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THE EFFECTS OF PROPHYLACTIC POSTOPERATIVE ORAL ANTIBIOTIC USE IN FOOT AND ANKLE SURGERY ON HEALTHCARE EXPENDITURES AND INFECTION RISK

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ABSTRACT

One of the main challenges facing the United States healthcare system is finding ways to minimize costs while still providing high quality care. One opportunity to address this problem is to adjust guidelines to ensure responsible use of antibiotics. There is currently evidence that physicians overprescribe antibiotics for conditions such as upper respiratory infections ("Appropriate Antibiotic Use"). This leads to unnecessary costs for antibiotics in the short term, and it can contribute to antibiotic resistance in the long term, which is a major health threat that could have detrimental impacts on health outcomes and costs in the future (Childress).

Another area where there is possible overuse of antibiotics is orthopedic surgery. Though there is still controversy about the best timing and duration of antibiotics, most research suggests that prophylactic postoperative antibiotics do not reduce infection risk in orthopedic surgical patients (Johnson; Dhammi, Haq, Kumar; Ruta, Kadakia, Irwin).

This study uses medical and pharmacy claims to examine the relationship between postoperative antibiotic use and infection rates while considering various risk factors that can affect infection outcomes. Routine antibiotic use does not reduce the risk of developing postoperative infections based on this data, so eliminating the use of preventative postoperative antibiotics may reduce healthcare costs and slow the progression of antibiotic resistance without compromising quality of care. Insurance companies could enforce this change by creating agreements that exclude or limit reimbursement for antibiotics, and professional organizations could publish evidence-based guidelines more clearly outlining when physicians should and should not use antibiotics. However, more research may be needed to ensure policymakers make fully informed decisions that both optimize health outcomes and reduce costs.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Chapter 1 : Introduction

In the United States, healthcare consistently appears as a key topic in social and political debates. Since the passing of the Patient Protection and Affordable Care Act (PPACA) in 2010, the flaws in the healthcare system have become of increasing interest to the general public. The PPACA has implemented many changes in our healthcare system to increase access to healthcare, improve quality of care, and control the costs of healthcare. Though the reform has led to progress in each of these areas, it has not entirely eliminated the issues (Hamel, Blumenthal, Abrams, Nuzum). To further the progress brought by the PPACA, healthcare professionals and patients must alter the ways they administer and consume healthcare services. This study will address the potential to reduce healthcare spending and maintain high quality of care by adjusting use of prophylactic postoperative oral antibiotics following foot and ankle surgeries.

Overview of Problem

Rapid growth of already high healthcare costs continues to plague our nation. According to an article in the *New England Journal of Medicine*, annual growth in national healthcare expenditures has slowed from 5.6% for 2000 to 2010 to just 3.2% for 2010 to 2013 (Hamel, Blumenthal, Abrams, Nuzum). Despite this improvement, the rise in healthcare costs still exceeds the current inflation rate. From 2010 to 2013, the annualized inflation based on CPI for 2010 to 2013 was only about 2.3% (author calculations based on “Inflation Calculator”).

Even more alarming than the high trend for overall healthcare expenditures is the trend in expenditures for pharmaceuticals. In 2015, the net cost of medicines in the United States increased by 8.5% (“IMS Health Study: U.S. Drug Spending”). Much of the increase in drug costs stems from specialty drugs and innovations that greatly improve outcomes for previously untreatable conditions (“IMS Health Study: U.S. Drug Spending”). Another, albeit smaller, factor driving the high trend in drug spend is over-prescription of antibiotics. According to the Center for Disease Control and Prevention, “more than $1.1 billion is spent annually on unnecessary antibiotic prescriptions for respiratory infections in adults” (“Appropriate Antibiotic Use”). In addition to the direct costs of the drugs, antibiotic over-prescription can advance the development of antibiotic resistant infections, which are estimated to produce $20 billion of excess medical costs per year (“Appropriate Antibiotic Use”).

Unnecessary antibiotic use is commonly studied for upper respiratory infections, but there is limited research around antibiotic overuse in other settings, such as orthopedic surgery. However, conclusions about optimal antibiotic use for orthopedic surgery based on what is currently known seem to conflict with the current practices for antibiotic use in orthopedic surgery. Several studies indicate that antibiotic use should not extend beyond twenty-four hours after the operation (Johnson; Dhammi, Haq, Kumar; Ruta, Kadakia, Irwin). Yet, a 2014 study, “What are the Patterns of Prophylactic Postoperative Oral Antibiotic Use After Foot and Ankle Surgery?”, found that 75% of foot and ankle surgeons who responded prescribe postoperative oral antibiotics, and the most common duration of the prescription was five to seven days (Ruta, Kadakia, Irwin). The disparity between recommended use and actual use indicates potential over-prescription of antibiotics for orthopedic surgery, particularly for foot and ankle surgery, that could contribute to increased drug spend and antibiotic resistance.

Though most research indicates that post-operative oral antibiotics may not be necessary, there is still controversy surrounding the appropriate timing, duration, and type of antibiotics to use to prevent infections in orthopedic surgeries (Johnson; Dhammi, Haq, Kumar; Ruta, Kadakia, Irwin). One possible explanation for the controversy is the variation among different types of orthopedic surgeries. For example, orthopedic literature generally concludes that preoperative antibiotic prophylaxis effectively lowers infection rates for orthopedic surgeries, but studies examining only foot and ankle surgeries found that preoperative antibiotic use has no significant impact on infection rates (Ruta, Kadakia, Irwin). Additionally, a 2013 study showed that postoperative oral antibiotics reduce infection rates for patients undergoing two-stage revision hip arthroplasty (Johnson, Zywiel, Jones, Delanois, Stroh, Mont). These differences among surgeries make it difficult to generate meaningful conclusions about antibiotic prophylaxis in all orthopedic surgeries.

Foot and Ankle Surgery

In order to produce more meaningful results, this study will focus specifically on prophylactic postoperative oral antibiotics used with foot and ankle surgeries. There are a few factors that make foot and ankle surgery particularly interesting for this study.

First, the Ruta et al. study discussed above suggests that postoperative oral antibiotics are used more often than recommended for foot and ankle procedures (Ruta, Kadakia, Irwin). By analyzing medical and pharmaceutical claims, the current study will examine whether this finding is reproduced in a different dataset and will also quantify the monetary effects of the overuse which are not documented in the Ruta et al. study.

Furthermore, foot and ankle surgeries have higher incidence of infection than many other types of orthopedic surgery (Ruta, Kadakia, Irwin). This suggests that antibiotic prophylaxis may be largely ineffective for foot and ankle surgery, meaning nearly every prescription could be considered overuse, which creates potential for substantial cost savings.

Another unique characteristic of foot and ankle surgeries is the prevalence of outpatient procedures. Since many procedures are performed in outpatient settings, patients often do not receive intravenous antibiotics following surgery, so surgeons are more likely to prescribe oral antibiotics (Ruta, Kadakia, Irwin). If results of the studies casting doubt on the efficacy of prophylactic postoperative oral antibiotics are reproduced in the current study, it suggests that there is a large population receiving unnecessary prescriptions, and, again, that there is the potential for considerable cost savings by eliminating overuse.

Potential Applications

The outcomes of this study may be of interest to health insurance companies, health policy-makers, and medical professionals as they seek methods to lower healthcare spending and reduce the threat of antibiotic resistance.

As noted earlier, healthcare expenditures are currently extremely high in the United States, particularly for drugs ("IMS Health Study: U.S. Drug Spending"). In 2009, the United States spent $10.7 billion on antibiotics alone (Suda, Hicks, Roberts, Hunkler, Danziger). Of that $10.7 billion, $982.7 million was spent on antibiotics in the cephalosporin class (Suda, Hicks, Roberts, Hunkler, Danziger), which is the class of antibiotics used most commonly for prophylaxis in foot and ankle surgeries (Ruta, Kadakia, Irwin). If there is indeed overuse of antibiotics for foot and ankle surgeries, then a portion of these expenditures could be eliminated by using prophylactic postoperative oral antibiotics more responsibly and discerningly.

By establishing and enforcing guidelines for appropriate use of various drugs, policymakers and medical associations can influence the way doctors prescribe drugs. Ideally, such guidelines would be sufficient to ensure drugs are only prescribed when medically necessary, which would eliminate overuse and the associated excess cost.

Insurers can also encourage appropriate drug use by designing policies that only cover the cost of prescriptions if cases meet certain criteria that illustrate the necessity of the prescription. This shifts the cost of unnecessary prescriptions to patients, which can incentivize patients to use more discretion before requesting or accepting prescriptions from their doctors. Unfortunately, this technique is not always effective, as the lack of transparency in the healthcare industry often means patients are unaware of the costs of their treatments. Without price information, patients cannot make logical economic decisions about their care. Insurers could alternatively shift the cost of unnecessary antibiotics to physicians by negotiating extremely low reimbursement rates for postoperative antibiotics unless certain criteria are met that indicate necessity. Essentially, doctors would lose money each time they prescribed unneeded antibiotics, which would encourage them to use the appropriate guidelines for antibiotic use. This would decrease the amount of money spent for each prescription as well as the overall number of unnecessary prescriptions.

In addition to the direct monetary costs of overprescribing antibiotics, overuse can increase costs indirectly and negatively impact the future health of the population by contributing to antibiotic resistance. Dr. Arjun Srinivasan, an associate director at the Centers for Disease Control and Prevention, said in an interview that “we’ve greatly overused antibiotics and in overusing these antibiotics, we have set ourselves up for the scenario we find ourselves in now, where we’re running out of antibiotics” (Childress). When bacteria are exposed to antibiotics, they evolve to survive in that environment, so antibiotics can no longer fight infections caused by the bacteria. This means that some infections that were easily cured by antibiotics in the past can no longer be cured with the same treatment. In some cases, doctors prescribe different antibiotics that the bacteria are not yet resistant to, but some bacteria have evolved to the point that all antibiotics are ineffective (Childress). Overall, the increase in antibiotic resistance has made infections more difficult to treat. Consequently, infections are more threatening to health, and also more expensive to treat. If policy-makers and doctors enforce standards that decrease antibiotic use for orthopedic surgeries, bacteria would have less exposure to antibiotics, which could slow the evolution of antibiotic-resistant bacteria and preserve the effectiveness of antibiotics.

Chapter 2 : Prior Research

Prophylactic Antibiotic Regimens

Though research regarding appropriate timing and duration of antibiotic prophylaxis brings mixed results, many scholars agree that preoperative prophylaxis is beneficial, and postoperative prophylaxis should be limited. They also agreed that based on the type of bacteria that often cause surgical site infections, cephalosporins are the most effective antibiotics for preventing infection (Dhami, Haq, Kumar).

The most commonly recommended practice for antibiotic prophylaxis involves administration of a cephalosporin, most often Cefazolin, thirty to sixty minutes prior to the incision (Johnson; Dhami, Haq, Kumar). Johnson, PharmD, also noted that surgeons might use Vancomycin in place of Cefazolin for patients with cephalosporin allergies and in hospitals where certain resistant bacteria are common (Johnson). Additionally, a review of literature conducted by Dhami, Haq, and Kumar confirmed that penicillins are equally as effective as second and third generation cephalosporins for preventing postoperative infections (Dhami, Haq, Kumar).

Dhami et al. also highlighted the contrasting findings about optimal duration of antibiotic use. Some studies recommend a single dose preoperatively, while others recommend several doses over a twenty-four hour period, and still others recommend even longer durations up to fourteen days. However, research collectively indicates that there is no benefit in extending antibiotic prophylaxis beyond twenty-four hours. Johnson endorsed a similar perspective, explaining that a single dose of antibiotics is sufficient for clean procedures, which include most orthopedic surgeries, and he recommends a twenty-four hour regimen for clean contaminated procedures, such as orthopedic surgeries involving prosthetics. Johnson also advises that antibiotic use should not exceed forty-eight hours. Another article from 1993, “Antimicrobial Prophylaxis for Surgical Wounds: Guidelines for Clinical Care,” presents an even more conservative view about the duration of antibiotics. The authors acknowledge the benefits of antibiotic prophylaxis such as reducing morbidity, shortening hospital stays, and reducing infection-related costs. Yet, they conclude that doctors should only use antibiotics intraoperatively, not postoperatively, and they should only use antibiotic prophylaxis for patients who are undergoing procedures with high morbidity risks or who present at least two risk factors for developing postoperative infections (Page, Bohnen, Fletcher, McManus, Solomkin, Wittmann). These recommendations for limited use of prophylactic antibiotics likely stem from a lack of evidence supporting improved outcomes with extended antibiotic use, combined with the known risks of antibiotic resistance that can develop with overuse of antibiotics.

A study published by Ruda, Kadakia, and Rumar looked beyond the recommended practices to the actual practices of foot and ankle surgeons in the United States. They found that doctors’ choice of antibiotic aligned with recommendations; Cephalexin, a cephalosporin, was the most commonly prescribed postoperative oral antibiotic (Ruda, Kadakia, Kumar). However, the duration did not align with recommendations found in literature. They found that most doctors prescribe postoperative oral antibiotics for several days following outpatient operations, with over half of prescriptions extending at least five days after surgery (Ruda, Kadakia, Kumar). This clearly deviates from the twenty-four and forty-eight hour maximums recommended in existing literature (Dhami, Haq, Kumar; Johnson). With such distinct differences, one must wonder why such deviations exist and how they affect the overall costs and outcomes of orthopedic surgeries.

Prevalence of Antibiotics

Despite numerous studies that question the effectiveness of postoperative antibiotics for orthopedic surgery, a majority of foot and ankle surgeons prescribe oral antibiotics for their patients to use following surgery (Ruta, Kadakia, Irwin). A survey of members and candidates of the American Orthopaedic Foot and Ankle Society found that 75% of surgeons prescribe postoperative oral antibiotics to their patients, with 12% of surgeons prescribing antibiotics for every patient they treat (Ruta, Kadakia, Irwin). When doctors routinely write prescriptions for all patients, it is likely that many patients receive antibiotics not because they need them to prevent infection, but because their doctors consider it standard practice. On the opposite end of the spectrum, 25% of foot and ankle surgeons never prescribe prophylactic postoperative oral antibiotics (Ruta, Kadakia, Irwin). This raises the question of whether or not any doctor needs to prescribe postoperative antibiotics for their patients given that a quarter of surgeons have never prescribed antibiotics and have not run into issues severe enough to cause them to begin using them. Lying between these two extremes, 62% of foot and ankle surgeons prescribe prophylactic postoperative oral antibiotics discretionally by considering risk factors to determine which patients should receive antibiotics (Ruta, Kadakia, Irwin).

Figure 1: Frequency of Antibiotic Use

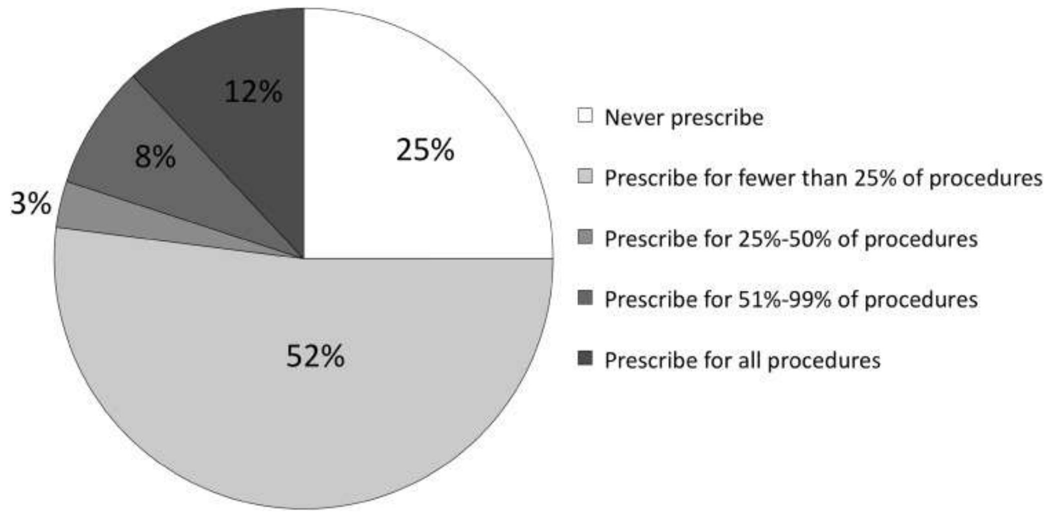

Figure from "What are the Patterns of Prophylactic Postoperative Oral Antibiotic Use After Foot and Ankle Surgery?"

Risk Factors

The study by Ruta et al. lists numerous factors that serve as indicators for doctors to prescribe prophylactic postoperative oral antibiotics. These include history of infection or poor wound healing, comorbidities such as diabetes and immunosuppression, prolonged duration of surgery, placement of hardware, performance of multiple operations, forefoot and hind foot incisions, and advanced age. They also list obesity, malnutrition, and tobacco use as factors that increase the risk of infection for patients (Ruta, Kadakia, Irwin). Female sex and preoperative hospital stays longer than seventy-two hours may indicate increased postoperative infection risk as well (Johnson). Though literature generally advises against prophylactic postoperative oral antibiotics, these risk factors may be valid indicators for prescribing them.

One of the most notable risk factors for developing infection, especially following foot and ankle surgery, is being diabetic. A study examining charts of 1000 patients who underwent foot and ankle surgery found that 13.2% of diabetic patients developed infections postoperatively, while only 2.8% of non-diabetic patients developed infections (Wukich, Lowery, McMillen, Frykberg). Moreover, peripheral neuropathy, a common side effect of diabetes, is the single most significant predictor of infection (Ruta, Kadakia, Irwin).

Literature also mentions age and placement of hardware as potential risk factors, but there is not strong evidence to support their significance (Ruta, Kadakia, Irwin). The same study mentioned above that highlighted the increased infection risk for diabetics found no relationship between age and infection risk (Wukich, Lowery, McMillen, Frykberg). In addition, orthopedic implants previously increased infection risks; however, improvements in operative techniques have reduced the relationship between hardware placement and infection (Ruta, Kadakia, Irwin).

Three of the risk factors—duration of procedure, length of preoperative stay, and number of operations performed—all seem to indicate the severity of the injury and the subsequent complexity of the surgery. Therefore, injury severity may be a significant predictor of infection and reason for oral antibiotic prescription.

Most of the remaining risk factors discussed in literature can be categorized as patient characteristics—obesity, tobacco use, history of infection or poor wound healing. Though this thesis will not address all of these risk factors in depth due to data limitations, they are important factors for predicting infection and guiding doctors' prescribing decisions. In fact, when the foot and ankle surgeons surveyed for Ruta, Kadakia, and Irwin's study were asked about how they determine when to prescribe antibiotics, the most common response was "history of previous infection" (Ruta, Kadakia, Irwin).

Based on prior research about risk factors for surgical site infection, it is clear that some populations are at higher risk for developing postoperative infections. It follows that for these high-risk populations, doctors may take additional measures, such as prescribing prophylactic postoperative oral antibiotics, to reduce their infection risk. Under the assumption that postoperative antibiotics do decrease infection rates for high-risk populations, extended antibiotic use is sometimes necessary even though literature generally argues against its effectiveness. Careful study of the effects of prophylactic postoperative oral antibiotics within these high-risk populations could guide policymakers in creating more clear guidelines for appropriate antibiotic use in orthopedic surgery.

Impacts of Surgical Site Infections

When infections do occur, they are very costly and present serious threats to patients' health. As seen below in Table 1, surgical site infection significantly increases both length of stay and cost of care. A study sponsored by the Society of Actuaries' Health Section used medical claims to determine that infection leads to an average of $13,312 in excess medical costs for each patient, with an even higher amount when only considering inpatient procedures (Shreve, Van Den Bos, Gray, Halford, Rustagi, Ziemkiewicz). Another study using the Nationwide Inpatient Sample from 2005 found a similar result, with $15,129 attributable to each infection (De Lissovoy, Fraeman, Hutchins, Murphy, Song, Vaughn), and a study of patients at two North Carolina hospitals calculated the increase in median direct costs due to surgical site infection to be $17,708 (Whitehouse, Friedman, Kirkland, Richardson, Sexton). In addition to the direct costs of hospitalization and medical treatments, the longer hospital stays associated with surgical site infections lead to more missed workdays and lost wages for patients (Whitehouse, Friedman, Kirkland, Richardson, Sexton).

Table 1: Estimated Increases in Cost and Length of Hospitalization Caused by Surgical Site Infections

Study	Source of Data	Procedures Included	Measure of Center Used	Increase in Length of Hospitalization in Days	Increase in Cost of Care
Whitehouse et al. 2002	Records from Duke University Medical Center and Durham Regional Hospital	Orthopedic	Median*	14	$17,708.00
Lissovoy et al. 2009	Nationwide Inpatient Sample 2005	Orthopedic	Mean	9.5	$15,129.00
Shreve et al. 2010	Inpatient medical claims from Medstat Marketscan and Medicare	Various	Mean	NA	$22,012.00
Shreve et al. 2010	Outpatient medical claims from Medstat Marketscan and Medicare	Various	Mean	NA	$4,814.00
Shreve et al. 2010	Inpatient and outpatient medical claims from Medstat Marketscan and Medicare	Various	Mean	NA	$13,312.00

*median based on direct costs only, which includes costs of healthcare services and medications provided at the initial hospital admission and any subsequent admissions related to the same event
NA=Data Not Available

The study by Whitehouse et al. looked at the differences in health outcomes for patients with and without surgical site infections in addition to the financial outcomes. They measured this using the Short Form 36 questionnaire, which assesses patients' health related quality of life based on eight categories: physical functioning, physical role functioning, emotional role functioning, social functioning, bodily pain, mental health, vitality, and general perception of health. One year after surgery, patients who did not develop infections reported higher scores for nearly every category, with the most significant difference—20 points on a 100 point scale—seen in physical functioning (Whitehouse, Friedman, Kirkland, Richardson, Sexton).

Seeing as surgical site infections have such substantial negative effects on health and healthcare spending, finding an appropriate way to prevent and manage infections is extremely important.

Chapter 3 : Objectives and Hypotheses

By examining current antibiotic use and infection rates in foot and ankle surgery in detail, this study will provide insight about the existence and severity of overuse of prophylactic postoperative oral antibiotics within the context of foot and ankle surgery. For the purpose of this study, overuse will be defined as any prescription that does not significantly reduce incidence of infection based on the data. Using information from medical and pharmacy claims, this study will also suggest and model various scenarios that may reduce healthcare spending and antibiotic overuse.

The primary goal of this research is to answer the following questions: Are prophylactic postoperative oral antibiotics overused for foot and ankle surgeries? If antibiotics are overused, how could reducing antibiotic use affect healthcare expenditures?

To answer these questions, the study will address a series of more specific questions as outlined below.

1. **What percent of foot and ankle surgical patients receive prophylactic postoperative oral antibiotics?**
2. **Are there any variables (gender, age, location, existing conditions, etc.) that predict prescription of antibiotics or incidence of infection?**
3. **Does the incidence of infection differ for patients who do and do not receive postoperative oral antibiotics?**
4. **How costly are antibiotics and surgical site infections?**
5. **Based on various models and assumptions, could healthcare costs be reduced by adjusting antibiotic use?**

I hypothesize the following results:

1. **Approximately 24% of patients receive prophylactic postoperative oral antibiotics.**

   Using a rough calculation of the weighted average of the frequencies of prescription that were reported in the Ruta et al. study, foot and ankle surgeons prescribe postoperative antibiotics to about 23.75% of patients. I expect the results of the current study will mirror this result.

2. **Diabetic and elderly patients are more likely to develop postoperative infections.**

   Current literature consistently cites diabetes and advanced age as risk factors for developing infection. I expect that this will be reflected in the dataset by higher frequencies of infection for patients with these risk factors compared to those without them.

3. **Prophylactic postoperative oral antibiotics do not affect incidence of infection in most patients, and therefore are overused.**

   I expect to find that in certain high-risk patients, such as those with diabetes or advanced age, postoperative antibiotics effectively prevent infection. However, based on the literature I have read, most patients do not benefit from postoperative antibiotics (Ruta, Kadakia, Irwin), so I anticipate finding no relationship between antibiotic prescription and infection rate for most types of patients. Therefore, any cases where patients receive antibiotics but do not present risk factors would constitute overuse, and I expect to find a sizeable number of these cases in the data since the best practices for prescribing postoperative antibiotics are still controversial (Johnson).

4. **Postoperative antibiotics cost about $30 per prescription, and each infection costs about $15,000.**

   Based on the results of previous studies reported in Table 1, it appears the average excess cost caused by postoperative infection is near $15,000. The cost of antibiotics is difficult to estimate since it varies based on the type of antibiotic and the prescribed dosage and duration. Since oral antibiotics are widely used and many similar antibiotics exist, I assume that the market for antibiotics is competitive, which drives prices down. Based on this frame of thought and personal experience, I expect that the average cost of antibiotics for a single patient is relatively low at $30.

5. **Models will illustrate that managing how and when doctors prescribe prophylactic postoperative oral antibiotics for patients undergoing foot and ankle surgeries will lead to reduced healthcare expenditures.**

   Since I expect to find that antibiotics do not affect infection rate for most patients, physicians could reduce overall antibiotic costs without increasing infection costs by not prescribing postoperative antibiotics to any patients without evidence that antibiotics would reduce their risk of infection. This would lead to an overall reduction in healthcare costs. I expect that models based on regression analysis will illustrate that projected costs decrease and infection rates remain unchanged when antibiotic use becomes more selective.

Chapter 4 : Research Methods and Approach

Design

This study uses medical and pharmacy claims to identify characteristics and outcomes of people who underwent foot and ankle surgery between July 31, 2014 and June 30, 2015. Specifically, this study focuses on the following variables: gender, age group, complex conditions, location of surgery, antibiotics, infection, and total spend. Analysis includes the creation of multivariate logistic regression models to understand the impact of each variable on the likelihood of receiving prophylactic postoperative oral antibiotics and the likelihood of developing an infection. These models are then used to project infection rates and medical costs with varied use of postoperative antibiotics.

Data

The data used for this study consists of de-identified medical and pharmacy claims filed with a large national health insurer with at least 1,000,000 members. The information in the dataset is from commercial members only; no Medicare or Medicaid members are included. Furthermore, only members who had foot or ankle surgery between July 1, 2014 and June 30, 2015 and remained enrolled for at least one year following surgery were considered. For each of these members, medical and pharmacy claims filed between the date of their first surgery in this timeframe, or their index date, and one year following the index date were included in analysis. These specifications led to a sample of 12,463 members with an average age of 39 years that is 59% female. Of these members, those who had at least one claim with a diagnosis code for sepsis or postoperative infection on their index date were excluded, bringing the total number of members to 12,408.

The data includes descriptive information about each member such as age, gender, state, and original effective and termination dates. For each medical claim, the records include information regarding the date of service, the diagnosis based on ICD-9 and ICD-10 codes, the procedure type based on HCPCS codes, the location based on AMA Place of Service codes, and cost information based on the amount billed by the provider. Pharmacy claims include similar information, providing the therapeutic class, fill date, days supplied, and cost information based on Average Wholesale Prices.

The dollar amounts provided in this dataset are billed amounts for medical claims, and average wholesale price, or AWP amounts, for pharmacy claims. Both of these amounts could be thought of as list prices, and patients and insurance companies rarely pay these full amounts. Therefore, the healthcare expenditures calculated for this study may be inflated.

Variables

Gender: Gender is defined as either *Male* or *Female* and represented by an indicator variable that is equal to 1 for males and 0 for females

Age Group: The sample is split into three age groups based on age at index date, and these age groups are represented by two indicator variables—*31-50* and *51+*. The *31-50* indicator variable is equal to 1 for members aged 31-50 and 0 otherwise. The *51+* indicator variable is equal to 1 for members over 50 and 0 otherwise. Age *0-30* is the reference level for age group, and members in this age group have values of 0 for both *31-50* and *51+*. The cutoffs for each age group were determined to create roughly equal numbers of members within each group.

Complex Conditions: There are three categories for this variable, which are represented by two indicator variables. The first indicator variable is *Diabetes*, which is equal to 1 for members with at least one claim with a diagnosis code for diabetes during the year after their index date, and 0 otherwise. The next is *Other*, which is equal to 1 for members who have no claims with diagnosis codes for diabetes but have at least one claim with a diagnosis code for cancer, end stage renal disease, chemotherapy, or obesity within one year after their index date and 0 otherwise. The reference level for this variable is *None*, and members in this group have a value of 0 for both *Diabetes* and *Other*.

Location of Surgery: This is the type of facility where the surgery was performed. There are four categories for this variable, represented by three indicator variables. *Inpatient Hospital* is equal to 1 if at least claim within the week after the index date has AMA Place of Service Code 21 and 0 otherwise. *Outpatient Hospital* is equal to 1 if there are no claims within the week after the index date with AMA Place of Service Code 21 and there is at least 1 claim within that week with AMA Place of Service Code 22 and 0 otherwise. *Emergency Room* is equal to 1 if every claim within a week after the index date has AMA Place of Service Code 23 and is 0 otherwise. The reference level for this variable is *Other Outpatient Facility*, and members in this group have a value of 0 for *Inpatient Hospital, Outpatient Hospital*, and *ER.*

Antibiotics: *Antibiotics* is an indicator variable that is equal to 1 for members who have at least one pharmacy claim with generic therapeutic class description “Antibiotics” and fill date the same as or up to two days after the index date and 0 otherwise.

Infection: *Infection* is an indicator variable equal to 1 for members with at least one claim with a diagnosis code for postoperative infection between the index date and the cutoff date and 0 otherwise. The cutoff date is defined as the minimum of the date of the first orthopedic surgery, as identified by HCPCS codes, more than a week after the index date, and 90 days after the index date.

Total Spend: *Total Spend* is a continuous variable equal to the sum of the billed amount for each medical claim and the AWP amount for each pharmacy claim for each member.

Wherever ICD-9 and ICD-10 codes were used, the criteria were determined based on “The Web's Free ICD-9-CM & ICD-10-CM Medical Coding Reference,” “Using Claims Data to Perform Surveillance for Surgical Site Infection: The Devil is in the Details” by Nickel, Wallace, Warren, Mines, and Olsen, and a list of “Applicable Cancer Diagnosis Codes.”

Chapter 5 : Analysis and Findings

Research Question 1: What percent of patients receive prophylactic postoperative oral antibiotics?

Table 2: Prevalence of Postoperative Antibiotic Prescription

Prevalence of Postoperative Antibiotic Prescription							
	n	% of Total	Frequency of Antibiotic		Difference from Reference Antibiotic Frequency	Test Statistic	p-value (One Tailed)
Total	12408	100%	1090	8.8%			
Gender							
Female	7350	59%	622	8.5%			
Male	5058	41%	468	9.3%	0.8%	1.53	0.06328
Age Group							
0-30	4033	33%	264	6.5%			
31-50	4080	33%	385	9.4%	2.9%	4.80	*0.00000*
51+	4295	35%	441	10.3%	3.7%	6.10	*0.00000*
Complex Condition							
None	10284	83%	834	8.1%			
Other	964	8%	87	9.0%	0.9%	0.99	0.16085
Diabetes	1160	9%	169	14.6%	6.5%	7.37	*0.00000*
Location of Surgery							
Other Outpatient Facility	6206	50%	414	6.7%			
Inpatient Hospital	938	8%	69	7.4%	0.7%	0.78	0.21801
Emergency Room	581	5%	59	10.2%	3.5%	3.15	*0.00081*
Outpatient Hospital	4683	38%	548	11.7%	5.0%	9.16	*0.00000*

This table shows the frequency of antibiotic prescription for each group listed in the leftmost column along with the difference and the significance of the difference between the value and the reference group, which is the first group listed in each major category.

Based on the sample, 8.8% of all members who underwent foot or ankle surgery received prophylactic postoperative oral antibiotics. Relative to the findings of the study by Ruta et al. that reported that 75% of surgeons prescribe postoperative oral antibiotics to at least some patients, this result seems extremely low (Ruta, Kadakia, Irwin). This could be a result of the limited time period of the data. The earliest claims included in the data were on the index date, so any antibiotics prescriptions that may have been filled in the days leading up to surgery to be taken after the operation could not be accounted for. Even so, the 8.8% found in this study is a sizeable portion that warrants further investigation given the limited evidence about benefits of postoperative antibiotics and the known threats created by antibiotic overuse.

In Table 2, frequency of antibiotic prescription is shown for several different groups. As expected, patients with certain characteristics are more likely to receive antibiotics. Without controlling for other variables, members in this study were significantly more likely to receive antibiotics if they were over age 30 compared to under age 30, had diabetes compared to had no complex conditions, or had surgery in an outpatient hospital or emergency room setting compared to in other outpatient facilities. This is a positive indicator in that it suggests that there may not be universal overuse, as it shows that doctors prescribe antibiotics based on risk factors rather than prescribing them for all patients.

Research Question 2: Are there any variables (gender, age, location, existing conditions, etc.) that predict prescription of antibiotics or incidence of infection?

Table 3: Predicting Antibiotic Prescription: Multivariate Logistic Regression

Predicting Antibiotic Prescription: Multivariate Logistic Regression			
Predictor	**Log Odds**	**Odds Ratio**	**p-value (One Tailed)**
Intercept	-2.98142	0.05072	*0.00000*
Gender			
Female			
Male	0.12437	1.13243	0.05995
Age Group			
0-30			
31-50	0.3277	1.38777	*0.00012*
51+	0.37444	1.45418	*0.00001*
Complex Condition			
None			
Other	0.05056	1.05186	0.67252
Diabetes	0.55491	1.74178	*0.00000*
Location of Surgery			
Other Outpatient Facility			
Inpatient Hospital	-0.08867	0.91515	0.53233
Emergency Room	0.47259	1.60414	*0.00133*
Outpatient Hospital	0.57794	1.78236	*0.00000*

This table shows the results of a multivariate logistic regression to examine the effects of each predictor on the odds of receiving antibiotics.

Building upon the results shown in Table 2, Table 3 shows the results of a multivariate logistic regression to understand how different variables affect the likelihood of receiving antibiotics when controlling for other variables. Using a significance level of .05, this analysis shows that members are more likely to receive postoperative antibiotics if they are over age 30 compared to under age 30, have diabetes compared to having no complex conditions, or have surgery at an emergency room or outpatient hospital setting compared to in another outpatient facility.

Interestingly, members with other complex conditions including cancer, end stage renal disease, obesity, and chemotherapy, were not significantly more likely to receive antibiotics.

One possible explanation for this could be that as more complicated patients, they may be monitored more closely by doctors who can keep their incisions clean and identify and treat any infections early. Alternatively, they may spend more time in hospitals or facilities where they can be given antibiotics intravenously, which would eliminate the need for oral antibiotics. Similar logic could explain why members who undergo surgery in inpatient hospital settings have a slightly reduced probability of receiving antibiotics, though it is not significant. Since these members are kept in a hospital after surgery, they can be closely monitored and receive intravenous antibiotics, which would reduce their need for oral antibiotics.

Table 4: Prevalence of Postoperative Infection

Prevalence of Postoperative Infection						
	n	% of Total	Frequency of Infection		Difference from Reference Infection Frequency	p-Value (One Tailed)
Total	12408	100%	117	0.9%		
Gender						
Female	7350	59%	51	0.7%		
Male	5058	41%	66	1.3%	0.6%	*0.00027*
Age Group						
0-30	4033	33%	21	0.5%		
31-50	4080	33%	40	1.0%	0.5%	*0.00828*
51+	4295	35%	56	1.3%	0.8%	*0.00010*
Complex Condition						
None	10284	83%	71	0.7%		
Other	964	8%	9	0.9%	0.2%	0.19510
Diabetes	1160	9%	37	3.2%	2.5%	*0.00000*
Location of Surgery						
Other Outpatient Facility	6206	50%	21	0.3%		
Inpatient Hospital	938	8%	43	4.6%	4.2%	*0.00000*
Emergency Room	581	5%	1	0.2%	-0.2%	0.25009
Outpatient Hospital	4683	38%	52	1.1%	0.8%	*0.00000*

This table shows the frequency of postoperative infection for each group as well as the difference and significance of difference from the reference level, which is the first group in each main category.

As seen in Table 4, the overall infection rate is .9% . Furthermore, without controlling for any other variables, certain members are significantly more likely to develop infections at a significance level of .05. Males are more likely to develop infections than females, members over age 30 are more likely to develop infections than those below age 30, those who have surgeries at inpatient and outpatient hospital settings are more likely to develop infections than those who have surgery at other outpatient facilities, and diabetics are more likely to develop infections than those with no complex conditions.

Surprisingly, the infection rates found in this study were much lower than those found in previous studies. In particular, the study by Wukich, Lowery, McMillen and Frykberb found postoperative infection rates of 13.2% for diabetics and 2.8% for non-diabetics (Wukich, Lowery, McMillen, Frykberg), while this study found that the infection rate for diabetics was only 3.2% . One possible explanation for this disparity could be the method of identifying postoperative infections. In this study, a list of ICD-9 and ICD-10 codes were used to identify postoperative infections, and it is possible that there were members with infections that did not have claims with any of these diagnosis codes. However, a study that used a very similar list of codes found that the presence of those codes in patients' claims is significantly associated with actual incidence of surgical site infection (Branch-Elliman, Strymish, Itani, Gupta), so it is likely that the codes used in this study were a good indicator for infection. Another likely cause of the low infection rates in this study is the age distribution. One of the risk factors mentioned in previous literature was advanced age, and since this dataset did not include Medicare members, it makes sense that the overall infection rates would be lower than for studies that include more elderly patients.

Table 5: Predicting Infection: Multivariate Logistic Regression

Predicting Infection: Multivariate Logistic Regression			
	Log Odds	**Odds Ratio**	**p-value (One Tailed)**
Intercept	-6.26158	0.00191	*0.00000*
Gender			
Female			
Male	0.32729	1.38720	0.09863
Age Group			
0-30			
31-50	0.39926	1.49072	0.15230
51+	0.44994	1.56822	0.10628
Complex Condition			
None			
Other	0.06513	1.06730	0.85663
Diabetes	0.90404	2.46956	*0.00011*
Location of Surgery			
Other Outpatient Facility			
Inpatient Hospital	2.29543	9.92870	*0.00000*
Emergency Room	-0.70232	0.49543	0.49279
Outpatient Hospital	1.10576	3.02152	*0.00002*
Antibiotics			
No Antibiotics			
Antibiotics	0.38233	1.46570	0.15799

This table shows the results of a multivariate logistic regression to examine the effects of each predictor on the odds of developing a postoperative infection.

According to the results of the multivariate logistic regression in Table 5, several variables significantly predict infection even when controlling for other variables. Diabetics and members who have surgery in inpatient and outpatient hospital settings have increased odds of infection.

The odds of developing infection is notably high for patients who have surgery in inpatient hospital settings compared to other outpatient facilities. A possible explanation for this extreme value is the method in which inpatient hospital members were identified. If a patient had any inpatient hospital claims within a week of surgery, they were categorized as an inpatient hospital member. This means that any members who had surgery at different types of locations and were admitted to an inpatient hospital facility within a week, possibly due to surgical complications such as infection, are in the inpatient hospital category even though they may not have actually had surgery there. This would lead to an artificially high infection rate for inpatient hospital members. In addition, patients who have surgery in inpatient hospital settings may actually face a higher risk of infection since there is a possibility that they are in the hospital long-term for a condition not considered in this analysis that increases their risk, or that they are exposed to more germs at a hospital than in other outpatient facilities.

Importantly, antibiotics are not a significant predictor of infection. This suggests that postoperative oral antibiotics may be unnecessary for patients who undergo foot and ankle surgeries.

Research Question 3: Does the incidence of infection differ for patients who do and do not receive postoperative oral antibiotics?

Table 6: Significance of Antibiotics for Predicting Infection in Subsets of Sample

Significance of Antibiotics for Predicting Infection in Subsets of Sample			
Subset of Sample	**Antibiotics Log Odds**	**Antibiotics Odds Ratio**	**Antibiotics p-value (One Tailed)**
All	0.38233	1.46570	0.15799
Gender			
Female	0.05885	1.06062	0.90202
Male	0.57161	1.77112	0.08636
Age Group			
0-30	1.18390	3.26709	*0.03920*
31-50	0.21074	1.23459	0.66790
51+	0.20870	1.23208	0.59602
Complex Condition			
None	0.68820	1.99013	*0.04019*
Other	-15.72226	0.00000	0.99310
Diabetes	0.06932	1.07178	0.88069
Location of Surgery			
Other Outpatient Facility	0.70568	2.02522	0.26200
Inpatient Hospital	0.34920	1.41793	0.48500
Emergency Room	-16.07050	0.00000	0.99900
Outpatient Hospital	0.27773	1.32013	0.45900

Based on multivariate logistic regression using only members of the sample within each group

Based on the results in Table 5, antibiotics do not significantly affect the frequency of infection. However, it is important to consider if antibiotics may be effective within certain subsets of the population even though they appear not to be for the sample as a whole. For example, a healthy individual with low risk of infection may not benefit from antibiotics, while a patient with diabetes or a compromised immune system may actually reduce their risk of infection by taking antibiotics. To study this, multivariate logistic regression was performed to predict the log odds of developing infection using all variables except the variable used to distinguish the subset. Table 6 shows the log odds, odds ratio, and p-value for the variable *Antibiotics* for each subset. This regression analysis showed that prescription of postoperative antibiotics does significantly affect the probability of developing infection for members aged 0-30 and members with no complex conditions at a significance level of .05. Relaxing the significance level to .1, use of antibiotics also significantly affects the infection rate for males. However, antibiotics affect the probability of infection in the opposite direction that you would expect; these subsets are more likely to develop postoperative infections if they receive antibiotics than if they do not receive antibiotics. Most notably, members age 0-30 who receive antibiotics are about 3.3 times as likely as those who do not receive antibiotics to develop a postoperative infection. Although research does not support the effectiveness of antibiotics following orthopedic surgery, it is surprising to find that antibiotics would be detrimental to infection rate. This result implies that there are likely other risk factors that predict both antibiotic prescription and infection that are not accounted for by this study. Still, based on this analysis, postoperative oral antibiotics do not appear to reduce infection rates, and therefore their use following foot and ankle surgeries is questionable.

Research Question 4: How costly are antibiotics and surgical site infections?

This study measured the cost of antibiotics based on AWP amounts for antibiotics prescribed within two days of the index date. The average cost of postoperative antibiotics was $56.43 for each person who received them, which combines to a total of $61,504.48 for the entire sample. This makes up an extremely small portion, only 0.01%, of the total spend for the sample.

To measure the cost of postoperative infections, the summation of the billed amounts for all claims with a diagnosis code for postoperative infection between the index date and cutoff date was used. Using this method, the average cost of infection given that an individual has an infection is $19,605.07. This adds up to $3,567,244.16 for the entire sample, which is .76% of the total spend.

Research Question 5: Based on various models and assumptions, could healthcare costs be reduced by adjusting antibiotic use?

Table 7: Multivariate Regression to Predict Total Spend

Multivariate Regression to Predict Total Spend		
	Estimated Coefficient	**p-value (One Tailed)**
Intercept	12505	0.00000
Gender		
Female		
Male	1173	0.37300
Age Group		
0-30		
31-50	6988	0.00001
51+	12081	0.00000
Complex Condition		
None		
Other	27375	0.00000
Diabetes	33290	0.00000
Location of Surgery		
Other Outpatient Facility		
Inpatient Hospital	84797	0.00000
Emergency Room	2240	0.46400
Outpatient Hospital	17734	0.00000
Antibiotics	1233	0.58300

To answer this question, multivariate regression was used to create a model to predict total spend for each patient. Table 7 shows the results of this regression. Even though infection is likely a significant predictor of total spend, it is not included in this model because it is assumed that the predictors that are included in this model also predict infection. Accordingly, it is assumed that adjusting antibiotics, which is the variable that will be manipulated to project different outcomes, may affect infection rate. Therefore, it would not make sense to include infection in this regression model. Using the results in Table 7, the following equation was created to predict total spend for each member:

***Total Spend*=12505+(*Male*)*1173+(*Age 31-50*)*6988+(*Age 51+*)*12081+**

(*Other Complex Condition*)*27375+(*Diabetes*)*33290+

(*Inpatient Hospital*)*84797+(*Emergency Room*)*2240+

(*Outpatient Hospital*)*17734+(*Antibiotics*)*1233

Although not every predictor is significant based on Table 7, all predictors were included in this equation for the purpose of creating a simple hypothetical model.

Using the results in Table 5, another equation was constructed to predict the probability that each member would develop an infection.

Probability of Infection=$e^x/(1+e^x)$

Where

X= -6.26158+0.39926*(*Age 31-50*)+0.44994*(*Age 51+*)+0.32729*(*Male*)+

0.90404*(*Diabetes*)+0.06513*(*Other Complex Condition*)-

0.70232*(*Emergency Room*)+2.29543*(*Inpatient Hospital*)+

1.10576*(*Outpatient Hospital*)+0.38233*(*Antibiotics*)

Using the original data and adjusting only the values for Antibiotics, predicted outcomes for infection rates and total spend were calculated. The results of this calculations are shown in Table 8.

Table 8: Predicted Outcomes for Various Patterns of Antibiotic Prescription

Predicted Outcomes for Various Patterns of Antibiotic Prescription				
Members Receiving Antibiotics	**Predicted Overall Infection Rate**	**Predicted Total Spend**	**Predicted Infection Rate as Percent of Observed Rate**	**Predicted Total Spend as Percent of Observed Spend**
None	0.00901	$ 470,389,257	**95.5245%**	**99.7158%**
Age 31-50 Age 51+ Diabetic	0.01230	$ 480,771,117	130.4350%	101.9166%
Age 31-50 Age 51+ Diabetic Male	0.01275	$ 474,808,329	135.2270%	100.6526%
Diabetic	0.01021	$ 471,819,537	108.2320%	100.0190%
Diabetic Male	0.01161	$ 477,327,348	123.0739%	101.1866%
Age 31-50 Age 51+ Diabetic UNLESS ALSO Male Age 0-30 No Condition	0.00953	$ 471,787,479	101.0472%	100.0122%
Diabetic UNLESS ALSO Male Age 0-30	0.00937	$ 471,064,941	**99.3225%**	**99.8590%**

Observed Total Spend:	$471,729,970
Observed Overall Infection Rate:	0.00943

The categories listed in the first column indicate that members having any combination of the listed characteristics are given antibiotics.

The first simulation in the table shows the projected infection rate and total spend using the original data but setting the value of Antibiotics to 0 for all members. Based on this simulation, eliminating the use of prophylactic postoperative antibiotics would decrease the overall infection rate by about 4.5% from .943% to .901%. It would also reduce total spend, but only by about .3%.

The next four simulations assign values of 1 for *Antibiotics* for members having characteristics that significantly predict antibiotic prescription and probability of infection based on the results in Table 3 and Table 5 at different significance levels. Of the significant predictors, locations were not considered due to the quirks in defining the categories and the less direct policy implications. Each of these simulations projected increases in infection rate and total spend.

The next three simulations use similar criteria as the four above, but assigning a value of 0 for Antibiotics for any members who are part of the groups that were shown to have increased risk of infection with antibiotics in Table 6. The final scenario simulated prescribing antibiotics to diabetic members unless they were male or under age 31. The projected total spend and infection rate for this scenario were slightly below the observed values, but by less than 1%.

Examining each scenario that was simulated, none reduces the infection rate or total spend enough to be a valid and worthwhile solution to help decrease healthcare expenditures in the United States.

Chapter 6 : Conclusion

Based on the results of this study, prophylactic postoperative oral antibiotics do not reduce the risk of infection for patients who undergo foot or ankle surgery. Therefore, use of postoperative oral antibiotics after foot and ankle surgery could be considered overuse, and it follows that ceasing to prescribe them could slightly reduce healthcare expenditures and slow the progression of antibiotic resistance. Health insurers could encourage this by not agreeing to reimburse providers for prophylactic postoperative oral antibiotic prescriptions. Policymakers could also create rules or guides that advise against prescribing them.

However, the results of this study are not strong enough to suggest a major change in policy. Not only were the projected reductions in healthcare expenditures and infection rate very minor, but certain results indicate that this study failed to capture important risk factors. The fact that some subsets of the sample had a higher risk of developing infection with antibiotics than without is only logical if there are confounding variables that increases the probabilities of receiving antibiotics and developing infection. Additionally, since this is a retrospective study, the results are not as powerful as a randomized study.

Even though prior research and the results of this study suggest there is no need for prophylactic postoperative oral antibiotics, the impacts of postoperative infections on patients' health are too severe to make policy changes without knowing the full affects they would have on all types of individuals. At least, that is one side of the argument. On the other hand, one could argue that the threat of antibiotic resistance and growing healthcare expenditures is too severe to continue prescribing antibiotics without strong evidence that they are necessary. Either way, randomized trials studying the effects of prophylactic postoperative oral antibiotics for foot and ankle surgery patients of all ages with varying risk factors are needed before fully informed policy decisions can be made. Further research could also look beyond foot and ankle surgeries to encompass all orthopedic surgeries so that more holistic and impactful policy changes could be made regarding the use of prophylactic postoperative oral antibiotics following orthopedic surgery. Such policies could help ensure the healthcare system runs more efficiently by taking steps to provide quality care using evidence based medicine while minimizing costs and preventing long-term threats like antibiotic resistance.

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Smeal College of Business
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EXPERIENCE:

UnitedHealthcare, Shelton, CT — June 2016-August 2016
Actuarial Intern

- Designed summaries of specialty drug claims using Excel and Access
- Identified trends in expenditures for specialty drugs for various disease classes and locations
- Analyzed pharmacy and medical claims to study patterns in drug use, place of service, and medical outcomes that could potentially uncover opportunities to reduce costs while maintaining high quality of care
- Attended Executive Speaker Series and We Are UHG events to learn about the company and potential career paths

Camp Merri-Mac, Black Mountain, NC — June 2014-August 2014
Counselor and Head Gymnastics Instructor

- Collaborated with 3 other counselors to care for a cabin of 22 girls during their time at camp
- Trained and managed a team of 4 gymnastics coaches in instructing 300+ girls in gymnastics skills
- Prepared and implemented lesson plans for coaching
- Created and enforced safety policies within the gym

LEADERSHIP AND SERVICE:

RUF for THON
Overall Chair — Fall 2015-present

- Communicate with city officials, business owners, and hosts to organize Fundraising Outreach and Canning Weekends, canvassing trips, and other fundraisers
- Co-lead weekly meetings with other chairs and organization members to discuss updates and plan upcoming projects

RUF Ministry Team
Secretary — Fall 2016-present

- Attend weekly meetings to discuss the health of RUF and invent ideas to improve the organization
- Evoke change in the organization by building intentional relationships and demonstrating the changes we would like to see occur

ACTIVITIES AND AWARDS:

Finalist in Liberty Mutual Insurance Case Competition — October 2014
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Penn State Gymnastics Club — Fall 2013-Spring 2015
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SKILLS:

Excel—Completed a Course in Spring 2015
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