Variation in practice for preoperative antibiotic prophylaxis: a survey from an academic tertiary referral center in the United States

Nikhil Ailaney1*, Elizabeth Zielinski2, Michelle Doll3, Gonzalo M. Bearman3, Stephen L. Kates2 and Gregory J. Golladay2

Abstract

Background: Antibiotic surgical prophylaxis is a core strategy for 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. This study was designed to determine the individual perspectives of perioperative providers at an academic tertiary referral center regarding their knowledge of preoperative antibiotic choice, dosing, and timing.

Methods: A prospective survey was conducted amongst surgical and anesthesia team members involved in preoperative antibiotic decision making. The survey addressed ten key principles relating to preoperative antibiotic use, including antibiotic choice, timing and rate of infusion, and dosing. The survey was distributed among orthopaedic surgeons, residents, and anesthesia providers at their respective monthly service line meetings between August 2017 to June 2019. The data was stored and analyzed in a Microsoft Excel worksheet.

Results: A total of 73 providers completed the survey. Twenty-two (30%) of the providers agreed and 47 (64%) disagreed that both vancomycin and cefazolin are equally effective for antibiotic prophylaxis. As for antibiotic choice in patients with penicillin allergies, 37 (51%) agreed with vancomycin, 21 (29%) agreed with clindamycin, and 15 (21%) disagreed with both alternatives. When providers were surveyed regarding the appropriateness of standard versus weight adjusted dosing, 67 (92%) agreed that vancomycin should be weight adjusted and 63 (86%) agreed that cefazolin should be weight adjusted.

Conclusions: There is no clear consensus amongst providers for which antibiotic to administer for antibiotic prophylaxis despite existing guidelines. Discrepancy also exists between orthopaedic surgery and anesthesia providers in regards to appropriate antibiotic choice for patients with reported penicillin allergies. Institutions should implement evidence-based protocols for preoperative antibiotic prophylaxis and continue to prospectively monitor compliance in order to identify any inconsistencies that could result in inappropriate antibiotic prophylaxis for patients.

Keywords: Antibiotic prophylaxis, Surgical site infection, Orthopaedic surgery, Quality improvement

Background

Surgical site infections (SSI) continue to be one of the most common complications after orthopaedic surgery [1, 2]. 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 [3, 4]. 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 [5]. 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 [6]. 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 [2]. 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 [7-9]. A study involving 2,965 hospitals, including 34,133 patients, determined that only 56% of patients received antibiotic prophylaxis within 60 min of the incision and another 20% of the patients received antibiotics between one and two hours before incision [7]. In addition, almost 10% of the patients received their first dose of antibiotics greater than four hours after the time of incision [7]. The authors also analyzed the time which antibiotics were discontinued and determined that antibiotics were discontinued within 24 h in only 41% of the patients studied [7].

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 (VCU) Health regarding preoperative antibiotic choice, dosing, and timing.

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. An Institution Review Board (IRB) approved survey (Fig. 1) was distributed amongst both orthopaedic surgery (nurse practitioners (NP’s), resident physicians, and attending physicians) and anesthesia (certified registered nurse anesthetists (CRNA’s), resident physicians, and attending physicians) team members involved in preoperative antibiotic decision making from August 2017 to June 2019. The survey was distributed to all providers that met inclusion criteria during one monthly mandatory department meeting and anonymously collected at the end of the meeting. To meet inclusion criteria, providers that completed surveys had to be practicing resident physicians, advanced practice providers (NP’s/CRNA’s), or attending physicians within the orthopaedic surgery or anesthesiology departments at VCU Health. Medical students and ancillary surgical staff (surgical technicians, circulating nurses, and general perioperative nursing staff) were excluded from the study. Orthopaedic surgery residents and NP’s were surveyed in August 2017, attending orthopaedic surgeons in October 2018, and anesthesia providers in June 2019. The survey addressed ten key practices relating 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 surveys by providers, the data was stored and analyzed in a Microsoft Excel worksheet.

Results
Nurse practitioner and resident orthopaedic surgery providers
A total of 2 orthopaedic NP’s and 25 orthopaedic surgery residents were approached to complete the survey. Both NP’s (100%) and 22 (88%) residents completed the survey. A total of 3 providers (13%) agreed that vancomycin and cefazolin are equally effective for antibiotic prophylaxis whereas 19 (79%) disagreed, and 2 (8%) were unsure (Fig. 2). As for the antibiotic choice for patients with a penicillin allergy, 17 providers (71%) agreed with vancomycin as the preferred alternative, 2 (8%) preferred clindamycin, and 5 (21%) disagreed with both practices. When providers were surveyed regarding the appropriateness of standard versus weight adjusted dosing, 22 (92%) agreed that vancomycin should be dose adjusted by weight and 19 (79%) agreed that cefazolin should be weight adjusted. Specific to vancomycin administration, the results indicated barriers to its effectiveness as a suitable method for prophylaxis. 22 providers (92%) agreed that vancomycin infusion at the time of incision does not allow for adequate concentrations for appropriate antibiotic prophylaxis. In addition, 24 providers (100%) recognized that vancomycin cannot be infused rapidly in order to maximize the proportion of dose infused prior to the time of incision. Furthermore, only 13 providers (54%)
agreed that vancomycin infusions are completed at the time of surgery. Common barriers 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.

**Attending orthopaedic surgery providers**

A total of 28 attending orthopaedic surgeons were approached to complete the survey. Twenty-three (82%) attending orthopaedic surgeons completed the survey. Ten (44%) attending orthopaedic surgeons agreed that vancomycin and cefazolin are equally effective for antibiotic prophylaxis whereas 12 (52%) disagreed, and 1 (4%) was unsure (Fig. 3). Nine providers (39%) preferred vancomycin as the antibiotic choice for patients with a penicillin allergy, 8 (35%) preferred clindamycin, and 6 (26%) disagreed with both practices. All 23 (100%) of the attending orthopaedic surgeons surveyed agreed that vancomycin should be dose adjusted by weight and 21 (91%) agreed that cefazolin should be weight adjusted. The attending orthopaedic surgeon data also indicated

---

**Table: Provider Questionnaire**

| 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: |
|----------------|
barriers to vancomycin’s effectiveness as a suitable method for prophylaxis. Twenty-two (87%) agreed that vancomycin infusion at the time of incision does not allow for adequate concentrations for appropriate antibiotic prophylaxis. In addition, 22 providers (96%) recognized that vancomycin cannot be infused rapidly in order
to maximize the proportion of dose infused prior to the time of incision. Furthermore, only 8 providers (35%) agreed that vancomycin infusions are completed at 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 (CRNA's, Residents, Attendings)**

Twelve CRNA’s, 6 anesthesia residents, and 8 attending anesthesiologists completed the survey. Nine (35%) anesthesia providers agreed that vancomycin and cefazolin are equally effective for antibiotic prophylaxis whereas 16 (62%) disagreed, and 1 (4%) was unsure (Fig. 4). Eleven (42%) anesthesia providers preferred vancomycin as the antibiotic choice for patients with a penicillin allergy, 11 (42%) preferred clindamycin, and 4 (15%) disagreed with both practices. As for the question regarding standard versus weight adjusted dosing, 22 (85%) anesthesia providers agreed that vancomycin should be dose adjusted by weight and similarly 23 (88%) agreed that cefazolin should be weight adjusted. Similar to all of the other providers surveyed in this study, the anesthesia provider data also indicated barriers to vancomycin’s effectiveness as a suitable method for prophylaxis. Nineteen (73%) providers agreed that vancomycin infusion at the time of incision does not allow for adequate concentrations for appropriate antibiotic prophylaxis. In addition, 24 (92%) providers recognized that vancomycin cannot be infused rapidly in order to maximize the proportion of dose infused prior to the time of incision. Furthermore, only 8 (31%) 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 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, a large difference in responses between provider type (residents, attendings, NP’s, or CRNA’s) or service (anesthesia or orthopaedics) was not observed. However, there was significant disagreement regarding preferred agent for penicillin allergies, with residents more frequently indicating agreement with vancomycin (20 out of 28, 71% agreement) compared to CRNA’s/NP’s (4 out of 14, 29% agreement), and attendings (13 out of 31, 42% agreement). There were also differences between anesthesia and orthopaedics regarding awareness of patients’ MRSA status with 30 (64%) orthopaedic providers in agreement that MRSA status is known and only 9 (35%) anesthesia providers in agreement. Lastly, anesthesia was more likely to agree that frequent switches from cefazolin to vancomycin occur at
the last minute (17 out of 26 (65%) in agreement versus 16 out of 47 (34%) amongst orthopaedic providers).

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 64% disagreed that both antibiotics are equally effective. Similarly, there was also no consensus on the antibiotic choice for patients with a penicillin allergy since 51% of those surveyed agreed with vancomycin, 29% agreed with clindamycin, and the remaining 21% 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 [10]. Similarly, Hawkins et al. performed a study involving 143 pediatric procedures and found that although 99% of the patients were correctly given or withheld prophylactic antibiotics, complete adherence to antibiotic guidelines was only present in 48% of cases [11]. In fact, weight-based dosing was present in only 77% of cases, timing of administration was correct in only 73% of cases, and only 7% of cases were appropriately re-dosed [11]. 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 they studied [12]. In addition, specific to patients with beta-lactam allergies, Nguyen et al. demonstrated that among the cohort of patients they studied, only 37% of patients with labeled beta-lactam allergies received appropriate preoperative antibiotic prophylaxis compared to 76% appropriateness in patients without labeled allergies [13]. 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, which is often a key component of successful quality improvement initiatives [14].

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 [15]. 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 [16]. 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 including prophylactic antibiotics at time out, and both OR, educating resident physicians during orientation, only recommended antibiotics readily available in the OR, and advertising appropriate prophylaxis practices throughout their institution [17]. After the intervention, the researchers determined that overall adherence was unchanged with adherence at 18% pre-intervention and 15% post-intervention [17]. In a study from Canada by So et al., the researchers also compared pre-intervention antibiotic prophylaxis practices to compliance after implementation of an intervention program that included displaying prophylaxis guidelines in surgical areas and advertising appropriate prophylaxis practices amongst providers for which antibiotic to administer antibiotic prophylaxis and continue to prospectively implement evidence-based protocols for preoperative prophylaxis for patients with reported penicillin allergies. Therefore, based on our results, institutions should approach all anesthesia team members at VCU Health to complete surveys. Lastly, it is important to mention that these results are based on responses from providers only at one institution.

Conclusions
Our survey indicated that there is no clear consensus amongst providers for which antibiotic to administer for prophylaxis against SSI despite existing internally developed and surgery-type specific guidelines. There is also great discrepancy between orthopaedic surgery and anesthesia providers in regards to appropriate antibiotic choice for patients with reported penicillin allergies. Therefore, based on our results, institutions should implement evidence-based protocols for preoperative antibiotic prophylaxis and continue to prospectively monitor compliance in order to identify any inconsistencies that could result in inappropriate antibiotic prophylaxis for patients.

Abbreviations
SSI: Surgical site infections; MSSA: Methicillin-sensitive Staphylococcus aureus; MRSA: Methicillin-resistant Staphylococcus aureus; CoNS: Coagulase-negative Staphylococci; VCU: Virginia Commonwealth University; IRB: Institution Review Board; NP’s: Nurse practitioners; CRNA’s: Certified registered nurse anesthetists; IV: Intravenous; EMR: Electronic medical record; OR: Operating room.

Acknowledgements
Not applicable.

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.

Funding
There were no sources of funding for this research study.

Availability of data and materials
The data sets used and analyzed during the current study are available from the corresponding author on reasonable request.

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.

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

Author details
1 Department of Orthopaedic Surgery, Virginia Commonwealth University School of Medicine, 1200 Broad Street, 9th Floor, VA 23298 Richmond, USA.
2 Department of Orthopaedic Surgery, Virginia Commonwealth University Health, VA 23298 Richmond, USA.
3 Department of Infectious Disease, Virginia Commonwealth University Health, VA 23298 Richmond, USA.

Received: 29 April 2021 Accepted: 21 September 2021
Published online: 27 October 2021

References
1. Edwards JR, Peterson KD, Mu Y, Banerjee S, Allen-Briddon K, Morrell G, Dudek MA, Pollock DA, Horan TC. National Healthcare Safety Network (NHSN) report: data summary for 2006 through 2006, issued December 2009. Am J Infect Control. 2009;37(10):783–805. https://doi.org/10.1016/j.ajic.2009.10.001. PMID: 20004811.
2. Southwell-Keely JP, Russo RR, March L, Cumming R, Cameron I, Brnabic AJ. Antibiotic prophylaxis in hip fracture surgery: a metaanalysis. Clin Orthop Relat Res. 2004;419:179–84. https://doi.org/10.1097/00003086-200402000-00029.
3. Ban KA, Minei JP, Laronga C, Harbrecht BG, Jensen EH, Fry DE, Itani KM, Dellinger EP, Ko CY, Duane TM. American College of Surgeons and Surgical Infection Society: Surgical Site Infection Guidelines, 2016 update. J Am Coll Surg. 2017;224(1):59–74. https://doi.org/10.1016/j.jamcollsurg.2016.10.029. Epub 2016 Nov 30. PMID: 27915053.
4. Badia JM, Casey AL, Petrosillo N, Hudson PM, Mitchell SA, Crosby C. Impact of surgical site infection on healthcare costs and patient outcomes: a systematic review in six European countries. J Hosp Infect. 2017;96(1):1–15. https://doi.org/10.1016/j.jhin.2017.03.004. Epub 2017 Mar 8. PMID: 28410710.
5. Copanitsanou P. Recognising and preventing surgical site infection after orthopaedic surgery. Int J Orthop Trauma Nurs. 2020;37:100751. https://doi.org/10.1016/j.ijotn.2019.100751. Epub 2019 Dec 18. PMID: 31954634.
6. AlBuhrain B, Hind D, Hutchinson A. Antibiotic prophylaxis for wound infections in total joint arthroplasty: a systematic review. J Bone Joint Surg Br. 2008;90(7):915–9. https://doi.org/10.1302/0301-620X.90B7.20498.
7. Bratzler DW, Houck PM, Richards C, Steele L, Dellinger EP, Fry DE, Wright C, Ma A, Carr K, Red L. Use of antimicrobial prophylaxis for major surgery: baseline results from the National Surgical Infection Prevention Project. Arch Surg. 2005;140(2):174–82. https://doi.org/10.1001/archsurg.140.2.174. PMID: 15724000.
8. Braitzer DW, Dellinger EP, Olsen KM, Perl TM, Wuaweaer PG, Bolon MK, Fish DN, Napoliolano LM, Sawyer RG, Slain D, Steinberg JP, Weinstein RA. American Society of Health-System Pharmacists; Infectious Disease Society of America; Surgical Infection Society; Society for Healthcare Epidemiology of America. Clinical practice guidelines for antimicrobial prophylaxis in surgery. Am J Health Syst Pharm. 2013;70(5):195–283. https://doi.org/10.2146/ahj120568. PMID: 23327981.
9. Mankowski P, Cherukupalli A, Slater K, Carr N. Antibiotic prophylaxis in plastic surgery correlation between practice and evidence. Plast Surg. 2021;29(2):132–8. https://doi.org/10.1177/229550321997007. Epub 2021 Mar 2. PMID: 34026678; PMCID: PMC8120557.
10. Ou Y, Jing BQ, Guo FF, Zhao L, Xie Q, Fang YL, Cui J, Xiao W, Wu DW, Zhou W. Audits of the quality of perioperative antibiotic prophylaxis in Shang-dong Province, China, 2006 to 2011. Am J Infect Control. 2014;42(5):S16–20. https://doi.org/10.1016/j.ajic.2014.01.001. Epub 2014 Mar 20. PMID: 24657875.
11. Hawkins RB, Levy SM, Senter CE, Zhao JY, Doody K, Kao LS, Lally KP, Tsao K. Beyond surgical care improvement program compliance: antibiotic prophylaxis implementation gaps. Am J Surg. 2013;206(4):451–6. https://doi.org/10.1016/j.amjsurg.2013.02.009. Epub 2013 Jun 27. PMID: 23809676.
12. Muller A, Leroy J, Hénon T, Patry J, Samain E, Chriouze C, Bertrand X. Surgical antibiotic prophylaxis compliance in a university hospital. Anaesth Crit Care Pain Med. 2015;34:289–94. https://doi.org/10.1016/j.accpain.2015.04.004.
13. Nguyen CT, Petrucci K, Daily E, Brown AM, Pettit NN, Pisano J. Investigating the impact of a β-lactam allergy label on preoperative antibiotic prophylaxis administration. Infect Control Hosp Epidemiol. 2021;42(6):710–4. https://doi.org/10.1017/ic.2020.1271. Epub 2020 Nov 17. PMID: 33198838.
14. Guerrero MA, Anderson B, Carr G, Snyder KL, Boyle P, Ugwu SA, Davis M, Bohnenkamp SK, Nifonsam V, Riall TS. Adherence to a standardized infection reduction bundle decreases surgical site infections after colon surgery: a retrospective cohort study on 526 patients. Patient Saf Surg. 2021;15(1):15. https://doi.org/10.1186/s13037-021-00285-7. PMID: 34690093.
15. Cotogni P, Barbero C, Passera R, Fossati L, Olivero G, Rinaldi M. Violation of prophylactic vancomycin administration timing is a potential risk factor for rate of surgical site infections in cardiac surgery patients: a prospective cohort study. BMC Cardiovasc Disord. 2017;17(1):73.
16. Putnam LR, Chang CM, Rogers NB, Podolnick JM, Sakhuja M, Matusczak M, Austin MT, Kao LS, Lally KP, Tsao K. Adherence to surgical antibiotic prophylaxis remains a challenge despite multifaceted interventions. Surgery. 2015;158(2):413–9. https://doi.org/10.1016/j.surg.2015.04.013. Epub 2015 Jun 6. PMID: 26054317.
17. Knox MC, Edye M. Educational antimicrobial stewardship intervention ineffective in changing surgical prophylactic antibiotic prescribing. Surg Infect. 2016;17(2):224–8. https://doi.org/10.1089/sur.2015.194.
18. So JP, Alemem IS, Tsang DS, Matlow AG, Wright JG. Sickkids Surgical Site Infection Task Force. Increasing compliance with an antibiotic prophylaxis guideline to prevent pediatric surgical site infection: before and after Study. Ann Surg. 2015;262(2):403–8. https://doi.org/10.1097/SLA.0000000000000954.
19. Saied T, Hafez SF, Kandeel A, El-kholy A, Ismail G, Aboushady M, Attia E, Hassan A, Abdel-Atty O, Elfekky E, Girgis SA, Ismail A, Abdou E, Okasha O, Talaat M. Antimicrobial stewardship to optimize the use of antimicrobials for surgical prophylaxis in Egypt: a multicenter pilot intervention study. Am J Infect Control. 2015;43(11):e67-e71. https://doi.org/10.1016/j.ajic.2015.07.004. Epub 2015 Aug 25. PMID: 26315059.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.