiotic prescribing in nursing homes. For instance, in a cross-sectional study on nurse and medical provider perspectives on antibiotic stewardship in nursing homes, Scales et al. (2017) found that, while nurses and medical providers reported commitment and efficacy to improve prescribing practices, both groups perceived resident and family pressure to prescribe as a significant influence on prescribing decisions. This finding demonstrates the need for antibiotic stewardship programs in nursing homes to address subjective norms that may impact adherence to the stewardship initiatives.

While the TPB helps to explain the determinants of antibiotic prescribing behaviors, the TDF, which draws from 33 behavioral change theories, was developed to inform the implementation of evidence-based practices and identify the key barriers and facilitators to implementation (Michie et al., 2005). The TDF includes 14 domains: knowledge, skills, memory, attention and decision processes, behavioral regulation, social or professional role and identity, beliefs about capabilities, optimism, beliefs about consequences, intentions, goals, reinforcement, emotions, environmental context and resources, and social influences (Michie et al., 2005). Chambers et al. (2019) used the TDF to identify barriers and facilitators that contribute to the overuse of antibiotics in long-term care settings, including communication, organizational structure, role clarity, resources, and family pressure, and mapped these influences to domains from the TDF. Implementation strategies were then developed to address each of the identified barriers and facilitators (Chambers et al., 2019). This framework has also been applied to examine perceived barriers to and facilitators of using shorter antibiotic courses in long-term care and to develop antibiotic stewardship interventions aimed at improving duration of antibiotic therapy in this setting (Langford et al., 2019).

Current Problem/Study Relevance

While the unnecessary use of antibiotics continues to persist in nursing homes at alarming rates (Cohen et al., 2020; van Buul et al., 2012), research is currently limited on the effectiveness of implementing antibiotic stewardship programs to improve antibiotic prescribing in this setting. The purpose of this study is to examine the impact of antibiotic stewardship interventions on antibiotic prescribing metrics in three Atlanta-based nursing homes enrolled in the EASIL Initiative. This study provides insight into the practical application of antibiotic prescribing guidelines in nursing homes as well as the impact of these practices over time and between facilities. Additionally, this study examines the use of different antibiotic prescribing metrics to characterize the effect of stewardship practices on antibiotic prescribing in nursing homes.

STUDENT CONTRIBUTION

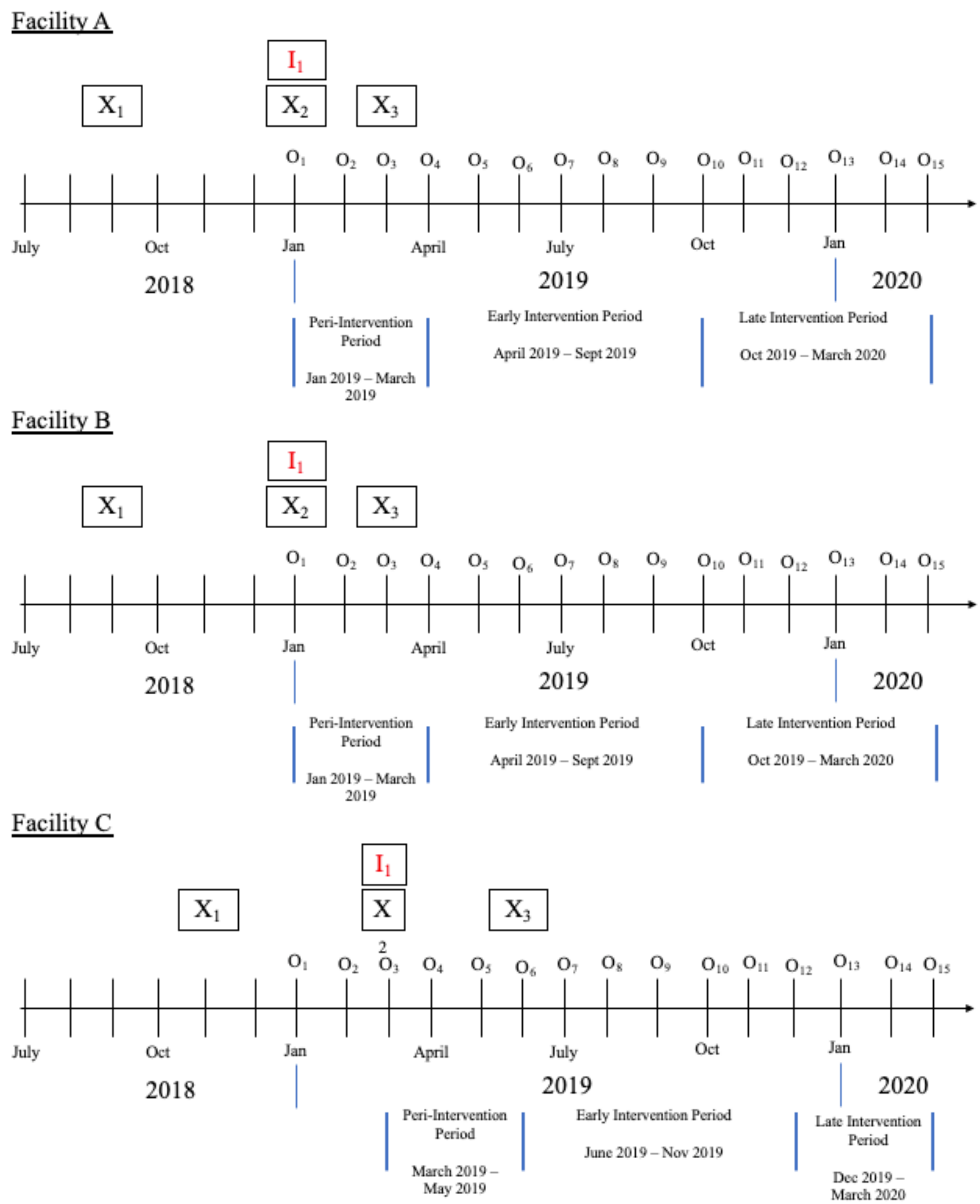
The current quantitative evaluation study was conducted using secondary data collected from the three participating nursing homes as part of the EASIL initiative. Each of the facilities collaborated with the EASIL team independently to implement activities as part of their antibiotic stewardship programs aimed at reducing unnecessary antibiotic use for presumed UTIs. Activities at each facility included a stewardship gap analysis, launch of best practice guidance for UTI antibiotic prescribing shared with prescribing staff, and start of a data feedback system. During the initial stewardship gap analysis, the EASIL team met with facility leadership to review the CDC's antibiotic stewardship guidelines and to identify gaps in the facility's current antibiotic stewardship programs. As part of the gap analysis, the EASIL team conducted directed interviews with leadership and staff during which possible areas of improvement were identified. The EASIL team then worked with each facility's medical director to determine a standardized approach to treating UTI's and the most appropriate methods for promoting these best practices within the facility. The determined best practices were then provided to nursing home staff through an antibiotic presentation as well as pocket cards that the staff could reference when making antibiotic prescribing decisions. Finally, the EASIL team provided each facility with regular feedback reports of antibiotic prescribing data.

As the primary researcher for this study, I was added to the EASIL project's Emory University Institutional Review Board (IRB) protocol and was provided access to the EASIL REDCap database which includes all antibiotic prescribing data entered by the EASIL team from standardized prescribing logs submitted from each facility over the course of the intervention. Each entry in the REDCap database represents a single antibiotic start and includes data on antibiotic start date, treatment site, antibiotic name, prescriber attribution, adherence to Loeb's Minimum Criteria, completion of the SBAR communication tool, and DOT. REDCap data for the three facilities were downloaded to my personal, password-protected laptop and loaded into RStudio (version 1.2.5042) for statistical analysis (RStudio Team, 2020).

As the first step of this study, I conducted a descriptive analysis to examine trends in antibiotic prescribing across the three facilities over the course of the intervention period. Basic characteristics of antibiotic starts, including treatment site, start status, rationale for prescription, and DOT, were first compared across facilities over the course of the entire intervention period. Frequencies and proportions were calculated for categorical data, and medians and quartiles were calculated for continuous data. Antibiotic starts for UTI's were then stratified by start status to compare characteristics of new UTI antibiotic starts versus transfer orders for UTIs within each facility. Finally, I examined temporal trends in key antibiotic prescribing metrics including number of starts per 1,000 resident days, DOT per 1,000 resident days, and proportion of antibiotic starts that were over the recommended duration for the antibiotic prescribed, based on recommendations from the Infectious Disease Society of America (IDSA) and consultation with facility leadership.

After conducting the descriptive analysis, I then collaborated with the EASIL team to examine the results and develop an appropriate analytic plan to evaluate the impact of the EASIL initiative. Due to the limited pre-intervention data available from each facility and the limited number of data points available in the EASIL dataset, it was determined that a time-series analysis would not be an appropriate technique for assessing changes in antibiotic metrics over the course of the intervention. Instead, the intervention was divided into three intervention periods for comparison: peri-intervention, early intervention, and late intervention (**Figure 1**).

Figure 1. Intervention and Study Period Timeline



X_1 = Gap analysis conducted and leadership commitment posters displayed
X_2 = Best practice educational initiative (session, pocket cards) first implemented
X_3 = Data feedback system presented in stewardship meetings
I_1 = Single best time point for intervention
O_i = Observation timepoint

The peri-intervention period for each facility included the first three months after initial implementation of the best practices educational initiative informed by the gap analysis. This period is the most representative of a pre-intervention period, as the key antibiotic stewardship activities were not yet fully implemented. The early intervention period was defined as the six months following the peri-intervention period. The late intervention was defined as the months between the end of the early intervention period and April 2020. The research team agreed to mark April 2020 as the end of the study period in order to reduce the impact of the COVID-19 pandemic on the results of the analysis. The intervention and study timelines for each facility are provided in Figure 1.

Once the study timeframe and intervention periods were defined, I conducted additional descriptive analyses to compare characteristics of aggregate data for each intervention period within each facility and visualized results of these analyses using RStudio. Based on these results, the research team chose to focus on two key comparative metrics to assess the impact of the EASIL initiative: new UTI antibiotic prescriptions over the recommended duration (the denominator including only the antibiotics for which we had recommended guidelines regarding duration of therapy) and DOT per 1,000 resident days. Figures were then produced in RStudio to illustrate trends over time for each of these metrics between facilities. Finally, these prescribing metrics were compared between the peri-intervention period to an early intervention and late intervention period by calculating risk and rate ratios and the associated 95% confidence intervals. Statistical significance for each test was assessed using mid-p exact methods and Wald approximation.

Subsequently, I drafted the initial manuscript for the study for submission to the Journal of the American Medical Directors Association (JAMDA). The thesis committee, including the EASIL team and my thesis faculty advisor, assisted with editing and revising the manuscript prior to submission.

JOURNAL ARTICLE

Title Page

Title: Changes in antibiotic prescribing metrics at 3 nursing homes in Atlanta collaborating on antibiotic stewardship

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Abstract

Objective: To examine changes in nursing home (NH) antibiotic prescribing metrics for urinary tract infections (UTI) over the course of an antibiotic stewardship intervention.

Design: Three independent NHs collaborated with the Emory Antibiotic Stewardship in Long Term Care (EASIL) Initiative Team to start activities to reduce unnecessary antibiotic use for presumed UTIs. Activities included a stewardship gap analysis, launch of best practice guidance for UTI antibiotic prescribing shared with prescribing staff, and start of a data feedback system.

Setting and Participants: Three Atlanta-based NHs enrolled in the EASIL Initiative.

Methods: Comparative metrics included facility-specific proportions of UTI antibiotic prescriptions over the recommended duration and days of therapy (DOT) per 1,000 resident days (RD). Risk and rate ratios were calculated to compare prescribing metrics between the peri-intervention period to an early intervention and late intervention period.

Results: Average monthly RD at the three NHs ranged from 3,535 to 5,981. During the peri-intervention period, 96 (28.2%) antibiotic prescriptions were for UTIs, of which, 51 (53.1%) were new antibiotic starts. Metrics did not differ significantly between peri- and early intervention periods; however, one facility reported a significant reduction in new UTI prescriptions over recommended duration in late-intervention compared to peri-intervention period (Risk Ratio = 0.35, 95% CI 0.13-0.93, $P = 0.033$), while the other two reported non-significant declines. One facility reported a significant reduction in DOT/1000 RD between late-intervention period compared to peri-intervention period (Rate Ratio = 0.52, 95% CI 0.40-0.67, $P < .001$), while another experienced a significant increase in DOT/1,000 RD (Rate Ratio = 2.05, 95% CI 1.52-2.76, $P < .001$).

Conclusions and Implications: While we observed some significant improvements in antibiotic prescribing metrics over the study period, changes were inconsistent across facilities. Exploring how effects of the intervention may vary due to differences in implementation or facility staffing between facilities is warranted.

Introduction

The unnecessary use of antibiotics is a growing public health challenge due to the rapid emergence of multi-drug resistant organisms across the globe.[1,2] According to the Centers for Disease Control and Prevention (CDC), more than 2.8 million antibiotic-resistant infections occur in the United States annually.[3] Antibiotic resistance is a particular concern for nursing home residents, as antibiotics are one of the most commonly prescribed medications in this setting, and an estimated 25% to 75% of these prescriptions may be inappropriately or unnecessarily prescribed.[4] The unnecessary use of antibiotics in this population can lead to increased rates of adverse side effects, such as *Clostridioides difficile* infections (CDI); increased costs; and can further contribute to antibiotic resistance.[4,5]

Ensuring accurate and appropriate prescribing of antibiotics in nursing homes is particularly challenging, as nursing home residents commonly present with symptoms that are difficult to diagnose due to comorbidities and cognitive impairment.[6] Historically, urinary tract infections (UTIs) are the most common indication for starting antibiotics among nursing home residents, with over one third of all antibiotics prescribed in this setting targeting UTIs.[7-10] Studies of antibiotic prescriptions for UTIs suggest that antibiotics are often used in the absence of clinical evidence of infection; one study identified that one third of antibiotic prescriptions for UTIs started before a laboratory test was even performed.[11,12] These studies also found that the use of antibiotics for UTIs often continues for prolonged durations, despite negative laboratory tests (e.g., urinalysis, urine culture, blood culture).[11,12]

In order to reduce inappropriate prescribing of antibiotics in healthcare settings, in 2014 the Centers for Disease Control and Prevention (CDC) released guidelines for developing and implementing antibiotic stewardship programs that incorporate seven core elements: leadership, accountability, drug expertise, action, tracking, reporting, and education.[13] While these guidelines were originally developed for acute-care settings, CDC adapted these core elements for nursing homes to provide practical ways facilities can initiate antibiotic stewardship activities aimed at improving antibiotic use, reducing adverse events, and preventing the emergence of antibiotic resistance. Additionally, in response to the growing emphasis on antibiotic stewardship in nursing homes, as of November 28, 2017, the Centers for Medicare and Medicaid Services (CMS) began requiring that nursing homes implement an antibiotic stewardship program that incorporates the CDC's Core Elements for Antibiotic Stewardship.[14] Despite these new requirements, many nursing homes still do not have such comprehensive antibiotic stewardship programs.[15-17]

As the CDC's guidelines for antibiotic stewardship were initially developed for acute-care settings, there is a critical need for further evaluation of the effectiveness of antibiotic stewardship program implementation in this setting as well as the facilitators and barriers to implementation.[7] The purpose of this study is to examine the impact of the Emory Antibiotic Stewardship in Long Term Care (EASIL) Initiative, a quality improvement initiative designed to support the antibiotic stewardship programs of three Atlanta-based nursing home facilities. Our study aimed to estimate the effect of the initiative on several UTI antibiotic prescribing metrics over the course of the intervention and how these changes varied between facilities.

Methods

Design/Setting

This study employed a multi-site repeated measures design with a 15-month data collection period. Three large, independent nursing homes, with bed sizes ranging from 150 to 250 beds,[18] collaborated with the EASIL Initiative aimed to reduce unnecessary antibiotic use for presumed UTIs. Activities included a stewardship gap analysis, launch of best practice guidance for UTI antibiotic prescribing shared with prescribing staff, and start of an antibiotic prescribing data feedback system.

As part of the initial stewardship gap analysis, the EASIL team met with leadership at each facility to review the CDC's antibiotic stewardship guidelines and identify gaps in stewardship programs. The EASIL team conducted interviews with leadership and staff during which possible areas of improvement were identified. Over the subsequent 5 months, the EASIL team worked with the medical directors to develop a set of standardized best practices for treating UTIs as well as the most appropriate methods for promoting these best practices within the facility (e.g., best practice guidelines, communication materials). Best practices were shared with prescribing staff through initial presentations on antibiotic stewardship and as pocket cards to guide daily antibiotic prescribing. Each facility was also provided posters demonstrating leadership commitment with information about the program to display in their facilities. The EASIL team engaged in outreach with family members and residents by providing pamphlets on "active monitoring" for antibiotic stewardship. The educational posters and outreach pamphlets were informed by focus groups with residents and family members. Finally, the EASIL team worked with consultant pharmacists to obtain and process antibiotic prescribing data. These data were provided to each facility through monthly feedback reports which continued for 12 months after completion of the initial activities.

Data

Data on facility characteristics were collected from the CMS Nursing Home Compare website.[18] Antibiotic prescribing data were collected via standardized prescribing logs submitted to the EASIL team monthly by each nursing home. The standardized prescribing logs included the following data for each antibiotic prescription: start date; antibiotic name; treatment site (modified from Agency for Healthcare Research and Quality [AHRQ] treatment codes); indication (e.g., active infection, prophylaxis); prescriber attribution; days of therapy (DOT); adherence to Loeb's Minimum Criteria, a standardized diagnostic tool for initiation of antibiotics in long-term care settings;[19] and completion of the Situation-Background-Assessment-Recommendation (SBAR) communication tool, which provides a framework for communicating about a patient's condition.[20,21] Each facility also provided monthly resident-days (RDs).

The start of the study period for each facility was defined as the month of initial implementation of the best practices educational initiative informed by the gap analysis.. The end of the study period for each facility was defined as March 2020, in an effort to prevent bias in the data due to effects of the COVID-19 pandemic. The study period was then divided into three intervention periods for comparison: peri-intervention, defined as the first three months of initial implementation of a best practices educational initiative at each facility; early intervention, defined as the subsequent six months after the peri-intervention period; and late intervention, defined as the period following the peri-intervention period through March 2020 (six months for Facilities A and B; four months for Facility C).

IRB approval was obtained through expedited review by the Emory University Institutional Review Board (IRB number: IRB00104059).

Measurement

Antibiotic Start Characteristics

Antibiotic start characteristics, including start date, antibiotic name, treatment site, indication, prescriber attribution, and DOT were assessed at the aggregate level across facilities. Antibiotic start characteristics were further examined for antibiotics prescribed for UTIs. These antibiotic starts for UTIs were also stratified by prescriber attribution (whether the antibiotic was prescribed within the facility [new start] or through a transfer order). DOT were used to identify whether each antibiotic was prescribed for the recommended duration for that specific antibiotic based on clinical practice guidelines developed by the Infectious Disease Society of America (IDSA) and consultation from facility leadership.[22-24] We further considered adherence to Loeb's criteria for appropriate and necessary prescription of antibiotics for UTIs as well as completion of the SBAR communication tool. Adherence to Loeb's criteria and SBAR completion (Yes, No, Not Applicable, and Unknown) were indicated by infection prevention staff for each antibiotic start on the prescribing logs.

Outcome Measures

Two key comparative metrics were calculated to examine changes in antibiotic prescribing practices for UTIs prescribed within facility over the duration of the intervention: (1) facility-specific proportions of UTI antibiotic prescriptions that were over the recommended duration and (2) facility-specific rates of DOT per 1,000 RD for UTI antibiotic prescriptions.

Statistical Analyses

Data were analyzed using RStudio Version 1.2.5042, the tidyverse, ggplot2, lubridate, and table1 packages.[25-28] The analyses were intended to examine the effect of the newly implemented antibiotic stewardship activities on the appropriateness of antibiotic prescribing for suspected UTIs.

Basic characteristics of antibiotic starts, including treatment site, prescriber attribution, rationale for prescription, and DOT, were first compared across facilities during the peri-intervention period, as this timeframe served as the reference period for changes across the course of the intervention. Frequencies and proportions were calculated for categorical data, and medians and quartiles were calculated for continuous data. Antibiotic starts for UTI's were then stratified by prescriber attribution to compare the basic characteristics of new UTI antibiotic starts with transfer orders for UTIs within each facility. Finally, temporal trends in key antibiotic prescribing metrics were calculated, including number of prescriptions per 1,000 RD, DOT per 1,000 RD, and proportion of antibiotic starts that were over the recommended duration for the antibiotic prescribed (antibiotics for which recommendations on duration of therapy were not available were excluded from this metric).

Facility specific changes in antibiotic prescribing practices for suspected UTIs over the study period were assessed by calculating risk and rate ratios comparing prescribing metrics between intervention periods. The peri-intervention period (first three months after initial stewardship gap analysis) was treated as the baseline reference period. Risk ratios (RR) and their 95% confidence intervals (CIs) were calculated to compare proportions of new antibiotic prescriptions for UTIs that were over the recommended duration between the peri-intervention period to the early intervention and late intervention periods.[29] Incidence rate ratios (IRR) and their 95% CIs were calculated to compare DOT per 1,000 RDs between the peri-intervention period to the early intervention and late intervention periods.[29] Statistical significance was defined as $P < .05$ and CIs were calculated using mid-p exact methods and Wald approximation.

Results

Bed size at the three participating NHs ranged from 150 to 250. A total of 1,578 recorded antibiotic prescriptions were included in the analytic dataset, with facility-level counts of prescriptions over the course of the intervention period ranging from 369 to 666.

During the peri-intervention period, 51.8% (n=176) of prescriptions were new starts and 93.8% (n=319) were prescribed empirically for an active infection (Table 1). As expected, UTIs were the most common indication for an antibiotic during the peri-intervention period, comprising 28.2% (n=96) of all prescriptions across the three facilities. Approximately 53.1% (n=51) of antibiotic prescriptions for UTIs during this period were new starts.

Among new UTI starts during the peri-intervention period (n=51), 4 (7.8%) prescriptions were for a quinolone antibiotic, 36 (70.6%) antibiotic prescriptions met Loeb’s Minimum Criteria, and 43 (84.3%) were prescribed using the SBAR communication tool (Table 2). Additionally, 18 (35.3%) prescriptions were over the recommended duration for the prescribed antibiotic (Table 2).

Facility-specific monthly values across the study period varied greatly for UTI prescribing rates (median 1.32, range 0.167-3.18) and DOT per 1,000 RD (median 6.18, range 0.50-14.45). Changes in proportions of new prescriptions for UTIs that were over the recommended duration and changes in rates of DOT per 1,000 RD were inconsistent across facilities over the course of the study period (Figure 2). None of the participating nursing homes reported significant changes in either metric between the peri- and early-intervention periods (Tables 3 and 4). However, one facility reported a significant reduction in new prescriptions for UTIs that were over the recommended duration in the late-intervention compared to the peri-intervention period (RR = 0.35, 95% CI = [0.13-0.93]). The other two facilities reported non-significant declines in new prescriptions for UTIs that were over the recommended duration; however, one of these facilities did report a significant reduction in DOT/1,000 RD between late-intervention period compared to peri-intervention period (IRR = 0.52, 95% CI = [0.40-0.67]). Another facility experienced a significant increase in DOT/1,000 RD (IRR = 2.05, 95% CI = [1.52-2.76]).

Discussion

Despite consistent efforts to implement a multi-modal antibiotic stewardship intervention aligned with the CDC's Core Elements for Antibiotic Stewardship across three large nursing homes, improvements in antibiotic prescribing metrics were inconsistent across facilities.

Overall, changes in antibiotic prescribing rates for UTIs per 1,000 RD varied considerably between facilities. This variability in changes over time for DOT per 1,000 RD for UTI prescriptions after program implementation could be attributed to the relatively high proportions of antibiotic prescriptions that adhered to Loeb's Minimum Criteria for initiation of an antibiotic for UTI (70.6%) and were prescribed using the SBAR communication tool (84.3%) during the peri-intervention period. Assuming the process metrics of compliance with Loeb's Minimum Criteria are accurate, these findings indicate that there may not have been much room for improvement in prescribing rates for UTIs at these facilities, as over 70% of antibiotics already adhered to Loeb's Minimum Criteria at the start of the intervention, and the median rate of new starts for UTI per month was only 1.32 starts per 1,000 RD.

However, another important element of antibiotic stewardship is ensuring that, when an antibiotic is prescribed, the correct antibiotic is chosen with the right dose, at the right time, and for the right duration.[13] Duration of antibiotic course is particularly important to consider, as shorter antibiotic courses have been found to be nearly as effective as longer courses in eliminating the infecting organism.[30] Furthermore, the longer the antibiotic exposure, the greater the selection pressure for antibiotic resistant bacteria, such as *C. difficile*, that may cause serious infection.[30] The first of two metrics evaluated that we would expect to be influenced by duration of treatment was DOT per 1,000 RD. However, only one facility reported a significant decrease in this metric between the late-intervention period and peri-intervention period, indicating that, while DOT per 1,000 RD is commonly used to assess the impact of antibiotic stewardship programs, this may not be the most suitable metric for assessing stewardship programs in facilities where the majority of antibiotic starts are meeting the Loeb's Minimum Criteria for initiation.

We also examined duration of antibiotic courses by indicating whether or not an antibiotic was prescribed over the recommended duration for that specific antibiotic type. We found that, during the peri-intervention period, over one third of antibiotics prescribed for a UTI were prescribed for longer than the recommended duration. Over the course of the intervention period, all three facilities reported reductions in this metric between the late-intervention period and the peri-intervention period, with only one of these facilities reporting significant results. While the significance of these findings is limited, the results suggest that examining whether an antibiotic course is longer than recommended may be a useful metric for assessing adherence to antibiotic prescribing guidelines over the course of an antibiotic stewardship intervention.

This study has several limitations that should be taken into account when interpreting results. First, the small sample size of the antibiotic stewardship initiative limits the generalizability of the results to other facilities, as the study was conducted in only three nursing homes located within the Atlanta metropolitan area. Additionally, the study period was limited to 15 months of data, ending in March 2020, due to the emergence of COVID-19, the infection caused by SARS-CoV-2. We ultimately decided not to include data after March 2020 in order to minimize confounding due to prioritization of COVID-19 treatment and prevention in nursing homes. Finally, we were unable to include data from a pre-intervention period in our data set, as our team did not have access to complete and sufficient data from each facility prior to implementation of the antibiotic stewardship activities. Therefore, our analysis relies on comparisons between intervention periods using the first three months of the intervention, i.e., the peri-intervention period, as the most representative baseline period, as this was the timeframe during which each facility first began implementing best practice guidelines and a data feedback system. Due to the small sample size, limited time points available in the data set, and lack of a pre-intervention period, we were unable to conduct a more traditional time series analysis to evaluate the impact of the intervention.

This assessment of an antibiotic stewardship initiative in three nursing homes demonstrates the practical challenges of implementing, monitoring, and evaluating stewardship activities in long-term care settings. Limited on-premises physician oversight and reliance on communication between nurses and prescribers may impact the influence of decision support tools (e.g., SBAR, education, pocket cards) regarding antibiotics.[7,12] An added challenge to influencing antibiotic prescribing practices in nursing homes relates to frequent staff turnover, making one-time investment in educational material as was done in EASIL less effective.[31] Despite excellent collaboration, monthly consultation, and quarterly feedback of data, complex dynamics between prescribers and nursing staff create a difficult setting for implementing effective antibiotic stewardship activities.

Conclusions and Implications

While we observed some statistically significant improvements in antibiotic prescribing metrics over the study period, these changes were inconsistent both within and across facilities. Future evaluations of antibiotic stewardship programs should thus explore how effects of the intervention may vary due to differences in facility characteristics, staffing, and resident populations. Future studies should also consider the most appropriate metric for assessing changes in antibiotic prescribing, taking into account both antibiotic prescribing rates and duration of therapy. For those planning to implement antibiotic stewardship programs in nursing homes, these findings suggest a need for further investment in enhancing program uptake and maintenance that persists even when there is high staff turnover. This could be achieved by gaining buy-in from administrative staff and identifying a "champion" to lead implementation at the facility; regularly educating staff, residents, and families on antibiotic stewardship; and developing clear protocols on antibiotic stewardship practices.

Conflicts of Interest: The authors have no conflicts of interest to report.

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Tables and Figures

Table 1. Comparison of Antibiotic Start Characteristics by Intervention Period (January 2019 - March 2020)

	Peri Intervention (N=340)	Early Intervention (N=705)	Late Intervention (N=533)	Overall (N=1578)
Treatment Site				
UTI	96 (28.2%)	216 (30.6%)	183 (34.3%)	495 (31.4%)
LRI	40 (11.8%)	110 (15.6%)	76 (14.3%)	226 (14.3%)
SST	65 (19.1%)	87 (12.3%)	119 (22.3%)	271 (17.2%)
Other	139 (40.9%)	291 (41.3%)	155 (29.1%)	585 (37.1%)
Missing	0 (0%)	1 (0.1%)	0 (0%)	1 (0.1%)
Start Status				
New Start	176 (51.8%)	339 (48.1%)	267 (50.1%)	782 (49.6%)
Transfer Order	164 (48.2%)	365 (51.8%)	266 (49.9%)	795 (50.4%)
Missing	0 (0%)	1 (0.1%)	0 (0%)	1 (0.1%)
Rationale				
Active Infection	320 (94.1%)	669 (94.9%)	510 (95.7%)	1499 (95.0%)
Prophylaxis	14 (4.1%)	34 (4.8%)	22 (4.1%)	70 (4.4%)
Other	6 (1.8%)	2 (0.3%)	1 (0.2%)	9 (0.6%)
Quinolone				
Yes	33 (9.7%)	82 (11.6%)	49 (9.2%)	164 (10.4%)
No	307 (90.3%)	623 (88.4%)	484 (90.8%)	1414 (89.6%)
Over Recommended Duration				
Yes	106 (31.2%)	205 (29.1%)	158 (29.6%)	469 (29.7%)
No	73 (21.5%)	161 (22.8%)	157 (29.5%)	391 (24.8%)
No Recommended Duration Available	148 (43.5%)	328 (46.5%)	210 (39.4%)	686 (43.5%)
Missing	13 (3.8%)	11 (1.6%)	8 (1.5%)	32 (2.0%)
Days of Therapy				
Median (Q1, Q3)	7.00 (5.00, 10.0)	7.00 (5.00, 10.0)	5.00 (5.00, 10.0)	6.00 (5.00, 10.0)
Missing	30 (8.8%)	40 (5.7%)	20 (3.8%)	90 (5.7%)

Table 2. Comparison of New UTI Antibiotic Start Characteristics by Intervention Period (January 2019 - March 2020)

	Peri Intervention (N=51)	Early Intervention (N=108)	Late Intervention (N=95)	Overall (N=254)
Rationale				
Active Infection	49 (96.1%)	107 (99.1%)	94 (98.9%)	250 (98.4%)
Prophylaxis	1 (2.0%)	1 (0.9%)	1 (1.1%)	3 (1.2%)
Other	1 (2.0%)	0 (0.0%)	0 (0.0%)	1 (0.4%)
Quinolone				
Yes	4 (7.8%)	11 (10.2%)	7 (7.4%)	22 (8.7%)
No	47 (92.2%)	97 (89.8%)	88 (92.6%)	232 (91.3%)
Over Recommended Duration				
Yes	18 (35.3%)	25 (23.1%)	21 (22.1%)	64 (25.2%)
No	24 (47.1%)	59 (54.6%)	54 (56.8%)	137 (53.9%)
No Recommended Duration Available	8 (15.7%)	22 (20.4%)	18 (18.9%)	48 (18.9%)
Missing	1 (2.0%)	2 (1.9%)	2 (2.1%)	5 (2.0%)
Loeb's Criteria Met				
Yes	36 (70.6%)	91 (84.3%)	76 (80.0%)	203 (79.9%)
No	10 (19.6%)	9 (8.3%)	15 (15.8%)	34 (13.4%)
Not Applicable	1 (2.0%)	3 (2.8%)	2 (2.1%)	6 (2.4%)
Unknown	4 (7.8%)	5 (4.6%)	2 (2.1%)	11 (4.3%)
SBAR Used				
Yes	43 (84.3%)	92 (85.2%)	82 (86.3%)	217 (85.4%)
No	8 (15.7%)	16 (14.8%)	13 (13.7%)	37 (14.6%)
Not Applicable	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Unknown	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Days of Therapy				
Median (Q1, Q3)	5.00 (3.00, 7.00)	5.00 (3.00, 6.00)	5.00 (3.75, 5.25)	5.00 (3.00, 6.00)
Missing	1 (2.0%)	7 (6.5%)	3 (3.2%)	11 (4.3%)

Figure 2. Percentage of New UTI Starts with Days of Therapy (DOT) over the Recommended Duration and DOT/1,000 Resident Days (RD), by Intervention Period (January 2019 - March 2020)

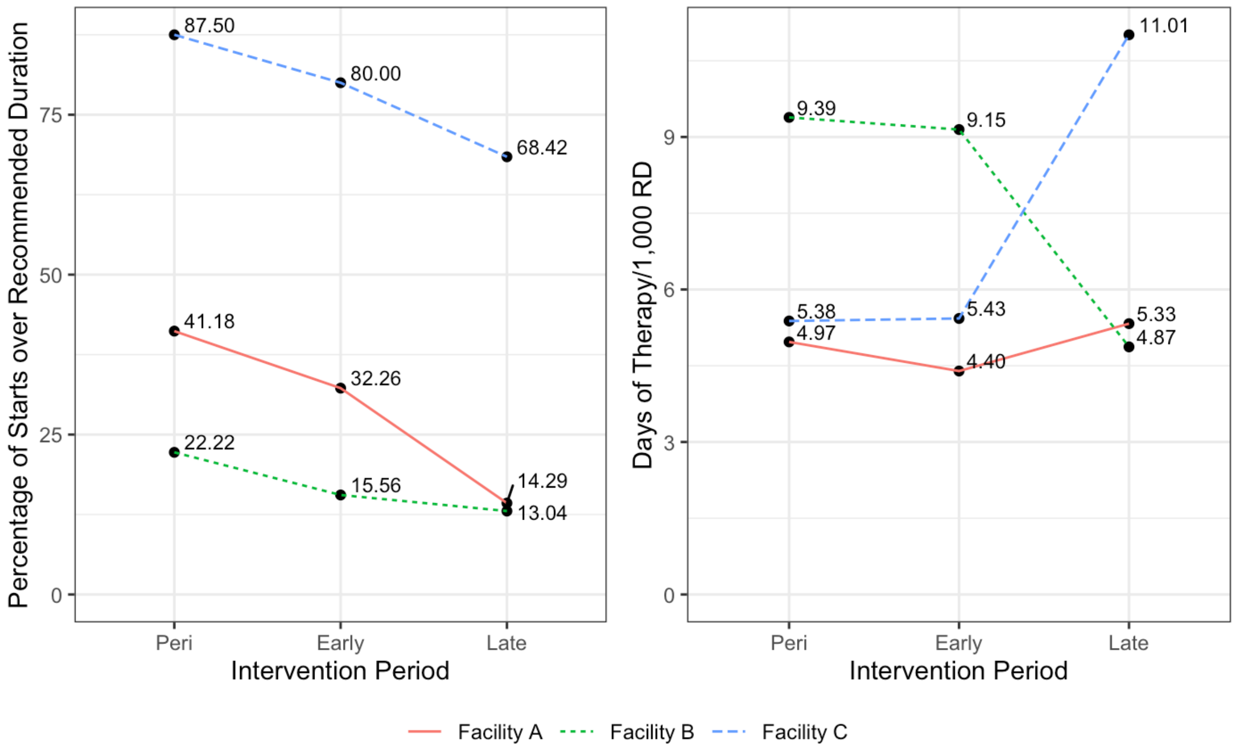

Table 3. New UTI Starts Over Recommended Duration, by Facility and Intervention Period, EASIL Study*

Facility	**Metric**	**Peri-Intervention Period**	**Early Intervention Period**	**Late Intervention Period**
Facility A	% (No./starts) Over Recommended Duration	41.2 (7/17)	32.3 (10/31)	14.3 (5/35)
	Risk Ratio	-	0.78	0.35**
	95% Confidence Interval		0.37-1.68, P = 0.54	0.13-0.93, P = 0.033
Facility B	% (No./starts) Over Recommended Duration	22.2 (4/18)	15.6 (7/45)	13.0 (3/23)
	Risk Ratio	-	0.70	0.59
	95% Confidence Interval		0.23-2.10, P = 0.53	0.15-2.30, P = 0.44
Facility C	% (No./starts) Over Recommended Duration	87.5 (7/8)	80.0 (8/10)	68.4 (13/19)
	Risk Ratio	-	0.91	0.78
	95% Confidence Interval		0.61-1.37, P = 0.68	0.52-1.17, P = 0.31

*Denominator values include only antibiotic starts for which guidelines for duration of therapy were available for the prescribed antibiotic
** Indicates statistically significant results

Table 4. Rate of New UTI Starts as Days of Therapy/1000 Resident Days by Facility and Intervention Period, EASIL Study

Facility	Metric	Peri-Intervention Period	Early Intervention Period	Late Intervention Period
Facility A	DOT/1000 RDs	4.97 (90/18,113)	4.40 (159/36,171)	5.33 (190/35,659)
	Rate Ratio	-	Rate Ratio = 0.88	Rate Ratio = 1.07
	95% Confidence Interval		0.68-1.15, P = 0.35	0.83-1.38, P = 0.59
Facility B	DOT/1000 RDs	9.39 (1087/11,507)	9.15 (223/24,380)	4.87 (121/24,841)
	Rate Ratio	-	Rate Ratio = 0.97	Rate Ratio = 0.52*
	95% Confidence Interval		0.77-1.23, P = 0.83	0.40-0.67, P < .001
Facility C	DOT/1000 RDs	5.38 (60/11,152)	5.43 (116/21,363)	11.01 (148/13,441)
	Rate Ratio	-	Rate Ratio = 1.01	Rate Ratio = 2.05*
	95% Confidence Interval		0.74-1.38, P = 0.95	1.52-2.76, P < .001

* Indicates statistically significant results

Appendix

Table 5. Comparison of New UTI Antibiotic Start Characteristics by Facility and Intervention Period (January 2019 - March 2020)

	Facility A			**Facility B**			**Facility C**			**Overall**		
	Peri (N=18)	**Early (N=38)**	**Late (N=44)**	**Peri (N=23)**	**Early (N=51)**	**Late (N=25)**	**Peri (N=10)**	**Early (N=19)**	**Late (N=26)**	**Peri (N=51)**	**Early (N=108)**	**Late (N=95)**
Rationale												
Active Infection	18 100.0%	38 100.0%	44 100.0%	23 100.0%	50 98.0%	24 96.0%	8 80.0%	19 100.0%	26 100.0%	49 96.1%	107 99.1%	94 98.9%
Prophylaxis	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 2.0%	1 4.0%	1 10.0%	0 0.0%	0 0.0%	1 2.0 %	1 0.9%	1 1.1 %
Other	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	1 10.0%	0 0.0%	0 0.0%	1 2.0%	0 0.0%	0 0.0%
Quinolone												
Yes	2 11.1%	4 10.5%	0 0.0%	2 8.7%	4 7.8%	0 0.0%	0 0.0%	3 15.8%	7 26.9%	4 7. %	11 10.2%	7 7.4%
No	16 88.9%	34 89.5%	44 100.0%	21 91.3%	47 92.2%	25 100.0%	10 100.0%	16 84.2%	19 73.1%	47 92.2%	97 89.8%	88 92.6%
Over Recommended Duration												
Yes	7 38.9%	10 26.3%	5 11.4%	4 17.4%	7 13.7%	3 12.0%	7 70.0%	8 42.1%	13 50.0%	18 35.3%	25 23.1%	21 22.1%
No	10 55.6%	19 50.0%	30 68.2%	14 60.9%	38 74.5%	20 80.0%	0 0.0%	2 10.5%	4 15.4%	24 47.1%	59 54.6%	54 56.8%
No Recommended Duration Available	1 5.6%	7 18.4%	9 20.5%	5 21.7%	6 11.8%	2 8.0%	2 20.0%	9 47.4%	7 26.9%	8 15.7%	22 20.4%	18 18.9%

	Facility A			Facility B			Facility C			Overall		
	Peri (N=18)	Early (N=38)	Late (N=44)	Peri (N=23)	Early (N=51)	Late (N=25)	Peri (N=10)	Early (N=19)	Late (N=26)	Peri (N=51)	Early (N=108)	Late (N=95)
Missing	0 0%	2 5.3%	0 0%	0 0%	0 0%	0 0%	1 10.0%	0 0%	2 7.7%	1 2.0%	2 1.9%	2 2.1%
Loeb's Criteria Met												
Yes	13 72.2%	34 89.5%	37 84.1%	16 69.6%	41 80.4%	19 76.0%	7 70.0%	16 84.2%	20 76.9%	36 70.6%	91 84.3%	76 80.0%
No	1 5.6%	4 10.5%	5 11.4%	7 30.4%	2 3.9%	4 16.0%	2 20.0%	3 15.8%	6 23.1%	10 19.6%	9 8.3%	15 15.8%
Not Applicable	0 0.0%	0 0.0%	0 0.0%	0 0.0%	3 5.9%	2 8.0%	1 10.0%	0 0.0%	0 0.0%	1 2.0%	3 2.8%	2 2.1%
Unknown	4 22.2%	0 0.0%	2 4.5%	0 0.0%	5 9.8%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	4 7.8%	5 4.6%	2 2.1%
SBAR Used												
Yes	14 77.8%	34 89.5%	38 86.4%	23 100.0%	39 76.5%	20 80.0%	6 60.0%	19 100.0%	24 92.3%	43 84.3%	92 85.2%	82 86.3%
No	4 22.2%	4 10. %	6 13.6%	0 0.0%	12 23.5%	5 20.0%	4 40.0%	0 0.0%	2 7.7%	8 15.7%	16 14.8%	13 13.7%
Not Applicable	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
Unknown	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%
Days of Therapy												
Median (Q1, Q3)	5.00 (3.50, 6.75)	4.50 (3.00, 5.25)	5.00 (3.00, 5.00)	5.00 (3.00, 5.00)	5.00 (4.75, 5.00)	5.00 (5.00, 5.00)	7.00 (7.00, 9.00)	7.00 (5.00, 10.0)	7.00 (5.00, 7.00)	5.00 (3.00, 7.00)	5.00 (3.00, 6.00)	5.00 3.75, 5.25)
Missing	0	2	0	0	3	1	1	2	2	1	7	3

	Facility A			Facility B			Facility C			Overall		
	Peri (N=18)	**Early (N=38)**	**Late (N=44)**	**Peri (N=23)**	**Early (N=51)**	**Late (N=25)**	**Peri (N=10)**	**Early (N=19)**	**Late (N=26)**	**Peri (N=51)**	**Early (N=108)**	**Late (N=95)**
	0%	5.3%	0%	0%	5.9%	4.0%	10.0%	10.5%	7.7%	2.0%	6.5%	3.2%

PUBLIC HEALTH IMPLICATIONS

Improving antibiotic prescribing practices in long-term care settings is an important patient safety measure, as the unnecessary use of antibiotics can contribute to increased rates of mortality due to infections caused by antibiotic resistant bacteria, such as *C. difficile*. The development and implementation of evidence-based antibiotic stewardship interventions to improve antibiotic prescribing is especially important for long-term care settings where a large percentage of antibiotic prescriptions are estimated to be inappropriately or unnecessarily prescribed, and resident populations are at higher risk of contracting CDI (CDC, n.d.-a; Jump & Donskey, 2015; van Buul et al., 2012). However, while long-term care residents are at increased risk of adverse outcomes due to the unnecessary use of antibiotics, current antibiotic stewardship guidelines were originally developed in the context of acute-care settings.

Research on the adaptation and implementation of these guidelines in long-term care settings is currently limited. Therefore, this study aimed to examine the impact of an antibiotic stewardship initiative in three Atlanta-based nursing homes on antibiotic prescribing metrics over the course of the intervention period. The study found some statistically significant improvements in antibiotic prescribing metrics over the course of the study period; however, these findings were inconsistent across facilities. These findings demonstrate the many practical challenges with implementing, maintaining, and evaluating antibiotic stewardship programs in the nursing home setting.

The inconsistencies in results between facilities included in this study may be partially due to differences in facility and resident population characteristics that influence the effectiveness of the stewardship activities in altering prescribing behaviors.

Additionally, limited on-premises physician oversight and reliance on communication between nurses and prescribers in this setting may have affected the influence of the decision support tools (e.g., pocket cards, SBAR tool) implemented as part of the intervention. Finally, the lack of a clear and significant trend in antibiotic prescribing metrics within each facility over time may be a result of staff turnover as well as varying levels of investment from facility leadership and staff. As the EASIL Initiative served as a one-time investment, the effects of these interventions may have diminished over time as leadership and staff initially involved in the initiative left the facility or faced competing priorities.

These findings demonstrate the need for antibiotic stewardship programs that are uniquely designed to meet the specific needs of a facility and are reassessed over time to ensure sustained impact. Development of effective and sustainable stewardship programs could be enhanced through the use of a theoretical framework, such as the TDF, to identify key barriers and facilitators to implementation and to design intervention strategies to address these factors. For example, a facility that experiences challenges with frequent staff turnover could benefit from the identification of an antibiotic stewardship "champion" who can continue to promote the program and educate new staff members on program policies and activities.

Furthermore, we observed inconsistencies in results across each of the key metrics assessed in this study: proportions of UTI antibiotic prescriptions that were over the recommended duration and rates of DOT per 1,000 RD for UTI antibiotic prescriptions. These findings reflect the need for interventions that address not only the overuse of antibiotics in this setting, but also the core elements of antibiotic therapy: dose, duration, and indication. While the facilities included in this study reported relatively high proportions of antibiotic prescriptions that met the Loeb's Minimum Criteria for initiation (>70%) at the start of the intervention, many of these antibiotics were prescribed for longer than the recommended duration according to IDSA guidelines. Therefore, antibiotic stewardship education and best practices for antibiotic prescribing should emphasize the importance of both indication as well as duration of antibiotic therapy.

In addition to the practical implications for antibiotic stewardship implementation, these findings also pose considerations for future evaluation research on antibiotic stewardship programs in nursing homes. For example, this study explored the use of various metrics to examine trends in antibiotic prescribing practices over the course of the intervention. The study found that, while DOT per 1,000 RD is a common metric for evaluating the impact of antibiotic stewardship programs, adherence to guidelines regarding duration of therapy may be a more suitable metric for facilities where the majority of antibiotics meet the Loeb's Minimum Criteria for initiation.

One limitation of this study was the inability to conduct a pre- and post-intervention comparison due to lack of complete and sufficient data from each facility prior to implementation of the antibiotic stewardship activities. Additionally, the data collection period was limited due to the COVID-19 pandemic. Future evaluations should aim to include data from a pre-intervention period, as well as data from a longer time period in order to conduct a more traditional time series analysis to evaluate the impact of the intervention. Future research should also use more advanced analyses to examine the influence of different facility and resident characteristics on the effectiveness of antibiotic stewardship interventions. Finally, additional research is needed to better understand the long-term impacts of antibiotic stewardship programs on resident quality of life and health indicators, such as CDI infection and mortality rates.

Antibiotic stewardship is essential for addressing the negative impacts of antibiotic resistance; however, there is a need for greater focus on the application of antibiotic stewardship guidelines for nursing homes to ensure that interventions are developed, implemented, and evaluated according to the unique characteristics of this healthcare setting.

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