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Orthopedic postoperative infection profile and antibiotic sensitivity of 2038 patients across 24 countries – Call for region and institution specific surgical antimicrobial prophylaxis

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ABSTRACT

Purpose: Improper utilization of surgical antimicrobial prophylaxis frequently leads to increased risks of morbidity and mortality.This study aims to understand the common causative organism of postoperative orthopedic infection and document the surgical antimicrobial prophylaxis protocol across various institutions in to order to strengthen surgical antimicrobial prophylaxis practice and provide higher-quality surgical care.
Methods: This multicentric multinational retrospective study, includes 24 countries from five different regions (Asia Pacific, South Eastern Africa, Western Africa, Latin America, and Middle East). Patients who developed orthopedic surgical site infection between January 2021 and December 2022 were included. Demographic details, bacterial profile of surgical site infection, and antibiotic sensitivity pattern were documented.
Results: 2038 patients from 24 countries were included. Among them 69.7 % were male patients and 64.1 % were between 20 and 60 years. 70.3 % patients underwent trauma surgery and instrumentation was used in 93.5 %. Ceftriaxone was the most common preferred in 53.4 %. Early SSI was seen in 55.2 % and deep SSI in 59.7 %. Western Africa (76 %) and Asia-Pacific (52.8 %) reported a higher number of gram-negative infections whereas gram-positive organisms were predominant in other regions. Most common gram positive organism was *Staphylococcus aureus* (35 %) and gram-negative was Klebsiella (17.2 %). Majority of the organisms showed variable sensitivity to broad-spectrum antibiotics.
Conclusion: Our study strongly proves that every institution has to analyse their surgical site infection microbiological profile and antibiotic sensitivity of the organisms and plan their surgical antimicrobial prophylaxis accordingly. This will help to decrease the rate of surgical site infection, prevent the emergence of multidrug resistance and reduce the economic burden of treatment.

1. Introduction

Healthcare-associated infections (HAI), infections acquired by patients during the process of care in the hospital or any healthcare facility are a financially burdensome issue, accompanied by substantial morbidity, diminished quality of life, and increase in healthcare expenditures.[1–4] According to Zimlichman et al., HAI extends stay by 6.5–11.2 days, significantly increasing inpatient costs ($9.8 billion annually in the USA).[5]

One of the most prevalent forms of HAI is surgical site infection (SSI), which is typically contracted within one month or one year after the implantation of mechanical or prosthetic material.[6] In the year 2017, the European Centre for Disease Prevention and Control (ECDC) conducted a study in thirteen different European countries, and the results showed that the prevalence of surgical site infections (SSI) ranged from 0.5 percent to 10 percent which was depended on the surgical procedure and the local microbiological profile of the region.[6] The reported rates of SSI in low and middle-income countries (LMICs) vary from 5.7 % to 19.1 %, according to the World Health Organisation (WHO), however they suggests that these estimates might be erroneous due to insufficient and unreliable data-gathering methods.[7] Studies have reported various prevalence of SSI in different parts of the world, with reported rate of 7.9 % in the Eastern Mediterranean region.[8] In India, the prevalence of SSI ranges from 1.6 % to 38 % in different regions of the country.[6,9,10]

Orthopedic procedures face the highest SSI risk due to their surgical complexity, patient variables such as age, comorbidities, and high prevalence of penetrating injuries. Moreover the implants used during the surgical procedures contribute to and foster persistent infections via biofilm formation, challenging their eradication.[11] *Staphylococcus aureus* (*S. aureus*) is the most common bacteria causing orthopedic infections, followed by *Pseudomonas aeruginosa*, *E. coli*, and Enterobacteriaceae. In addition, organisms that are resistant to multiple drugs are identified in 37.5–65.5 % of postoperative orthopedic infections.[11–14]

To decrease the rates of SSIs and improve the efficacy of infection prevention and control strategies, it is crucial to know the prevalence of orthopedic SSIs.[15] According to the WHO reports the prevalence of SSI in LMICs ranges from 1.2 % to 23.6 %, which is nearly three to five times higher than in high-income countries (HICs). The main reasons for this high prevalence of SSI is due to insufficient infection control programs, crowded hospital environments, and inappropriate use of antimicrobial agents. Inspite few studies, claim that the SSIs incidence in LMICs is underreported, mainly due to inadequate post-discharge follow up which necessitaes proactive and targeted surveillance methods to accurately quantify incidence.[4,16,17]

Surgical antimicrobial prophylaxis (SAP), which is administered 30–60 min before the skin incision at the recommended dosage, significantly reduces the incidence of SSIs.[18] The antibiotic chosen should be appropriate to the procedure performed and also selected according to the bacterial profile of that particular institution. At present, an effective surgical antimicrobial prophylaxis (SAP) is considered the most important preventive measure against SSIs.[18] More than 95 % of institutions routinely use cephalosporins as a routine SAP for various procedures, even though the spectrum of SSI ranges greatly across different parts of the world. An efficient SAP practice requires a thorough understanding of international guidelines and regular evaluations of prophylactic antibiotic regimens. Unlike HICs, where studies on SAP protocols are regularly undertaken and changed, this is not the case in LMICs, which poses a significant barrier to good surgical care.[19]

This study's overarching goals are to determine the global prevalence and geographic distribution of orthopedic SSIs and to identify the profile of common causative organisms and their antibiotic susceptibility.The study's findings will help to identify major gaps in the hospital's preventative measures, which in turn will guide the development of strategies to strengthen SAP practice and provide higher-quality surgical care for patients.

2. Materials and methods

This is a multicentric, multinational retrospective cohort study, including patients from twenty-four different countries all around the world done as a project of AOAlliance, a nonprofit development organization dedicated to strengthening care of the injured in over 30 low- and middle-income countries. The study was approved by the institutional review board from Ganga Hospital with IRB number 2022/10/02. The countries included in the study were divided into five different regions. The Asia-Pacific region included seven countries, namely India,

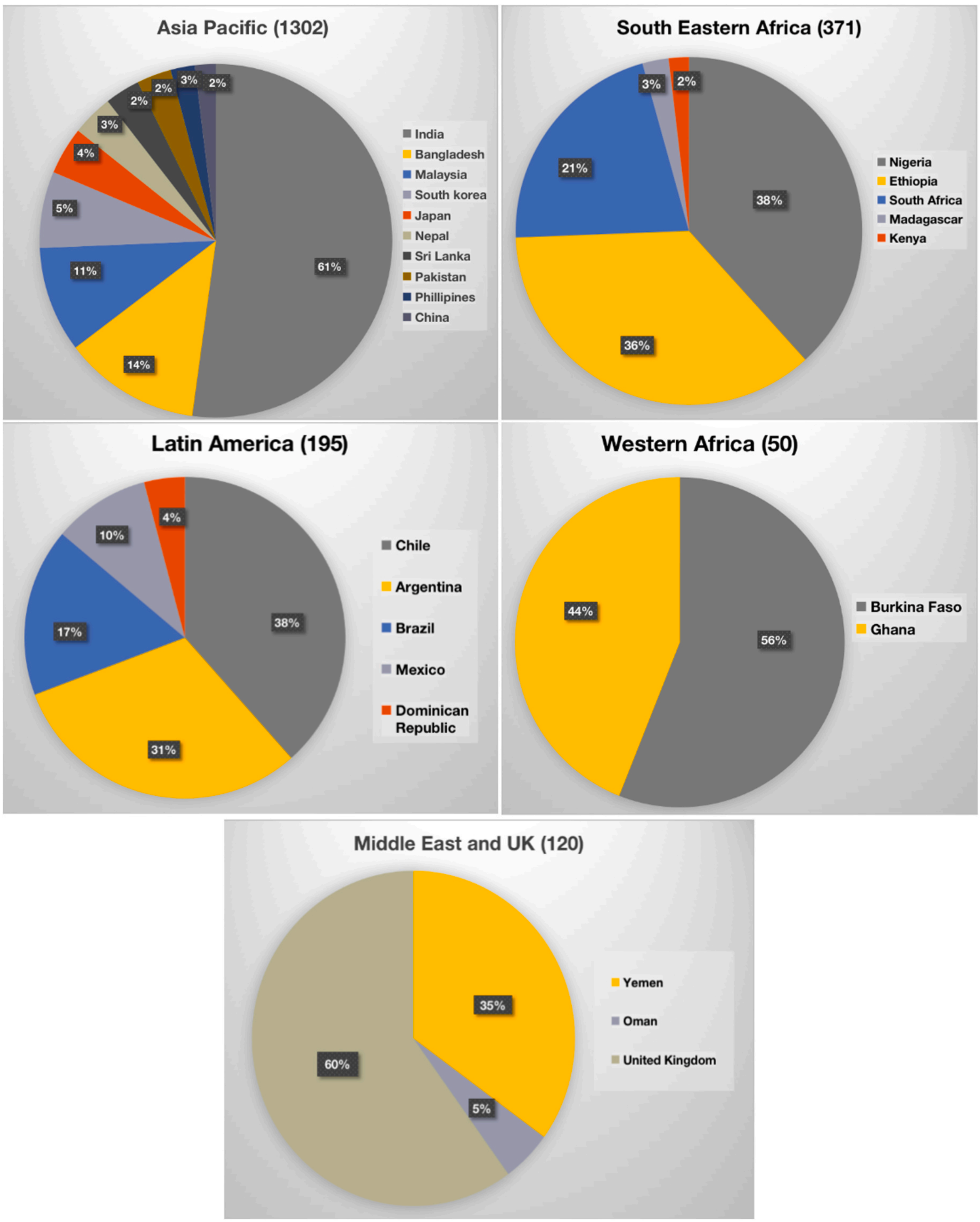

Fig. 1. Distribution of cases across various countries in five different regions.

China, Pakistan, Bangladesh, Malaysia, Japan, and the Philippines. South Eastern Africa included three countries, namely, South Africa, Madagascar, and Kenya. Latin America, which included four countries, namely Brazil, Argentina, Mexico, and Chile. Western Africa included three countries, namely Nigeria, Ghana, and Burkina Faso. The Middle East region included two countries, Oman and Yemen, and finally the United Kingdom (Fig. 1).

The patients who developed SSI following orthopedic procedures between January 2021 and December 2022 from the participating institutions were included in the study. Demographic details, the bacterial profile of SSI, and the antibiotic sensitivity pattern were obtained from the respective participating institutions. The anonymized data was collected using the Kobo Toolbox Android application. The variables collected include the socio-demographic characteristics of patients, country of data collection, working diagnosis with the procedure done, type of implants, type of SSI (Deep Vs superficial as defined by CDC), the time gap between procedure and diagnosis of SSI, laboratory result of microorganism identified with sensitivity profile.[20]

3. Results

3.1. Demographic characteristics

Overall, a total of 2038 patients from 24 countries were included in the study. 64 % patients were in the age group of 19–60 years, followed by those above 60 years (28 %). Nearly two-thirds (69.7 %) were males. 27.2 % patients were diabetic and 28 % were hypertensive. Few had coronary heart disease (6.9 %), chronic kidney disease (4.3 %), obesity (3.2 %), or thyroid disorder (2.3 %). Among 2038 patients, 452 (22.2 %) were smokers (Table 1).

70.3 % of patients had undergone trauma surgery, followed by spine surgery (16.7 %) and joint replacement surgery (13 %). Out of 2038 patients, implants were used in 1906 (93.5 %). Among them, the majority (57.7 %) had stainless steel implants, followed by titanium implants in 28.8 % of patients (Table 1). 55.2 % of infections were early surgical site infection occurring less than 2 weeks. 59.7 % had deep SSI, and 40.3 % has superficial SSI. Surgical intervention in the form of wound debridement was preferred in nearly 51.9 % of the patients and 48.1 % of the patients underwent conservative management in the form of wound care and intravenous antibiotics (Table 1).

Surgical antibiotic prophylaxis was given to all patients who underwent the initial procedure. Cephalosporin drugs were the most common class of preoperative prophylactic antibiotics preferred in nearly 95 % of the total study population, among which ceftriaxone was administered in 53.4 %, followed by cefazolin in 21.6 %, and cefuroxime in 16.3 % (Table 2). Ceftrixone was the preferred SAP in Asia Pacific (70 %) followed by Western Africa (56 %) whereas cefazolin was preferred in Latin America (68.2 %) and South Eastern Africa (54.7 %). Certain countries preferred a unique SAP which was quite different from routinely preferred SAP. For examples, few institutions in South Korea preferred Flomoxef.sodium and some of the UK institutions preferred a combination of Teicoplanin and Ciprofloxacin as SAP.

Table 1
Demographic characteristics of patients with Orthopedic SSI.

	Asia Pacific (1302)	South Eastern Africa (371)	Western Africa (50)	Latin America (195)	Middle East and UK (120)	Total (2038)
Age (years)						
≤18	115 (8.8)	21 (5.7)	6 (12.0)	14 (7.2)	6 (5.0)	162 (7.9)
19–40	446 (34.3)	131 (35.3)	16 (32.0)	33 (16.9)	41 (34.1)	667 (32.7)
41–60	426 (32.7)	99 (26.7)	22 (44.0)	45 (23.1)	47 (39.2)	639 (31.4)
>60	315 (24.2)	120 (32.3)	6 (12.0)	103 (52.8)	26 (21.7)	570 (28.0)
Sex						
Male	956 (73.4)	241 (65.0)	35 (70.0)	106 (54.4)	84 (70.0)	1422 (69.7)
Female	346 (26.6)	130 (35.0)	15 (30.0)	89 (45.6)	36 (30.0)	616 (30.3)
Comorbidities						
DM	403 (31.0)	67 (18.1)	19 (38.0)	38 (19.5)	27 (22.5)	557 (27.2)
HTN	345 (26.5)	102 (27.5)	14 (28.0)	72 (36.9)	38 (31.7)	571 (28.0)
CHD	96 (7.4)	15 (4.0)	1 (2.0)	21(10.8)	7 (5.8)	140 (6.9)
CKD	68 (5.2)	9 (2.4)	1 (2.0)	8 (4.1)	2 (1.7)	88 (4.3)
Thyroid disorder	30 (2.3)	4 (1.1)	4 (8.0)	8 (4.1)	1 (0.8)	47 (2.3)
Bronchial asthma	9 (0.7)	6 (1.6)	2 (4.0)	7 (3.6)	0	23 (1.1)
Malnutrition	30 (2.3)	2 (0.5)	1 (2.0)	1 (0.5)	0	34 (1.7)
HIV/AIDS	6 (0.5)	14 (3.8)	0	1 (0.5)	1 (0.8)	22 (1.1)
Steroid usage	17 (1.3)	2 (0.5)	0	15 (7.7)	0	34 (1.7)
Obesity	43 (3.3)	10 (2.7)	1 (2.0)	9 (4.6)	2 (1.7)	65 (3.2)
Cancer	31 (2.4)	0	0	0	0	31 (1.5)
PVD	4 (0.3)	2 (0.5)	0	0	0	6 (0.3)
Stroke	6 (0.5)	0	0	0	0	6 (0.3)
Smoking	333 (25.6)	51 (13.7)	9 (18.0)	22 (11.3)	37 (30.8)	452 (22.2)
Type of surgery						
Trauma surgery	980 (75.3)	251 (67.6)	45 (90.0)	51 (26.1)	106 (88.4)	1433 (70.3)
Arthroplasty	152 (11.7)	69 (18.6)	4 (8.0)	36 (18.5)	4 (3.3	265 (13.0)
Spine surgery	170 (13.0)	51 (13.8)	1 (2.0)	108 (55.4)	10 (8.3)	340 (16.7)
Type of implant						
Titanium	329 (25.3)	98 (26.4)	10 (20.0)	118 (60.5)	33 (27.5)	588 (28.8)
Stainless steel	858 (65.9)	198 (53.4)	36 (72.0)	26 (13.3)	57 (47.5)	1175 (57.7)
Other implants	62 (4.8)	54 (14.6)	3 (6.0)	22 (11.3)	2 (1.7)	143 (7.0)
No implants	53 (4.0)	21 (5.6)	1 (2.0)	29 (14.9)	28 (23.3)	132 (6.5)
Time interval b/n DOS and SSI						
<2weeks	842 (64.7)	157 (42.3)	30 (60.0)	43 (22.1)	52 (43.3)	1124 (55.2)
2–4 weeks	147 (11.3)	85 (22.9)	11 (22.0)	74 (37.9)	20 (16.7)	337 (16.5)
>4 weeks	313 (24.0)	129 (34.8)	9 (18.0)	78 (40.0)	48 (40.0)	577 (28.3)
Type of infection						
Superficial	630 (48.4)	108 (29.1)	32 (64.0)	24 (12.3)	27 (22.5)	821 (40.3)
Deep	672 (51.6)	263 (70.9)	18 (36.0)	171 (87.7)	93 (77.5)	1217 (59.7)
Type of management						
Conservative	694 (53.3)	142 (38.3)	36 (72.0)	35 (17.9)	73 (60.8)	980 (48.1)
Surgical	608 (46.7)	229 (61.7)	14 (28.0)	160 (82.1)	47 (39.2)	1058 (51.9)

Table 2
Prophylactic antibiotic.

	Asia Pacific (1302)	South Eastern Africa (371)	Western Africa (50)	Latin America (195)	Middle East and UK (120)	Total (2038)
Inj.Ceftriaxone	911 (70.0)	85 (22.9)	28 (56)	20 (10.3)	45 (37.5)	1089 (53.4)
Inj.Cefazolin	72 (5.5)	203 (54.7)	–	133 (68.2)	33 (27.5)	441 (21.6)
Inj.Cefuroxime	201 (15.4)	72 (19.4)	22 (44)	23 (11.8)	15 (12.5)	333 (16.3)
Inj.Flomoxef sodium	45 (3.5)	–	–	–	–	45 (2.2)
Inj.Cefoperazone Sulbactum	31 (2.4)	–	–	–	–	31 (1.5)
Inj.Co-amoxiclav	27 (2.1)	–	–	–	–	27 (1.3)
InjTeicoplanin & Inj. Ciprofloxacin	–	–	–	–	27 (22.5)	27 (1.3)
Inj.Cephalothin	–	–	–	19 (9.7)	–	19 (0.9)
Inj.Linezolid	15 (1.1)	–	–	–	–	15 (0.7)
Inj.Levofloxacin	–	7 (1.9)	–	–	–	7 (0.3)
Inj.Gentamycin	–	4 (1.1)	–	–	–	4 (0.2)

3.2. Bacteria identified

Of the total 2038 SSI, gram-negative isolates (1024) were relatively larger in number than the gram-positive isolates (1014). We observed that the gram-negative isolates outnumbered gram-positive isolates in the Asia Pacific and Western Africa, whereas in other regions, gram-positive infections were predominant (Table 3).

Among gram-positive isolates, the majority were *Staphylococcus aureus* (35 %), followed by Staphylococcus epidermidis (3.2 %) and Streptococcus species (2.6 %). MRSA was isolated in 2.6 % of patients. Among the gram-negative isolates, the majority were Klebsiella species (17.2 %), followed by Pseudomonas (14.4 %) and *E. coli* (13.2 %). In Asia Pacific region, though S.aureus (31.6 %) was the most common causative organism of SSI, gram negative infections by Klesiella (21 %), Pseudomonas (15 %) and E.Coli (12.5 %) were relatively higher. Similarly in Western Africa, Klebsiella (30 %) and Pseudomonas (24 %) SSI were higher than S.aureus (22 %) SSI. In other regions, gram positive infections by S.aureus was more common (Table 4). Based on the type of surgery, we observed that the gram negative infection was relatively higher in patients undergoing trauma surgery in Asia Pacific and Western Africa, Whereas in other regions, gram positive infection was more common. In arthroplasty and spine surgery, gram positive infection outnumbered gram negative in all the regions (Table 6).

3.3. Antibiotic susceptibility pattern

The antibiotics with the greatest sensitivity to gram-positive bacteria were gentamicin, amikacin, linezolid, and piperacillin tazobactum, while the antibiotics with the greatest sensitivity to gram-negative bacteria were amikacin, meropenam, gentamicin, and ciprofloxacin (Table 5).

4. Discussion

This study aimed to assess the postoperative SSI and usage of SAP appropriateness in 2038 patients across 24 countries. The study results highlight the variation in bacterial growth and antibiotic susceptibility in different institutions across the world and the fallacy of having a standard SAP protocol involving cephalosporin. Asia-Pacific countries like India and Bangladesh, as well as Western African countries like Burkina Faso and Ghana, reported a higher number of gram-negative infections, whereas gram-positive organisms were predominant in other regions.

Table 3
Type of bacteria across regions.

Region	Gram positive bacteria (1014)	Gram negative bacteria (1024)	Total (2038)
Asia Pacific	615 (47.2)	687 (52.8)	1302
South Eastern Africa	190 (51.2)	181 (48.8)	371
Western Africa	12 (24.0)	38 (76.0)	50
Latin America	121 (62.1)	74 (37.9)	195
Middle East and UK	76 (63.3)	44 (36.7)	120

SSIs bring about substantial health burdens, causing patient morbidity and mortality, longer hospital stays, increased treatment costs, microbial resistance to antimicrobials, and immense financial strain on healthcare systems. However, data on the prevalence of healthcare-associated infections remains limited in developing nations.[21,22] In developing countries, SSIs stand as the primary healthcare-associated infection, and their occurrence rates in Africa range from 2.5 to 30.9 %, as reported in systematic reviews.[23] Yet, the global epidemiological understanding of SSI is hindered due to the absence of standardized diagnostic methods and a lack of surveillance and reporting systems in many developing countries. Consequently, prioritizing SSIs becomes crucial for enhancing quality and implementing patient safety initiatives.[23,24]

The rates of surgical site infections (SSI) vary significantly between hospitals, between different regions of a single country, and even among continental groupings. Different aseptic techniques, different geographical distributions of causative agents, different resistant patterns of the bacterial isolates in question, and different surgical procedures are among the possible reasons for variation in the species isolated. Though the number of gram-positive and gram-negative infections were more or less the same in our study, there is variation in the geographic distribution of the bacteria in various regions of the world, with the predominance of gram-negative infections in the Asia Pacific (52.8 %) and Western Africa (76 %). In Asia Pacific region,the countries which reported higher number gram negative infections were Bangladesh (75 %),Philippines (72.4 %) and India (58.6 %). In Asia Pacific region though S.aureus (31.6 %) was the most common causative organism of SSI, gram negative infections by Klesiella (21 %), Pseudomonas (15 %) and E.Coli (12.5 %) were relatively higher. In Western African countries like Burkina Faso and Ghana, gram negative infections by Klebsiella (30 %) and Pseudomonas (24 %) SSI were higher than S. aureus (22 %). Similar studies have reported a higher prevalence of gram-negative infections in African countries like Tanzania, Ethiopia, and Uganda.[25–27]

Most of the studies have shown that the incidence of SSI is comparatively higher in the elderly population (>60 years) due to the presence of multiple co-morbid conditions as well as due to poor nutritional status.[28,29] However, in our study, SSI was relatively more common in the younger age group (<60 years). One possible explanation is that most of our patients (70.3 %) underwent surgery for long bone fractures following trauma which would have resulted in soft-tissue damage increasing the likelihood of SSI.[30,31] Studies have reported that the gram positive bacteria especially *Staphylococcus aureus* accounts for nearly 20–30 % of infection rate in fracture fixation patients whereas coagulase-negative staphalococci accounts for 20–40 % of

Table 4
Frequency of the isolated bacteria.

Bacteria Species	Asia Pacific (1302)	South Eastern Africa (371)	Western Africa (50)	Latin America (195)	Middle East and UK (120)	Total (2038)
Gram Positive						
Stap.aureus	412 (31.6)	158 (42.6)	11 (22)	65 (33.3)	68 (56.7)	714 (35.0)
Stap.epidermidis	28 (2.2)	15 (4.0)	–	18 (9.2)	4 (3.3)	65 (3.2)
Streptococcus	41 (3.1)	–	–	8 (4.1)	4 (3.3)	53 (2.6)
MRSA	20 (1.5)	–	–	23 (11.8)	–	43 (2.1)
Gram Negative						
Klebsiella	273 (21.0)	35 (9.4)	15 (30)	7 (3.6)	20 (16.7)	350 (17.2)
Pseudomonas	195 (15.0)	40 (10.8)	12 (24)	36 (18.5)	11 (9.2)	294 (14.4)
E.Coli	163 (12.5)	68 (18.3)	8 (16)	21 (10.8)	10 (8.3)	270 (13.2)
Enterobacter	15 (1.2)	5 (1.3)	1	7 (3.6)	2 (1.7)	30 (1.5)
Acinetobacter	25 (2.0)	–	–	–	–	25 (1.2)

Table 5
Antibiotic sensitivity pattern of common organisms.

Isolates	GM	AK	CF	VM	LZ	PT	MP	CT
Gram Positive								
Stap.aureus	130 (18.2)	115 (16.1)	90 (12.6)	110 (15.4)	60 (8.4)	58 (8.1)	86 (12.0)	23 (3.2)
Stap.epidermidis	23 (35.4)	14 (21.5)	10 (15.4)	6 (9.2)	6 (9.2)	13 (20)	4 (6.2)	NT
Streptococcus	14 (26.4)	18 (34.0)	7 (13.2)	9 (17.0)	10 (18.9)	7 (13.2)	4 (7.5)	NT
MRSA	5 (11.6)	8 (18.6)	NT	12 (27.9)	9 (20.9)	4 (9.3)	4 (9.3)	NT
Gram Negative								
Klebsiella	47 (13.4)	85 (24.2)	32 (9.1)	20 (5.7)	25 (7.1)	28 (8.0)	58 (16.6)	NT
Pseudomonas	63 (21.4)	42 (14.3)	32 (10.9)	14 (4.8)	15 (5.1)	14 (4.8)	23 (7.8)	NT
E.Coli	63 (23.3)	23 (8.5)	32 (11.9)	22 (8.1)	15 (5.6)	12 (4.4)	11 (4.1)	16 (5.9)

GM-Gentamicin, AK-Amikacin, CF- Ciprofloxacin, VM- Vancomycin, LZ-Linizolid, PT-Pipercillin-Tazobactum, MP-Meropenam, CT-Cefotaxime NT- Not tested.

Table 6
Distribution of organism across regions based on type of surgery.

Type of surgery	Asia Pacific (1302)	South Eastern Africa (371)	Western Africa (50)	Latin America (195)	Middle East and UK (120)	Total (2038)
Trauma surgery	**980**	**251**	**45**	**51**	**106**	**1433**
Gram positive	426 (43.5)	132 (52.6)	11 (24.4)	30 (58.8)	67 (63.2)	666 (46.5)
Gram negative	554 (56.5)	119 (47.4)	34 (75.6)	21 (41.2)	39 (36.8)	767 (53.5)
Arthroplasty	**152**	**51**	**1**	**36**	**4**	**244**
Gram positive	95 (62.5)	22 (43.1)	0 (0)	25 (69.4)	3 (75)	145 (59.4)
Gram negative	57 (37.5)	29 (56.9)	1 (100)	11 (30.6)	1 (25)	99 (40.6)
Spine surgery	**170**	**69**	**4**	**108**	**10**	**361**
Gram positive	94 (55.3)	36 (52.2)	1 (25)	66 (61.1)	6 (60)	203 (56.2)
Gram negative	76 (44.7)	33 (47.8)	3 (75)	42 (38.9)	4 (40)	158 (43.8)

prosthetic joint infection rate. Gram-negative bacilli, including *Pseudomonas aeruginosa* and Enterobacteriaceae account for approximately 6%–17 % infection rate.[32] In our study, majority of the infections (53.5 %) following fracture fixations was caused by gram negative bacteria especially Asia Pacific and Western Africa region had 56.5 % and 75.6 % gram negative infection. Klebsiella and Pseudomonas were the most common gram negative bacteria isolated in these regions. However infections following joint replacement surgery and spine surgery were caused by gram positive organisms especially staphylococcus aureus. In our study, the occurrence of SSI in the majority of the patients (55.2 %) was within 2 weeks following surgery which was similar to the previous reported studies.[31]

Diabetes, smoking, systemic steroid use, obesity, poor nutritional status, nasal colonization by *Staphylococcus aureus,* remote site infection and transfusion of specific blood products during surgery are some of the major risk factors for SSI. To lessen the likelihood of SSIs, the use of proper surgical antibiotic prophylaxis (SAP) is crucial. Antibiotic prophylaxis lowers the risk of wound infection in more than 80 % of joint replacement procedures, according to recent comparative studies.[11,12,15]

Choosing a safe, low-cost, narrow-spectrum antibiotic that is effective against the most common infectious organisms at the surgical site is what SAP is all about. Several criteria, like the patient's factors, type of surgical procedure, and possible causative organism, influence antibiotic selection. Several studies have reported that the penicillin group of drugs like augmentin, amoxicillin, and ampicillin as well as the cephalosporins (first, second, or third generation) like cefazolin, cefuroxime, or ceftriaxone, are the most commonly preferred SAP in the perioperative period.[16,17] Similarly, in our study, the most commonly preferred antibiotic was ceftriaxone (53.4 %) followed by cefazoline (21.6 %). Our findings, on the other hand, were inconsistent with the study results which reported that cefazolin and cefotaxime as the preferred SAP in South Africa and Botswana.[33,34]

The antimicrobial coverage against the types of suspected pathogens causing surgical site infections (SSIs) should determine the antibiotics used. This coverage can vary depending on the type of operation, the location of the infection, and the patterns of local antibiotic resistance. Furthermore, it is critical to take into account the cost, pharmacokinetics, and narrowness of the activity spectrum of antimicrobials when making a selection. While ceftriaxone was the most commonly used antibiotic for surgical prophylaxis in our study (53.4 %), cefazolin was recommended by several guidelines as the preferred antimicrobial agent. The possible explanation for the high utilization rate of ceftriaxone can be due to the scarcity of first- and second-generation cephalosporins and the consensus that broad-spectrum antibiotics are better at preventing SSIs.[35]

Studies have highlighted that the appropriate usage of ceftriaxone ranges from 12.1 to 78 %.[36–38] However a recent Drug Utilization

Evaluation (DUE) conducted in India analyzed that ceftriaxone was the antibacterial agent most commonly prescribed, however, its appropriateness was not evaluated.[39] Similar study by Sileshi et al. in a tertiary care hospital in Ethiopia highlighted that inappropriate usage of ceftriaxone was very high (87.9 %) resulting in increased health care cost.[40] Many other similar studies in Ethiopia and Iran and have reported the inappropriate usage of ceftriaxone ranges from 46.2 to 85.3 %.[37,41] Since the last decade due to the inappropriate usage of ceftriaxone, the susceptibility of multiple organisms has reduced gradually. For example, the susceptibility of *E. coli* has reduced from 97 % to 91 % in the span of 4 years.[42]

Inappropriate selection, timing, and duration of SAP is associated with significant increase in adverse drug reaction and emergence of antibiotic resistance, thereby increasing the risk of surgical site infection. SAP may alter the gut microbiota of patients, which could increase the risk of infections such as Clostridioides difficile infection (CDI) and the spread of microorganisms that are resistant to antibiotics. Even though antibiotic abuse and overuse are the main causes of antimicrobial resistance (AMR), SAP accounts for a significant amount of antibiotic consumption in healthcare systems around the world. However, there is a lack of comprehensive evidence on how the use of erroneous SAP affects the spread of AMR. Optimal SAP necessitates effectiveness against aerobic, facultative/anaerobic pathogens that might contaminate surgical sites, including gram-positive skin commensals or normal flora on incised mucosa. When indicated, it should align with local antimicrobial resistance patterns and the susceptibilities of the organisms recognized by the hospital's infection control committee.[43]

Our study has several limitation. First, its a retrospective study and hence the reliability of the data is questionable. Second, there exits an inhomogenity between various regions as the number of cases in specific regions are relatively larger than the other regions. Moreover the results and data validation is debatable, so are the methods of validation for bacteriology diagnosis between the different regions.In spite of these limitations, our study is one of the largest multicentric study on orthopedic postoperative infection and SAP which highlights the urgent need to reformulate SAP protocol at each specific institution based on their microbiological profile.

5. Conclusion

Our study shows that the incidence and prevalence of SSI differs from each region which depends on the bacterial flora in the specific region. The high prevalence of gram-negative isolates in certain regions necessitates the need to reformulate the type of SAP and its correct dosage and timing of dosage. Our study strongly proves that every institution has to look into the microbiological profile and antibiotic sensitivity of the organisms causing SSI and plan their SAP accordingly to prevent the emergence of multidrug resistance and adverse effects of the drugs.

Ethics approval

Approved by the Institutional Review Board of Ganga Medical Center and Hospital, Coimbatore. (IRB number 2022/10/02).

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Guardian/patient's consent

Not applicable as it is a retrospective study and patients data are not revealed.

CRediT authorship contribution statement

Mengistu G. Mengesha: Data curation, Investigation, Writing – review & editing. **Shanmuganathan Rajasekaran:** Writing, Conceptualization, Supervision, Writing – review & editing. **Karthik Ramachandran:** Data curation, Investigation, Writing – original draft. **Vetrivel Chezian Sengodan:** Data curation, Investigation. **Nor Faissal Yasin:** Data curation, Investigation. **Luke Michael Williams:** Data curation, Investigation. **Kota Watanabe:** Data curation, Investigation. **O.Z.M. Dastagir:** Data curation, Investigation. **Akinola Akinmadr:** Data curation, Investigation. **Hizkyas K. Fisseha:** Data curation, Investigation. **Amer Aziz:** Data curation, Investigation. **Ratko Yurac:** Data curation, Investigation. **Ephrem Gebrehana:** Data curation, Investigation. **Mohammed AlSaifi:** Data curation, Investigation. **Kalaventhan Pathinathan:** Data curation, Investigation. **G. Sudhir:** Data curation, Investigation. **Amran Ahmed Shokri:** Data curation, Investigation. **Yong Chan Kim:** Data curation, Investigation. **Sharif Ahmed Jonayed:** Data curation, Investigation. **Gonzalo R. Kido:** Data curation, Investigation. **Jose Manuel Ignacio:** Data curation, Investigation. **Matiyas Seid Mohammed:** Data curation, Investigation. **Kabir Abubakar:** Data curation, Investigation. **Jonaed Hakim:** Data curation, Investigation. **Sailendra Kumar Duwal Shrestha:** Data curation, Investigation. **Abdullah Al Mamun Choudhury:** Data curation, Investigation. **Malick Diallo:** Data curation, Investigation. **Marcelo Molina:** Data curation, Investigation. **Sandeep Patwardhan:** Data curation, Investigation. **Yong Hai:** Data curation, Investigation. **Ali M. Ramat:** Data curation, Investigation. **Momotaro Kawai:** Data curation, Investigation. **Jae Hwan Cho:** Data curation, Investigation. **Rosan Prasad Shah Kalawar:** Data curation, Investigation. **Sung-Woo Choi:** Data curation, Investigation. **Baron Zarate-Kalfopulos:** Data curation, Investigation. **Alfredo Guiroy:** Data curation, Investigation. **Nelson Astur:** Data curation, Investigation. **AlexisD.B. Buunaaim:** Data curation, Investigation. **Anton L. Human:** Data curation, Investigation. **Atiq Uz Zaman:** Data curation, Investigation.

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