

Orthopaedic surgical antibiotic prophylaxis administration compliance with prescribing guidelines in a private hospital in North West province, South Africa

Miché Jordaan,¹ Jesslee du Plessis,^{1*} Dorcas Rakumakoe, Liané Mostert

Medicine Usage in South Africa, Faculty of Health Sciences, North-West University, Potchefstroom Campus, South Africa

*Corresponding author: jesslee.duplessis@nwu.ac.za

Abstract

Background

The correct use of surgical antibiotic prophylaxis (SAP), as stipulated in evidence-based guidelines, is essential to prevent surgical site infections (SSIs) following orthopaedic procedures and consequently the impact thereof on the patient and healthcare system. Orthopaedic SSIs are associated with devastating complications with a great burden of disease on patients.

Methods

A cross-sectional study was performed in a 186-bed private hospital, located in North West province, South Africa. Retrospective data of adult patients who underwent orthopaedic surgery from 1 January 2020 to 31 December 2020 were included. Data were obtained from the study hospital's theatre registers, anaesthetic notes, patient medical records and patient antimicrobial prescription charts. Descriptive statistical analysis was used to determine the compliance (indication, choice, route of administration, dose, administration time, re-dosing and duration) of orthopaedic SAP administration with prescribing guidelines.

Results

Of the 942 orthopaedic procedures, SAP was correctly administered or omitted in 742 cases (78.8%). The total choice of SAP was correct in 738 cases (78.3%). SAP was administered intravenously 100% of the time and was prescribed at the correct dose in 632 cases (77.5%). However, SAP re-dosing occurred only in one of the three prolonged procedures, and the preoperative SAP administration time was only indicated in 34.4% of the cases. The correct duration of SAP was 75.9%. The overall compliance rate to SAP guidelines regarding indication, choice, dose and duration was 57.5%. SSIs developed in 0.9% of the patients, resulting in the death of one.

Conclusion

Orthopaedic SAP practices moderately deviated from current SAP guidelines. Apparent overuse, incorrect dosing and prolonged duration were identified as burdens to overcome. Special attention should be paid to dosing adjustments for patients weighing more than 120 kg. However, certain components such as route of administration, administration time, SAP indication and SAP correct choice showed greater compliance percentages. The low prevalence of SSIs supports a positive reporting of the findings.

Level of evidence: Level 4

Keywords: orthopaedic, guidelines, adherence, surgical site infection, South Africa

Citation: Jordaan M, Du Plessis J, Rakumakoe D, Mostert L. Orthopaedic surgical antibiotic prophylaxis administration compliance with prescribing guidelines in a private hospital in North West province, South Africa. *SA Orthop J.* 2023;22(2):86-90. <http://dx.doi.org/10.17159/2309-8309/2023/v22n2a4>

Editor: Dr Luan Nieuwoudt, University of KwaZulu-Natal, Pietermaritzburg, South Africa

Received: November 2022

Accepted: January 2023

Published: May 2023

Copyright: © 2023 Jordaan M. This is an open-access article distributed under the terms of the Creative Commons Attribution Licence, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Funding: No funding was received for this study.

Conflict of interest: The authors declare they have no conflicts of interest that are directly or indirectly related to the research.

Introduction

Surgical antibiotic prophylaxis (SAP) entails the prevention of surgical site infections (SSIs) through the administration of effective antibiotics prior to possible contaminant exposure during surgery.¹ The primary purpose and benefit of SAP is to prevent SSIs and, subsequently, the impact thereof on the patient and healthcare system.² SSIs are surgical site microbial infections that can develop within 30 days of an operation or within one year following an orthopaedic procedure with the insertion of an implant.³ An estimated 60% of SSIs are preventable with the correct use of SAP, consequently decreasing the patient's length of stay (LOS)

in hospital.^{2,4} The appropriate use of SAP is founded on evidence-based research describing the correct SAP indication, antibiotic choice, route of administration, antibiotic dosing and re-dosing, administration time and duration.⁵⁻⁷

The efficacy of SAP is based on the ability of the antibiotic to inhibit bacterial growth at the surgical site, enabling the host's immune mechanism to prevent infections.⁵ SAP in orthopaedic procedures is indicated for clean-contaminated, contaminated and dirty surgical wounds as they have an increased risk of SSIs.⁵ Clean-contaminated surgical wounds involve surgical wounds affecting the respiratory, alimentary, genital or urinary tracts

under controlled conditions.⁸ Contaminated surgical wounds are open, fresh, accidental wounds with inflammation.⁸ Dirty surgical wounds are old traumatic wounds with necrotic tissue suggesting a preoperative infection present at the surgical site.⁸ SAP is recommended in clean procedures involving orthopaedic implant devices, as these devices may introduce microorganisms during surgery, increasing the risk of SSIs.⁵

SAP choice entails the use of a safe, inexpensive narrow-spectrum antibiotic, while ensuring activity against the most likely infectious organisms at the surgical site.⁶ Intravenous (IV) administration of SAP will ensure a rapid onset of action with adequate antibiotic blood and tissue concentrations.^{6,7}

Effective SAP dosing requires adequate blood and tissue concentrations of the indicated antibiotic, from the incision time until wound closure (when the surgical site is at risk of bacterial contamination).⁷ For SAP to exert a functional antibacterial effect, an antibiotic concentration above the required concentration must be achieved and maintained, in order to inhibit the bacterial growth for the duration of the procedure.⁷ Additional intraoperative antibiotic is required to maintain effective concentrations in prolonged procedures or significant blood loss (more than 1 500 mL in adults).⁵⁻⁷ Intraoperative re-dosing should occur when the duration of the procedure exceeds twice the half-life of the administered antibiotic.⁶

The continuation of SAP postoperatively must not exceed 24 hours, as there is no SSI preventative benefit to the patient.^{1,6,7} Clinical guidelines for effective SSI-prevention provide evidence-based recommendations for SAP use regarding indication, antibiotic choice, duration, dosage, dosing intervals and administering time.^{6,7} Guideline development does not guarantee the successful implementation thereof, as there are documented inconsistencies between SAP guidelines and clinical practice.⁹ Non-compliance with orthopaedic SAP guidelines leads to inadequate antibiotic prophylaxis, increasing the risk of SSIs, antibiotic usage, treatment cost and risk of antibiotic resistance.^{2,5,7,10}

In Australia, orthopaedic surgery was found to be the surgical discipline with the lowest SAP guidelines compliance rate.¹¹ Guidelines compliance was also found to be low in Ireland; however, this improved from 20% to 78% after the implementation of interventions.¹² There are concerns with regard to the SAP guidelines compliance in South African hospitals.¹⁰ The absolute compliance with SAP guidelines in different surgical departments at a Cape Town teaching hospital was found to be 44.4%.⁹ A study conducted at a Gauteng hospital revealed a 29% compliance rate with SAP dosing recommendations among eight different surgical disciplines.¹³ Furthermore, an unnecessarily prolonged duration of SAP was observed in 66% of the cases.¹³ A study conducted in a private hospital in KwaZulu-Natal found that only 39.5% of antibiotics prescribed for SAP in general reflected the recommended antibiotic choice, dose and duration.¹⁴ Another South African study, conducted among 34 hospitals, found that only 34.7% of the antibiotics used for SAP were administered at the correct time.¹⁵ Research revealed that a mere 15.6% of anaesthetists of the Department of Anaesthesiology in Johannesburg followed a specific SAP guideline in their practice.¹⁰ This study also found the anaesthetists' overall SAP knowledge to be lacking, specifically regarding SAP indication, re-dosing and duration.¹⁰

SAP guidelines compliance is important, as orthopaedic SSIs may result in expensive and devastating complications, with an overall SSI incidence ranging from 0.8% to 71%.² Injuries and afflictions of the joints, bone segments and limbs, resulting from a growing ageing population and increase in traffic accidents, result in the increased occurrence of orthopaedic procedures.^{16,17}

Orthopaedic SSIs are difficult to eradicate due to the organisms'

ability to form a biofilm on the inert surface of the orthopaedic implant device.⁵ SSIs result in delayed wound healing, additional treatment and revision surgery and subsequently an increase of hospital LOS by up to 14 days and a three-fold increase in healthcare cost, when compared to uninfected patients.^{4,18} Orthopaedic implantation device infections are associated with complex revision procedures and even implant failure, necessitating complete removal.¹⁷ The cost of revision surgeries following orthopaedic SSIs is more than double compared to readmission because of implant failure.¹⁹ Orthopaedic SSIs decrease the patient's quality of life due to physical limitations caused by pain, functional disability and the negative psychological impact, and increases the mortality risk up to 11 times.^{4,20}

The increasing prevalence of orthopaedic procedures, and therefore the increasing risk of SSIs, strongly suggests the need for increased compliance with orthopaedic SAP guidelines. This study aimed to determine the SAP administration compliance with SAP guidelines, in light of the seemingly limited knowledge about the drug administration compliance with orthopaedic SAP guidelines, specifically among adult patients in South Africa.

Patients and methods

An observational retrospective study was conducted by collecting data from the study hospital's theatre registers, anaesthetic notes, patient medical records and patient antimicrobial prescription charts. The study took place in one of the largest private hospitals, located in North West province of South Africa, that consists of six theatres with five orthopaedic surgeons and an established antimicrobial stewardship programme. The study population consisted of all adult patients (18 years and older) admitted to the study hospital for orthopaedic surgery from 1 January 2020 to 31 December 2020. Patients were excluded if they were already on antibiotic therapy for an established infection prior to surgery, if they underwent surgery other than orthopaedic surgery or if their patient files were not available at the time for data collection.

Patients who underwent orthopaedic surgery were identified by means of the theatre registers. The duration and type of procedure, and patient sex and age were obtained from these registers. Patient medical records were then identified to obtain information from anaesthetic notes and antimicrobial prescription charts. The anaesthetic notes were reviewed to document the type of procedure, prescribed SAP choice and dose, time of preoperative administration, time of incision and intraoperative re-dosing. The antimicrobial prescription charts were reviewed to document postoperatively prescribed SAP and dose, patient antibiotic allergies, patient weight and duration of postoperative SAP. Patient medical records were reviewed to document the reason for hospital admission and the data were then captured onto a Microsoft® Excel® spreadsheet. Data were analysed using Statistical Package for the Social Sciences® (SPSS®). Descriptive statistical analysis was used to determine the orthopaedic SAP administration compliance with prescription guidelines. Orthopaedic SAP compliance was assessed for indication, choice, dose, administration time, route of administration, re-dosing and duration. All variables were expressed using descriptive statistics (frequencies, percentages and means).

The SAP compliance criteria were analysed according to the following parameters:

Indication: The use of SAP was deemed appropriate if prescribed in clean wounds that involve orthopaedic implantation devices as well as clean-contaminated wounds, contaminated wounds and dirty wounds.⁹ The omission of SAP in clean orthopaedic procedures that did not involve orthopaedic implantation devices or prosthetic devices was considered appropriate.^{6,7,9}

Table 1: Orthopaedic SAP dosing and re-dosing

Antibiotic	Recommended adult dose	Recommended re-dosing interval
Cefazolin	1 g < 60 kg 2 g ≥ 60 kg ≤ 120 kg 3 g > 120 kg	4 hours
Cefuroxime	1.5 g	4 hours
Ceftriaxone	2 g	Not applicable due to long half-life
Vancomycin	15 mg/kg	Not applicable due to long half-life
Teicoplanin	400–800 mg	Not applicable due to long half-life
Clindamycin	600 mg	6 hours
Amoxicillin-clavulanic acid	1.2 g	4 hours

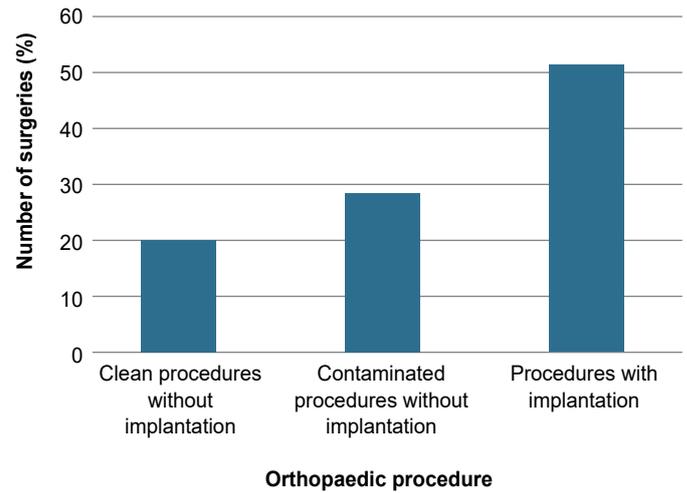


Figure 1. Categories of orthopaedic procedures performed

median age of the patients was 58 years (IQR 48–69 years), with a preponderance of females 51.9% (489 of 942). The mean estimated weight was 86.0 kg (SD = 22.6). *Figure 1* illustrates the different categories of orthopaedic procedures performed.

Indication

SAP was indicated in 81.4% (767, n = 942) of the procedures and not indicated in 18.6% (175) of the clean procedures. SAP was correctly omitted for these clean procedures in 23.4% (41) of the cases and unnecessarily prescribed in 76.6% (134) cases. Of the 767 cases where SAP was indicated, 91.4% (701) were prescribed SAP and 8.6% (66) SAP was incorrectly omitted. SAP was prescribed or omitted as recommended in 78.8% (742, n = 942) cases.

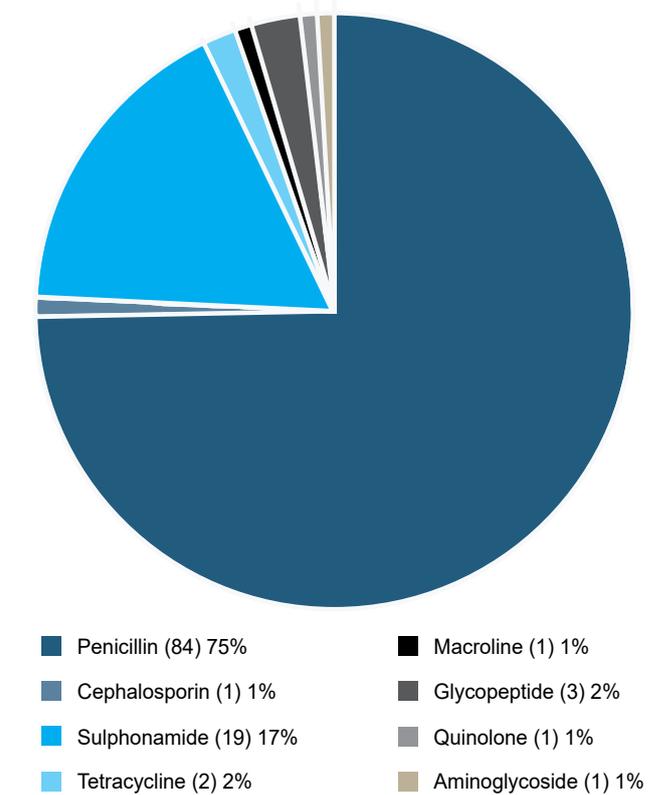


Figure 2. Reported antibiotic allergies

Antibiotic choice: Orthopaedic SAP choice was deemed correct if a cephalosporin such as cefazolin, cefuroxime or ceftriaxone was prescribed with vancomycin, teicoplanin or clindamycin as indicated alternatives due to cephalosporin allergy or suspected methicillin-resistant *Staphylococcus aureus* (MRSA) infection.^{6,9,13}

Route of administration: Antibiotics indicated for orthopaedic SAP use should be administered intravenously (IV).

Antibiotic dose: Orthopaedic SAP dosage was considered correct according to the World Health Organization’s global guidelines for the prevention of surgical site infections; the Scottish Intercollegiate Guidelines Network for antibiotic prophylaxis in surgery; the South African Government’s Standard Treatment Guidelines and Essential Medicines List for South Africa Hospital Level of adults (2019 edition); and the Ampath National Laboratory Services’ Antibiotic Prophylaxis for Surgical Procedures Guidelines, as summarised in *Table 1*.^{1,6,7,9,21,22} Weight-based dosing is only applicable to cefazolin and vancomycin. Therefore, correct cefazolin or vancomycin dosing is determined by patient weight.

Antibiotic re-dosing: Antibiotic re-dosing intraoperatively was considered indicated if the duration of the procedure exceeded twice the half-life of the administered SAP. Antibiotic re-dosing should occur four hours after preoperative dose administration for antibiotics with shorter half-lives such as cefazolin, cefuroxime and amoxicillin-clavulanic acid. Clindamycin has a longer half-life and should be administered intraoperatively at six hours. Ceftriaxone, vancomycin and teicoplanin does not require re-dosing due to their long half-life as summarised in *Table 1*.^{1,6,7,9,21,22}

Administration timing: Time of preoperative SAP administration was considered correct if the SAP was administered at the induction of anaesthesia or within 60 minutes of incision for cefazolin, cefuroxime, ceftriaxone, teicoplanin and amoxicillin-clavulanic acid. Vancomycin administration should occur within 60 to 120 minutes prior to incision.^{6,7}

Duration: Postoperative continuation of SAP for up to 24 hours following orthopaedic surgery was deemed correct. Allowances were made for cases with extensive surgical site contamination where antibiotic treatment beyond SAP was necessitated based on the International Classification of Diseases (ICD-10) code that is used to code all diagnoses, symptoms and procedures.²²

Results

This study comprised 942 orthopaedic procedures which do not include the 160 patient files that were irretrievable at the time of data collection leading to the unfortunate exclusion thereof. The

Choice

SAP was prescribed in 835 of the 942 procedures. Cefazolin was prescribed in 63.6% (531, n = 835) of the cases, followed by cefuroxime in 31.5% (263) of the cases, amoxicillin-clavulanic acid in 2.2% (18) of the cases, ceftriaxone in 2.0% (17) of the cases and clindamycin and teicoplanin in 0.6% (5) and 0.1% (1) of the cases, respectively.

Antibiotic allergies were reported in 112 cases, of which a penicillin allergy was the most common (84), followed by sulphonamide allergy (19,) as illustrated in *Figure 2*.

Only one patient with cephalosporin allergy was reported, and clindamycin was prescribed as the indicated alternative. The total choice of SAP was according to guidelines in 78.3% (738; n = 942) of cases, when the correct allergy alternative and SAP omission are considered.

Route of administration, dose and re-dosing

All 835 cases of preoperative SAP were administered intravenously.

Cefazolin requires weight-based dosing and therefore the correct cefazolin dose was undeterminable in 19 of the 531 cefazolin cases as the patients' weight was not indicated. Therefore, cefazolin dosing was correct in 72.5% (512, n=371) of the cases, dosed too low in 21.1% (108) and dosed too high in 6.4% (33). Cefazolin was under-dosed in all the patients weighing more than 120 kg (29) and frequently over-dosed in patients weighing less than 60 kg (33). Cefuroxime was correctly dosed in 90.5% (238) of the cases, while all ceftriaxone cases (17) were under-dosed. All the cases of amoxicillin-clavulanic acid (18) were correctly dosed, and four of the five clindamycin doses were correct.

SAP dosing was overall correct in 77.5% (632; n = 816), too low in 18.5% (151) and too high in 4.0% (33) of the cases where SAP was administered. The total determinable dosing of SAP was correct in 64.6% when the unnecessary use of SAP and the incorrect allergy alternatives were taken into account.

Only one of the three (33.3%) prolonged procedures (extending four hours) received intraoperative SAP re-dosing as required.

Administration timing

The preoperative SAP administration time was indicated in 287 cases of the 835 patients that received SAP (34.4%), of which 276 were correctly administered at the induction of anaesthesia (96.2%). In 11 cases, SAP was administered more than 60 minutes prior to incision (3.8%). Therefore, the correct SAP administration time could be determined as 96.2% (276, n = 287).

Duration

The postoperative continuation of SAP occurred in 224 cases. Postoperative SAP without preoperative SAP was prescribed in 15 cases. The duration of postoperative SAP extended 24 hours in 94 cases, of which 41 could be justified as treatment for suspected infection and five consisted of SSI treatment. SAP was discontinued correctly within 24 hours postoperatively in 130 cases. Unnecessary SAP continuation beyond 24 hours postoperatively occurred in 48 cases. The postoperative continuation of SAP was correct in 75.9% (170) of the cases when the unnecessary SAP, extended SAP duration without cause and ceftriaxone continuation against recommendations were brought into consideration.

Surgical site infections

Eight patients out of the 850 were readmitted to the study hospital due to the development of SSIs following orthopaedic procedures, resulting in an incidence rate of 0.9%. These patients, above the mean age of 65 years old, spent an additional total of 135 days in hospital (mean = 16.9 days per patient) with a cumulative total of

28 revision surgeries (mean = 3.5 additional surgeries per patient). A total of 16 hospital readmissions occurred due to SSIs (mean = 2 readmissions per patient). SSIs developed in 0.9% of the patients, resulting in the death of one.

Length of hospital stay

SSIs increased the LOS. Patients without SSIs spent a mean one day in the hospital following the procedure compared to a 16.9-day stay due to an SSI.

Discussion

Results displayed a variable rate of compliance with orthopaedic SAP guidelines. A general compliance rate of 57.5% was obtained according to orthopaedic SAP guidelines with regard to SAP indication, choice, dose and duration. The overall compliance rate drops to 20.0% when SAP administration time is also considered due to inadequate documentation of SAP administration time in the anaesthetic notes. Certain components such as route of administration (100%), SAP indication (78.8%) and SAP choice (78.3%) showed greater compliance rates. Lack of knowledge is the most recurring theme cited as a reason for noncompliance with SAP guidelines and could be a contributing factor towards deviations from SAP guidelines.²² Deviations from these guidelines are primarily attributed to the unnecessary prescribing of SAP in clean procedures, cefazolin underdosing in all patients weighing more than 120 kg, consistent ceftriaxone underdosing and the unjustified prolongation of SAP duration.

According to literature, the overuse of antibiotics and deviation from SAP guidelines were found to be driven by the surgeon's fear of complications which can arise from SSI development.²³ The administration of additional antibiotic doses adds a perceived layer of comfort for surgeons, by adding a line of defence for the surgeon if the patient develops an SSI.²³ Antibiotic re-dosing during surgery is often incorrectly omitted during complex prolonged procedures, as it has been deemed 'low priority' in comparison to the competing demands of the operating theatre, thus preventing the patient from receiving adequate prophylaxis.²³

Antibiotics were prescribed according to guidelines in the presence of cephalosporin allergy; however, in the presence of a penicillin allergy the recommended first-choice cefazolin with no beta-lactam cross-allergy was replaced with clindamycin. Clindamycin was prescribed as an alternative in penicillin allergy, contradictory to SAP guidelines which recommend cefazolin as an alternative, demonstrating no allergy cross-reaction to beta-lactam allergies. The safe use of cefazolin in patients with a reported beta-lactam allergy is based on recent data and the knowledge thereof might not have been brought into practice at the time of data collection.²⁴

The administration time of SAP was omitted in the anaesthetic notes in 548 (65.6%) cases. Documenting the time of SAP administration is crucial to determine SAP administration time compliance. Inadequate documentation could be attributed to work overload, lack of awareness of the importance to record SAP administration time or various activities being performed simultaneously at the time of induction of anaesthesia or surgical incision.⁹

In this study, 15 patients received postoperative SAP without preoperative SAP, which is associated with a higher SSI rate.⁶ The prevalence of SSIs found in this study (0.9%) is in line with the mean SSI range following orthopaedic procedures (0.5–3.0%).²⁵ The death of one patient as a result underlines the devastating complications associated with orthopaedic SSIs. It is noteworthy that the mean age of the patients that developed SSIs was above 65 years. This may be due to decreased immunity, increased comorbidity and decreased wound healing rates associated with ageing.²⁰

This study identified areas of orthopaedic SAP practice that are not aligned with guideline recommendations. Improving on these identified areas is fundamental in effectively preventing SSIs.

Missing information was a significant study limitation. The retrospective nature of the study led to the unfortunate exclusion of patient files as missing data were unobtainable from the patients. An additional 160 patient files were irretrievable at the time of data collection which led to the unfortunate exclusion thereof. Compliance with cefazolin weight-based dosing could not be determined in 19 cases due to neglecting to document patient weight. It was challenging to determine intraoperative SAP administration compliance as there was no dedicated space for it on the anaesthetic notes. Accurate preoperative SAP administration time could not be determined in 548 cases as the time of preoperative administration on the anaesthetic notes was frequently omitted.

Conclusion

This study's findings resonate with findings from existing literature, which described variation in SAP use. Orthopaedic SAP practices in this private hospital in South Africa deviate from current official SAP guidelines. SAP overuse, inappropriate omission of initial and intraoperative doses, prolonged postoperative duration and inadequate documentation of SAP administration time, were problems identified in the orthopaedic SAP practice in this hospital. To improve SAP compliance, special attention should be paid to allergy alternatives for patients with penicillin or cephalosporin allergies as well as cefazolin dose adjustments for patients weighing less than 60 kg or more than 120 kg. Compliance with orthopaedic SAP guidelines significantly reduces SSI rates and consequently the impact thereof on the patient and the healthcare system as verified in the literature. Therefore, identifying the rate of compliance with orthopaedic SAP guidelines is an important step in improving compliance with SAP guidelines.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

Prior to the commencement of the study, ethical approval was obtained from the ethical review board: Human Resources Ethics Committee (HREC) of the North-West University, South Africa (NWU-00155-21-A1).

All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. A waiver of informed consent documentation was approved by HREC due to the use of retrospective data that put the subjects to minimal risk of harm.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

MJ: literature review writing, data collection, interpretation of results, manuscript development and writing, manuscript drafting

JMdP: conceptualised research idea, administration and supervision of the study concept and manuscripts, manuscript and dissertation revision, approval of version to be published

DMR: administration and supervision of the study concept and manuscripts, manuscript and dissertation revision, evaluation and approval of manuscript version to be published

CSM: administration and supervision of the study concept and manuscripts, manuscript and dissertation revision, evaluation of manuscript version to be published

ORCID

Jordaan M  <https://orcid.org/0000-0002-8911-8544>

Du Plessis JM  <https://orcid.org/0000-0001-9189-393X>

Rakumakoe DM  <https://orcid.org/0000-0002-9620-3368>

Mostert CS  <https://orcid.org/0000-0001-9082-4342>

References

1. The World Health Organization. Global guidelines for the prevention of surgical site infections, 2018. Available from: <https://www.who.int/infection-prevention/publications/ssi-guidelines/en/>. Accessed 22 Oct 2021.
2. Babu S, Al-Obaidi B, Jardine A, et al. A comparative study of 5 different antibiotic prophylaxis regimens in 4500 total knee replacements. *J Clin Orthop Trauma*. 2020;11(1):108-12. <https://doi.org/10.1016/j.jcot.2018.12.003>
3. Horan TC, Gaynes RP, Martone WJ, et al. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. *Infect Control Hosp Epidemiol*. 1992;13(10):606-608. <https://doi.org/10.2307/30148464>
4. Segala FV, Murri R, Taddei E, et al. Antibiotic appropriateness and adherence to local guidelines in perioperative prophylaxis: Results from an antimicrobial stewardship intervention. *Antimicrob Resist Infect Control*. 2020;9(1):1-6. <https://doi.org/10.3390/antibiotics9100713>
5. Santoshi JA, Behera P, Nagar M, et al. Current surgical antibiotic prophylaxis practices: a survey of orthopaedic surgeons in India. *Indian J Orthop*. 2021;55(3):749-57. <https://doi.org/10.1007/s43465-020-00306-0>
6. Scottish Intercollegiate Guidelines Network. Antibiotic prophylaxis in surgery: A national clinical guideline. Scottish Intercollegiate Guidelines Network; 2014. http://medicinainterna.net.pe/images/guias/GUIA_PARA_LA_PROFILAXIS_ANTIBIOTICA_EN_CIRUGIA.pdf. Accessed 14 Oct 2021.
7. Jocum J. Surgical antibiotic prophylaxis: Are you doing it right? *South Afr J Anaesth Analg*. 2018;28:S49-53. <https://sajaa.co.za/index.php/sajaa/article/view/2100>. Accessed 10 October 2021.
8. Onyekwelu I, Yakkanti R, Protzer L, et al. Surgical wound classification and surgical site infections in the orthopaedic patient. *J Am Acad Orthop*. 2017;1(3). <https://doi.org/10.5435/JAOSGlobal-D-17-00022>
9. Schuster DS, Fagan JF, Flint MF, et al. Compliance with surgical antibiotic prophylaxis guidelines: a prospective descriptive study at a tertiary level hospital in Cape Town, South Africa. *South Afr J Anaesth Analg*. 2020;26(6):300-305. <https://doi.org/10.36303/SAJAA.2020.26.6.2402>
10. Jocum J, Lowman W, Perrie H, Scribante J. Anaesthetists' knowledge of surgical antibiotic prophylaxis: a prospective descriptive study. *South Afr J Anaesth Analg*. 2018;24(4):97-102. <https://doi.org/10.1080/22201181.2018.1487634>
11. Ierano C, Thursky K, Marshall C, et al. Appropriateness of surgical antimicrobial prophylaxis practices in Australia. *JAMA Netw Open*. 2019;2(11):e1915003. <https://doi.org/10.1001/jamanetworkopen.2019.15003>
12. Conaty O, Gaughan L, Downey C, et al. An interdisciplinary approach to improve surgical antimicrobial prophylaxis. *Int J Health Care Qual*. 2018;12. <https://doi.org/10.1108/ijhca-05-2017-0078>
13. Tshweu JK, Malan L, Bronkhorst E. The evaluation of surgical antimicrobial prophylaxis prescribing patterns in Dr George Mukhari Academic Hospital, Gauteng Province (Doctoral dissertation, Sefako Makgatho Health Sciences University). Available from: <https://repository.smu.ac.za/handle/20.500.12308/686>. Accessed 15 Jul 2021.
14. Jacob VT. Antimicrobial prescribing in the surgical and medical wards at a private hospital in KwaZulu-Natal (Doctoral dissertation). Available from: <https://researchspace.ukzn.ac.za/handle/10413/19167>. Accessed 15 Jul 2021.
15. Brink AJ, Messina AP, Feldman C, Richards GA, Van den Bergh D, Netcare Antimicrobial Stewardship Study Alliance. From guidelines to practice: a pharmacist-driven prospective audit and feedback improvement model for perioperative antibiotic prophylaxis in 34 South African hospitals. *J Antimicrob Chemother*. 2017;72(4):1227-34. <https://doi.org/10.1093/jac/dkw523>
16. Verster T, Fourie E. The good, the bad and the ugly of South African fatal road accidents. *S Afr J Sci*. 2018;114(7-8):63-69. <https://doi.org/10.17159/sajs.2018/20170427>
17. Campoccia D, Montanaro L, Ariola CR. The significance of infection related to orthopedic devices and issues of antibiotic resistance. *Biomater Sci*. 2006;27(11):2331-39. <https://doi.org/10.1016/j.biomaterials.2005.11.044>
18. Kallala RF, Vanhegan IS, Ibrahim MS, et al. Financial analysis of revision knee surgery based on NHS tariffs and hospital costs: does it pay to provide a revision service? *Bone Joint J*. 2015;97(2):197-201. <https://doi.org/10.1302/0301-620X.97B2.33707>
19. Torres LM, Turrini RN, Merighi MA. Patient readmission for orthopaedic surgical site infection: an hermeneutic phenomenological approach. *J Clin Nurs*. 2017;26(7-8):1011-20. <https://doi.org/10.1111/jocn.13719>
20. Amaradeep G, Prakash S, Manjappa CN. Surgical site infections in orthopedic implant surgery and its risk factors: A prospective study in teaching hospital. *Int J Orthop Sci*. 2017;3(3):169-72. <https://doi.org/10.22271/ortho.2017.v3.i3c.28>
21. South African Government. Standard Treatment Guidelines and Essential Medicines List for South Africa Hospital Level, Adults 2019 Edition. 2019. Available from: <https://www.gov.za/documents/standard-treatment-guidelines-and-essential-medicines-list-south-africa-hospital-level>. Accessed 12 Oct 2021.
22. Ampath National Laboratory Services. antimicrobial stewardship: from theory to practice. Chapter 5: Antibiotic prophylaxis for surgical procedures. 2017. Available from: <https://www.ampath.co.za/pdfs/antibiotic-guidelines/Chapter-5-Antibiotic-Prophylaxis-For-Surgical-Procedures.pdf>. Accessed 24 Oct 2021.
23. Hassan S, Chan V, Stevens J, Stupans I. Factors that influence adherence to surgical antimicrobial prophylaxis (SAP) guidelines: a systematic review. *Syst Rev*. 2021;10(1):1-20. <https://doi.org/10.1186/s13643-021-01577-w>
24. Jeimy S, Ben-Shoshan M, Abrams EM, et al. Practical guide for evaluation and management of beta-lactam allergy: position statement from the Canadian Society of Allergy and Clinical Immunology. *J Allergy Clin Immunol*. 2020;16(1):1-0. <https://doi.org/10.1186/s13223-020-00494-2>
25. Thirukumaran CP, Zaman A, Rubery PT, et al. Natural language processing for the identification of surgical site infections in orthopaedics. *J Bone Jt Surg Am*. 2019 Dec 18;101(24):2167-74. <https://doi.org/10.2106/JBJS.19.00661>