

# Understanding of Optimum Antibiotic Prophylaxis is Inconsistent Among Orthopaedic Surgery and Anesthesia Teams

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## Research

**Keywords:** antibiotic prophylaxis, surgical site infection, orthopaedic surgery, quality improvement

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# Abstract

**Background** Antibiotic surgical prophylaxis is a core strategy for the prevention of surgical site infections (SSI). Despite best practice guidelines and known efficacy of antibiotic prophylaxis in decreasing SSI risk, there is often wide variation in its use. We performed this study to assess antibiotic prophylaxis perspectives of orthopaedic surgery and anesthesiology teams at our institution regarding preoperative antibiotic choice, dosing, and timing.

**Methods** An IRB approved questionnaire was distributed amongst orthopaedic surgery and anesthesia team members involved in preoperative antibiotic decision making from August 2017 to June 2019. The questionnaire addressed ten key practices relating to preoperative antibiotic use, including antibiotic choice, timing, rate of infusion, and dosing. Provider and service type responses were also compared using Chi-square tests.

**Results** Two nurse practitioner (NP), 22 resident, and 23 attending orthopaedic surgery providers completed the survey. Twelve nurse anesthetist (CRNA), 6 resident, and 8 attending anesthesiology providers completed the survey. Only 30% of all providers agreed that both vancomycin and cefazolin are equally effective for the purpose of antibiotic prophylaxis. As for the antibiotic choice in patients with penicillin allergies, 50% agreed with vancomycin, 28% agreed with clindamycin, and 22% disagreed with both alternatives. Furthermore, resident physicians more frequently agreed with vancomycin (71%) compared to NPs (29%), and attendings physicians (35%) ( $p=0.014$ ). A majority of providers agreed with the necessity of weight-based dosing and timely infusion of vancomycin.

**Conclusions** There is no clear consensus amongst providers for which antibiotic to administer for antibiotic prophylaxis despite existing guidelines. Discrepancy exists between orthopaedic and anesthesia providers for which antibiotic to administer in patients with penicillin allergies. Institutions should evaluate antibiotic prophylaxis perspectives amongst their perioperative staff in order to identify any inconsistencies that could result in inappropriate antibiotic prophylaxis for patients. A multifactorial quality improvement strategy that includes development of a protocol, displaying prophylaxis guidelines in perioperative areas, educational training, a preoperative checklist, and optimizing the electronic medical record should be implemented to standardize prophylaxis practices. It is also integral to involve both the orthopaedic and the anesthesia staff in the quality improvement process otherwise discrepancies may continue to persist.

## Background

Surgical site infections (SSI) continue to be one of the most common complications after orthopaedic surgery.<sup>1,2</sup> Patients who develop SSI are at an increased risk of morbidity and mortality, often have longer hospital length of stays, and also have greater health care associated costs. One of the most important strategies to reduce the risk of SSI is antibiotic prophylaxis, with a goal of decreasing the overall burden of microorganisms at the operative site. Since the most common pathogen associated with SSI in

orthopaedic procedures is Methicillin-sensitive Staphylococcus aureus (MSSA), antibiotics with excellent gram-positive coverage, such as first or third generation cephalosporins are often preferred. However, Methicillin-resistant Staphylococcus aureus (MRSA), Coagulase-negative Staphylococci (CoNS), and gram-negative bacilli are also important pathogens to consider. In addition, patient allergies, the side effect profile, and the cost associated with the antibiotic must also be considered.

The efficacy of antibiotic prophylaxis within the field of orthopaedic surgery is well documented. In total knee and total hip arthroplasty, a study reported an 81% decrease in risk of SSI with the use of antibiotic prophylaxis compared to without.<sup>3</sup> Similarly, in hip fracture surgery, a study reported almost 50% reduction in the rate of SSI with the use of antibiotic prophylaxis compared to without.<sup>2</sup> However, despite best practice guidelines and the known efficacy of antibiotic prophylaxis in reducing the risk of SSI, there is evidence of wide variation in antibiotic prophylaxis practices.<sup>4,5</sup> A study involving 2,965 hospitals, including 34,133 patients, determined that only 56% of patients received antibiotic prophylaxis within 60 minutes of the incision and another 20% of the patients received antibiotics between one and two hours before incision.<sup>4</sup> In addition, almost 10% of the patients received their first dose of antibiotics greater than four 4 hours after the time of incision.<sup>4</sup> The authors also analyzed the time which antibiotics were discontinued and determined that antibiotics were discontinued within 24 hours in only 41% of the patients studied.<sup>4</sup>

Considering the effectiveness of antibiotic prophylaxis for decreasing the risk of SSI but the potential for great variability in its use despite best practice guidelines, we performed a qualitative study to assess the antibiotic prophylaxis perspectives of the orthopaedic surgery and anesthesiology teams at Virginia Commonwealth University Health regarding preoperative antibiotic choice, dosing, and timing and to identify any potential barriers which may contribute to its aberrant use.

## Methods

This study was conducted at an 850-bed tertiary care hospital with institutional pre-operative prophylaxis guidelines in place that prefer cefazolin, with vancomycin as an alternative for penicillin allergy or an addition for MRSA-colonized patients, for antimicrobial prophylaxis. An Institution Review Board (IRB) approved questionnaire (Figure 1) was distributed amongst both orthopaedic surgery (nurse practitioners (NP), resident physicians, and attending physicians) and anesthesia (certified registered nurse anesthetists (CRNAs), resident physicians, and attending physicians) team members involved in preoperative antibiotic decision-making from August 2017 to June 2019. The questionnaire addressed ten key practices related to preoperative antibiotic use, including antibiotic choice for given clinical scenarios, timing and rate of antibiotic infusion, and antibiotic dosing. In addition, we collected opinions regarding barriers to timely antibiotic administration. After completion of the questionnaires by providers, summary statistics were analyzed in a Microsoft Excel worksheet. Provider type and service type responses were compared using Chi-square tests in Statistical Analysis System (SAS) version 9.4 (Cary, NC).

# Results

## *Orthopaedic Surgery Providers (Nurse Practitioners and Residents)*

A total of 2 NP and 25 resident providers were eligible to complete the questionnaire, of which all of the NP and 22 of the residents completed the questionnaire. 13% agreed that vancomycin and cefazolin are equally effective for antibiotic prophylaxis whereas 79% disagreed, and 8% were unsure (Figure 2). As for the antibiotic choice for patients with a penicillin allergy, 71% of providers agreed with vancomycin as the preferred alternative, 8% preferred clindamycin, and the remainder of those surveyed disagreed with both practices. Specific to vancomycin administration, the results indicated barriers to its effectiveness as a suitable method for prophylaxis. 92% of providers agreed that vancomycin infusion at the time of incision does not allow for adequate concentrations for appropriate antibiotic prophylaxis. In addition, 100% of providers recognized that vancomycin cannot be infused rapidly in order to maximize the proportion of dose infused prior to the time of incision. In fact, at our institution, only 54% of providers attested that vancomycin infusions were completed by the time of surgery. Common barriers identified to timely administration of vancomycin prior to incision included issues with the availability of the medication from the pharmacy, the availability of equipment required for infusion, incorrect medication ordering, the lack of intravenous (IV) access for the patient, and other issues with the preoperative nursing staff.

## *Orthopaedic Surgery Providers (Attendings)*

Of the 28 attending orthopaedic surgery providers that were eligible for the study, twenty-three completed the questionnaires. Similar to the NP and resident orthopaedic providers, the attending faculty had varying opinions regarding the appropriate antibiotic use in the preoperative period (Figure 3). 44% of attending orthopaedic surgeons agreed that vancomycin and cefazolin are equally effective for antibiotic prophylaxis (Figure 3). For patients with penicillin allergies, 39% of providers preferred vancomycin, 35% preferred clindamycin, and the remainder of those surveyed disagreed with both practices. The attending orthopaedic surgeon data also indicated barriers to vancomycin's effectiveness as a suitable method for prophylaxis. Although 86% agreed that vancomycin infusion at the time of incision does not allow for adequate concentrations for appropriate antibiotic prophylaxis, only 35% of providers noted that vancomycin infusions were complete at the time of surgery. Similar to the NP and resident data, additional reported barriers to timely administration of vancomycin prior to incision included issues with the preoperative nursing or anesthesia staff which delayed administration.

## *Anesthesia Providers (CRNAs, Residents, Attendings)*

A total of 12 CRNA, 6 resident and 8 attending anesthesia providers completed questionnaires. 35% of attending anesthesiologists agreed that vancomycin and cefazolin are equally effective for antibiotic prophylaxis whereas 62% disagreed (Figure 4). 43% of anesthesia providers preferred vancomycin as the antibiotic choice for patients with a penicillin allergy, 43% also preferred clindamycin, and the remainder of those surveyed disagreed with both practices. These responses were significantly different from the

orthopaedic providers, who generally disagreed with clindamycin as the preferred agent ( $p=0.007$ ). As for the question regarding standard versus weight adjusted dosing, 85% of anesthesia providers agreed that vancomycin should be dose adjusted by weight and similarly 88% agreed that cefazolin should be weight adjusted. Similar to all of the other providers surveyed in this study, the attending anesthesiologist data also indicated barriers to vancomycin's effectiveness as a suitable method for prophylaxis. 74% of providers agreed that vancomycin infusion at the time of incision does not allow for adequate concentrations for appropriate antibiotic prophylaxis. In addition, 92% of providers recognized that vancomycin cannot be infused rapidly in order to maximize the proportion of dose infused prior to the time of incision. Similar to their orthopaedic colleagues, only 30% of providers agreed that vancomycin infusions are completed at time of surgery. Additional reported barriers to timely administration of vancomycin prior to incision included issues with the availability of the vancomycin from the pharmacy, the availability of equipment required for infusion, lack of an appropriate order, lack of patient IV access, and issues with the preoperative nursing staff.

### *Impact of Service and Role on Survey Responses*

For most survey questions, there was no difference in responses between provider type (resident, attending, NP, or CRNA) or service (anesthesia or orthopedics). However, there was significant disagreement regarding preferred agent for penicillin allergies, with residents more frequently indicating agreement with vancomycin (71% agreement) compared to NPs (29%), and attendings (35%) ( $p= 0.014$ ). There were also differences between orthopedic and anesthesia providers regarding knowledge of a patient's preoperative MRSA status. 64% of orthopaedic providers indicated that they knew a patient's MRSA status prior to surgery whereas only 35% of the anesthesia providers were aware. ( $p=0.023$ ). Lastly, anesthesia was more likely to agree that frequent switches from cefazolin to vancomycin occur at the last minute (65% in agreement versus 34% of orthopaedic providers,  $p=0.029$ ).

## **Discussion**

Despite well established guidelines and the known efficacy of antibiotic prophylaxis for reducing the risk of SSI, there continues to be wide variation amongst antibiotic prophylaxis practices. Therefore, we performed this study to assess the perspectives of providers at our institution regarding some of these practices including preoperative antibiotic choice, dosing, and timing. We determined that there is no clear consensus regarding the effectiveness of vancomycin and cefazolin for antibiotic prophylaxis since 30% of providers agreed and 65% disagreed that both antibiotics are equally effective. Similarly, there was also no consensus on the antibiotic choice for patients with a penicillin allergy since 50% of those surveyed agreed with vancomycin, 28% agreed with clindamycin, and the remaining 22% disagreed with both alternatives. In contrast, providers did generally agree with necessity of weight based dosing and timely infusion of vancomycin.

Overall, the results from this study indicate that there is no clear consensus amongst the providers at our institution when it comes to which antibiotic to administer for prophylaxis against SSI despite

institutional guidelines developed by surgical service leadership. Several institutions from all over the world have determined that antibiotic prophylaxis is often inadequately administered. In a study from China that included 53 hospitals and a total of 14,525 procedures, Ou et al. determined that in only 9.4% of the procedures was antibiotic prophylaxis appropriate and correct in all steps, which included antibiotic choice, dose, dosing strategy, time of administration and duration of prophylaxis.<sup>6</sup> Similarly, Hawkins et al. found that although 99% of the patients studied were correctly given or withheld prophylactic antibiotics, complete adherence to antibiotic guidelines was only present in 48% of cases in a study involving 143 pediatric procedures.<sup>7</sup> In fact, weight-based dosing was present in only 77% of cases, the timing of administration as correct in only 73% of cases, and only 7% of cases were appropriately re-dosed.<sup>7</sup> Similarly, in a study from France including 1,312 procedures, Muller et al. determined that non-compliance to the French national recommendations was evident in 44% of cases.<sup>8</sup> Most notably, the appropriate antibiotic for patients with a beta-lactam allergy was incorrect in 45% of cases and the timing of antibiotic prophylaxis relative to incision time was too close in almost 35% of cases.<sup>8</sup> In addition, in a study from Australia involving 1033 lower extremity arthroplasty procedures, Friedman et al. determined that the optimal antibiotic choice, cefazolin alone, was administered in only 75% of patients.<sup>9</sup> Therefore, although well-established antibiotic prophylaxis guidelines exist, great variability and poor compliance are major obstacles to adequate prophylactic antibiotic administration.

The explanations for our results are multifactorial. One reason for the lack of consensus in terms of appropriate antibiotic choice may be due to the fact that best practice guidelines are not widely displayed throughout preoperative and operative areas at our institution. Therefore, lack of awareness could be a potential contributor to our results. Another potential explanation is that since there is no formal education or training for both orthopaedic surgery and anesthesia team members regarding the topic of antibiotic prophylaxis, providers at our institution may not possess the most up-to-date knowledge in regards to this topic. Furthermore, as antibiotic resistance and drug allergies continue to increase in our communities, there is a need to continually educate health care providers on the most current literature available. Thus, an educational gap could be another contributing factor to our results. Lastly, there is also no antibiotic prophylaxis checklist at our institution to help standardize prophylaxis practices.

In contrast to antibiotic choice, there was agreement at our institution that cefazolin and vancomycin dose should be weight adjusted. This consensus is most likely explained by the fact that the electronic medical record (EMR) at our institution prompts physicians to use weight-based dosing when ordering prophylactic antibiotics. We also determined that providers agreed that vancomycin infusion at the time of incision at our institution is often not adequate for antibiotic prophylaxis. This has severe implications because it is well documented that patients with inadequate vancomycin infusion have a significantly higher risk of SSI compared to patients where infusion is complete prior to incision. In a study by Cotogni et al. involving 741 cardiac surgery patients, patients where vancomycin infusion was violated (i.e surgical skin incision was performed before the end of vancomycin infusion) had greater than five times increased odds of SSI compared to patients where vancomycin infusion was completed prior to incision.<sup>10</sup> Through our survey, we learned that this finding was most likely due to many factors such as

problems with antibiotic availability from the pharmacy, missing infusion equipment in the preoperative areas, problems with the preoperative nursing staff, no EMR order, or a lack of patient IV access which delayed the start of antibiotic infusion.

Based on the results from this study, we have determined that there may be many potential areas for improvement at our institution when it comes to antibiotic prophylaxis. However, results of quality improvement programs to improve antibiotic prophylaxis have been mixed. In a study from the University of Texas at Houston, Putnam et al. implemented three cycles of interventions from 2011 to 2014 to improve antibiotic prophylaxis.<sup>11</sup> A few of their interventions included modifying their pre-incision checklist to include all four elements of antibiotic administration (i.e. type, dose, timing, redosing), assigning the anesthesia team the role of antibiotic administration, and distributing and displaying prophylaxis guidelines.<sup>11</sup> After the interventions, the researchers found that although redosing compliance significantly improved, overall adherence and adherence to the correct dose and timing was unchanged. Furthermore, antibiotic type errors significantly increased after the interventions.<sup>11</sup> Similarly, in a study from Australia, Knox and Edye compared preintervention antibiotic prophylaxis practices to compliance after implementation of an interventional program that included displaying prophylaxis guidelines in surgical areas and advertising appropriate prophylaxis practices throughout their institution.<sup>12</sup> After the intervention, the researchers determined that overall adherence was unchanged with adherence at 18% preintervention and 15% postintervention.<sup>12</sup> In a study from Canada by So et al., the researchers also compared preintervention antibiotic prophylaxis compliance to postintervention compliance.<sup>13</sup> Their interventions included posting antibiotic protocols in the operating room (OR), having only recommended antibiotics readily available in the OR, educating resident physicians during orientation, including prophylactic antibiotics at time out, and both computerized alerts and emails to physicians when protocols were not followed.<sup>13</sup> In contrast to the studies mentioned above, the researchers found that within the field of orthopaedics, complete compliance to established guidelines drastically increased from 4.5% preintervention to 54% postintervention.<sup>13</sup> Furthermore, the greatest improvement was in regards to the duration of antibiotics, where compliance improved from 9.5% preintervention to 75% postintervention.<sup>13</sup> Similarly, in a study from Egypt, Saied et al. developed and taught a two-day curriculum designed to educate anesthesiologists and surgeons at five institutions about proper antibiotic prophylaxis practices, specifically focusing on the time and duration of antibiotic administration.<sup>14</sup> The researchers determined that compared to preintervention antibiotic prophylaxis practices, the optimal timing of the first dose significantly improved in three of the five institutions and the optimal duration of prophylaxis improved by 25% in all five institutions, postintervention.<sup>14</sup> Therefore, based on the studies mentioned above, implementation of a multifactorial quality improvement strategy that includes an educational component may be beneficial to improve antibiotic prophylaxis adherence.

Our study has several important limitations. First, the study is purely qualitative since we gathered provider data with the use of a questionnaire. Second, the purpose of this study was to only assess the antibiotic prophylaxis perspectives at our institution; we did not perform a retrospective analysis to determine the actual adherence to antibiotic prophylaxis guidelines at our institution. Therefore, although

we found no clear consensus amongst our providers when it comes to which antibiotic to administer for prophylaxis against SSI, we cannot determine if this finding directly translates to poor adherence to antibiotic guidelines at our institution. Third, our study is subject to selection bias since our sample size of 73 providers is small and we only surveyed providers involved with the care of orthopedic patients. Lastly, it is important to mention that these results are based on responses from providers only at one institution.

## Conclusions

The rates of SSI can be reduced by standardizing antimicrobial prophylaxis practices. Our questionnaire indicated that there is no clear consensus amongst providers when it comes to which antibiotic to administer for prophylaxis against SSI despite existing internally developed and surgery-type specific guidelines. There is also great discrepancy between orthopaedic and anesthesia providers in terms of which antibiotic to administer in patients with penicillin allergies. Therefore, based on our results, institutions should evaluate the antibiotic prophylaxis perspectives amongst their perioperative staff in order to identify any inconsistencies that could result in inappropriate antibiotic prophylaxis for patients. A multifactorial quality improvement strategy that includes development of a protocol to standardize prophylaxis practices, displaying prophylaxis guidelines in perioperative areas, further educational training, a preoperative checklist, and embedding preferred choices into the EMR along with computerized alerts should also be implemented to standardize prophylaxis practices. Lastly, it is integral to involve both the orthopaedic surgery and the anesthesia staff in the quality improvement process otherwise discrepancies may continue to persist.

## List Of Abbreviations

Surgical site infections (SSI); Methicillin-sensitive Staphylococcus aureus (MSSA); Methicillin-resistant Staphylococcus aureus (MRSA); Coagulase-negative Staphylococci (CoNS); Institution Review Board (IRB); Nurse practitioners (NP); Certified registered nurse anesthetists (CRNAs); Intravenous (IV); Electronic medical record (EMR); Operating room (OR)

## Declarations

*Ethics approval and consent to participate*

The present research was submitted to the Institutional Review Board (IRB) at Virginia Commonwealth University prior to performing the study and was determined to be exempt.

*Consent for publication*

Not applicable.

*Availability of data and materials*

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

### *Competing interests*

The authors declare that they have no competing interests in relation to this work.

### *Funding*

There were no sources of funding for this research study.

### *Authors' contributions*

GJG conceived of the presented research idea. EZ created the questionnaire used in the study and also performed both the data collection and analysis. NA, EZ, MD, and GMB prepared the manuscript draft with important intellectual input from SLK and GJG. All authors participated in critical revision of the manuscript draft. All authors have approved of the final manuscript to be published and the entirety of the submission.

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Not applicable.

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## Figures

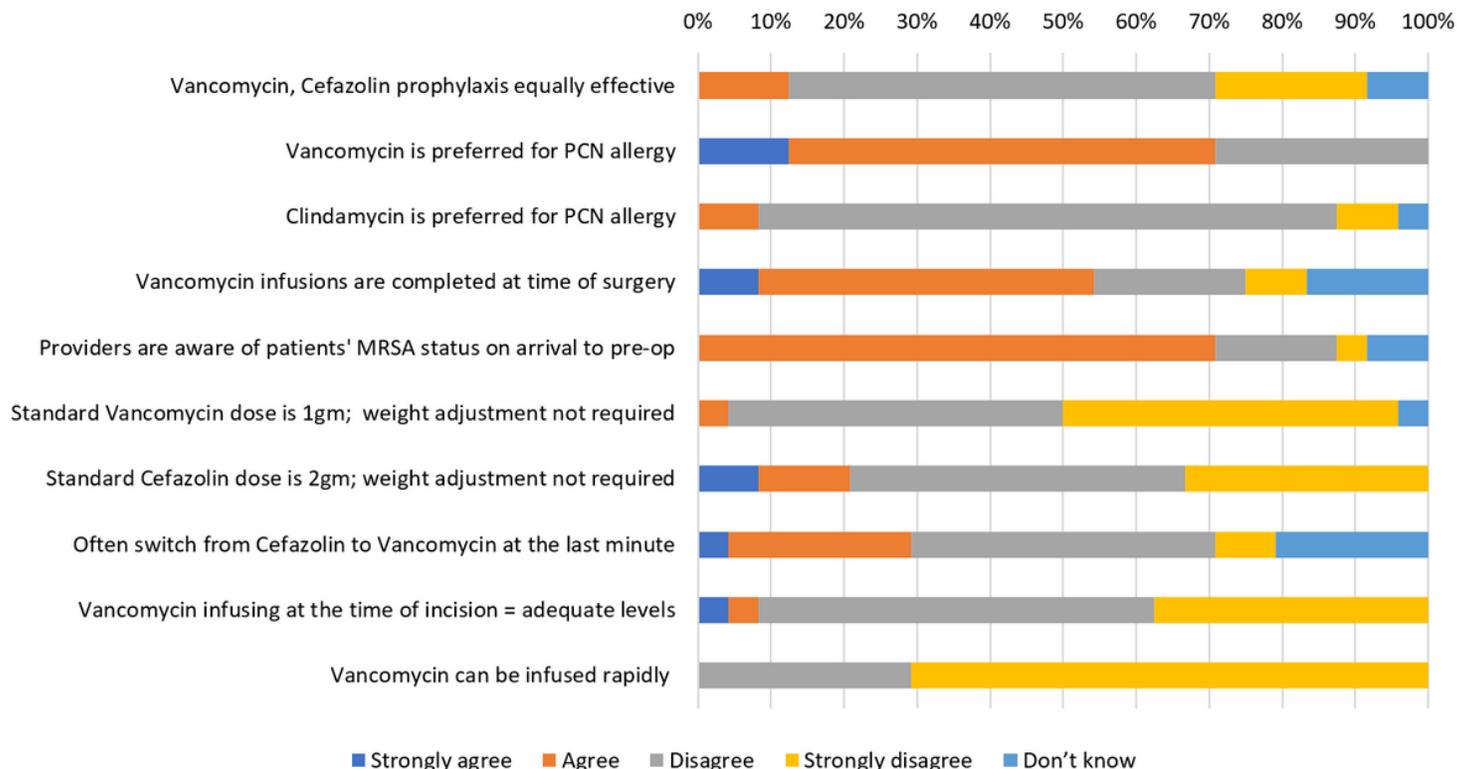
**Provider Questionnaire : Pre-operative Antibiotic Prophylaxis**

For each statement or question, choose the ONE response that most closely fits you/your opinion.

1. Please identify your role:
  - a. Surgeon – attending
  - b. Surgeon –intern/resident/fellow
  - c. Surgical NP/PA
  - d. Anesthesia – attending
  - e. Anesthesia – intern/resident/fellow
  - f. Anesthesia NP
  - g. RN in OR
  - h. RN in PSU
  - i. Other \_\_\_\_\_
2. Vancomycin prophylaxis is as effective as Cefazolin prophylaxis in preventing surgical site infections.  
Strongly Agree    Agree    Disagree    Strongly disagree    Don't know
3. When a patient has a penicillin allergy, Vancomycin is preferred for prophylaxis  
Strongly Agree    Agree    Disagree    Strongly disagree    Don't know
4. When a patient has a penicillin allergy, Clindamycin is preferred for prophylaxis  
Strongly Agree    Agree    Disagree    Strongly disagree    Don't know
5. When Vancomycin is used for prophylaxis, the infusion is usually completed by time of incision.  
Strongly Agree    Agree    Disagree    Strongly disagree    Don't know
6. Providers are usually aware of a patient's MRSA status when the patient arrives to the pre-op area.  
Strongly Agree    Agree    Disagree    Strongly disagree    Don't know
7. The standard dose of Vancomycin is 1000mg, and adjustments for weight are generally not required.  
Strongly Agree    Agree    Disagree    Strongly disagree    Don't know
8. The standard dose of Cefazolin is 2gm, and adjustments for weight are generally not required.  
Strongly Agree    Agree    Disagree    Strongly disagree    Don't know
9. We often discover a need to switch from Cefazolin to Vancomycin prophylaxis at the last minute.  
Strongly Agree    Agree    Disagree    Strongly disagree    Don't know
10. Vancomycin infusing at the time of incision produces adequate levels for optimal SSI prevention.  
Strongly Agree    Agree    Disagree    Strongly disagree    Don't know
11. Vancomycin can be infused rapidly in order to maximize the proportion of dose infused prior to the incision.  
Strongly Agree    Agree    Disagree    Strongly disagree    Don't know
12. What are the current barriers to administering Vancomycin infusions at least 60 minutes prior to incision?  
(Please mark all that apply):
  - Availability of supplies/equipment for infusion
  - Lack of an appropriate order
  - Lack of IV access
  - Don't feel it is beneficial/necessary to give prior to entry to OR
  - Availability of the medication from pharmacy
  - Other \_\_\_\_\_
13. Comments:  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

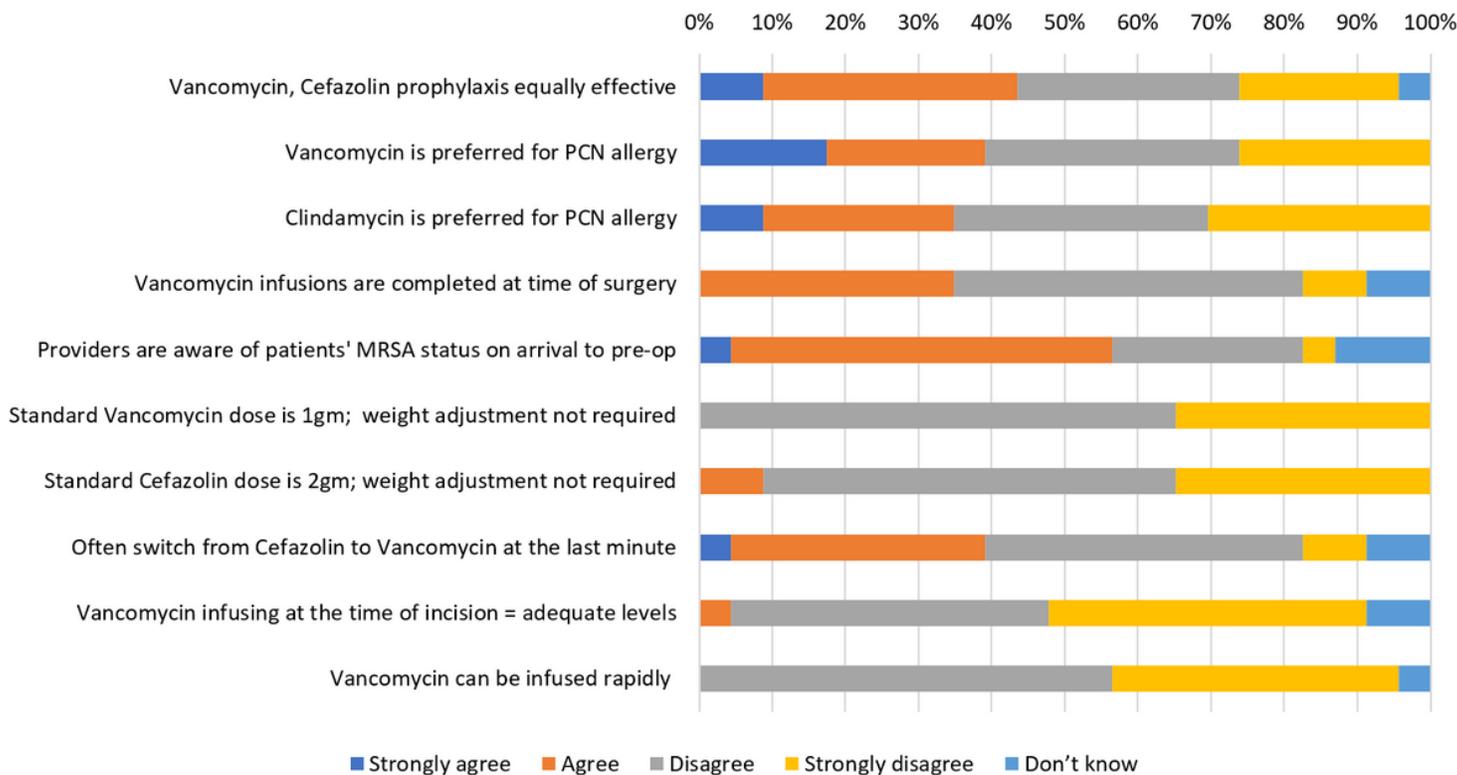
**Figure 1**

Provider Questionnaire Regarding Preoperative Antibiotic Prophylaxis



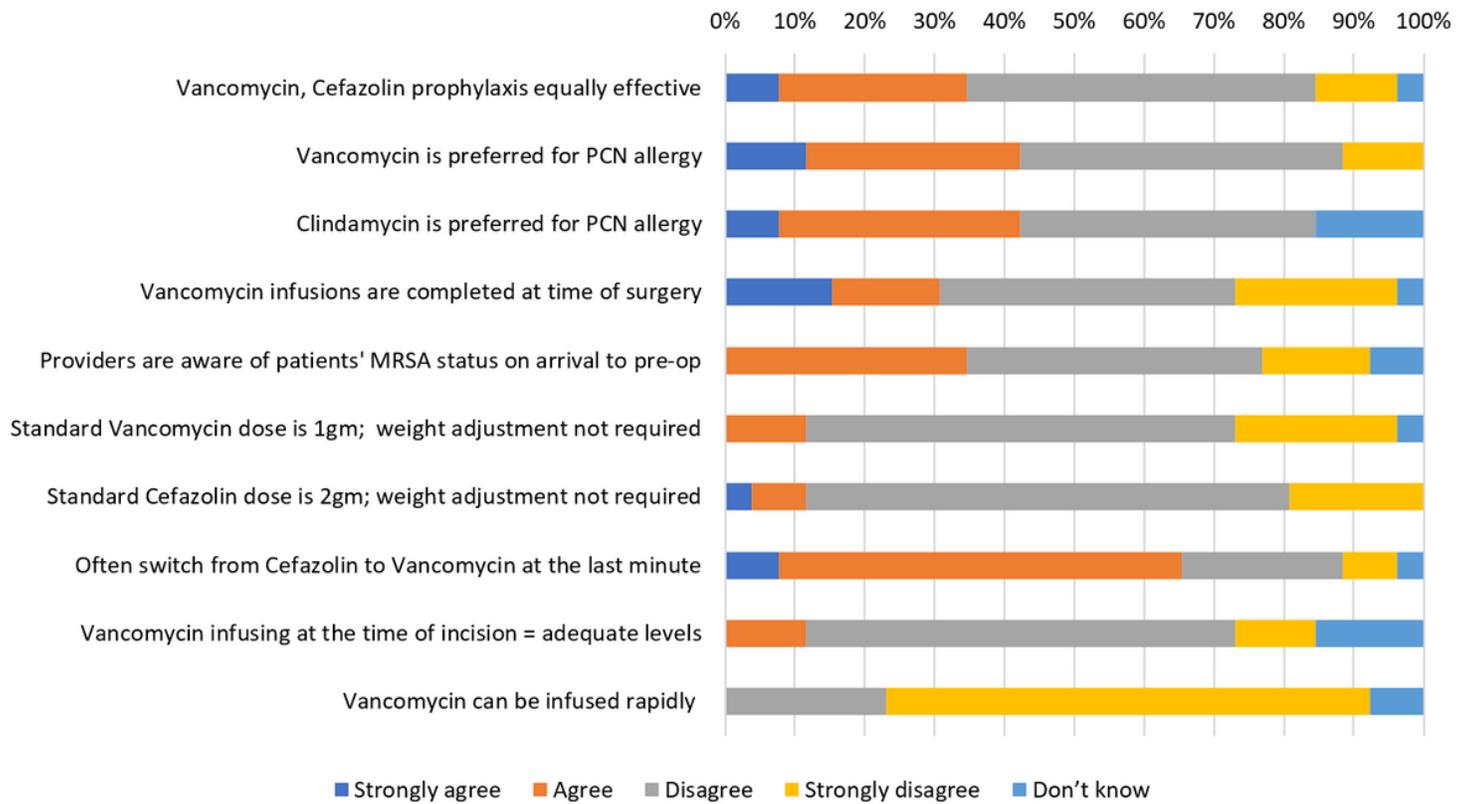
**Figure 2**

Nurse Practitioner and Resident Orthopaedic Surgery Provider Responses Regarding Surgical Antibiotic Prophylaxis



**Figure 3**

## Attending Orthopaedic Surgery Provider Responses Regarding Surgical Antibiotic Prophylaxis



**Figure 4**

## Anesthesia Provider Responses Regarding Surgical Antibiotic Prophylaxis