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RESEARCH ARTICLE

SURGICAL SITE INFECTIONS: PREVALENCE, ASSOCIATED FACTORS AND ANTIMICROBIAL SUSCEPTIBILITY PATTERNS OF THE BACTERIAL ISOLATES AMONG POSTOPERATIVE PATIENTS IN SANA'A, YEMEN

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Abstract

Background: Surgical site infections (SSIs) are infections that occur one month after a surgical operation or one year after implant surgery and a surgical procedure, either at the injury site or near the injury site. Despite SSIs are still a major problem causing increased morbidity and mortality globally, especially in developing countries, there is a dearth of information in Yemen.
Objective: This study was aimed to assess the prevalence of SSIs, associated factors and antimicrobial susceptibility patterns of the bacterial isolates among post-operative patients in public and private hospitals in Sana'a, Yemen.
Methods: This is a cross-sectional study carried out on 309 postoperative patients, aged one year and over that underwent surgery in selected public and private hospitals between January 2019 and January 2020 in Sana'a. Patients' demographic and clinical information were assessed using an interviewer-administered, pretested, structured questionnaire. Wound swabs and aspirates were collected, placed in Stuart transport media and transferred to the Bacteriology Department of the National Center for Public Health Laboratories in Sana'a for bacterial isolation, identification and antimicrobial susceptibility testing.
Results: The mean age of postoperative patients was 34.0±18.3 (SD) years, age group 25-34 years was 93 (30.1%), and females were 105 (33.8%). Total 309 postoperative patients, 98 (31.7%) were presented with SSI. Having postoperative antibiotics (OR=7.0, 95%CI: 4.1-12.0), dirty surgical wound (OR=10.5, 95%CI: 5.0-21.9), emergency surgery (OR=3.1, 95%CI: 1.8-5.1), amputation (OR=2.5, 95%CI: 1.1-5.7), excision (OR=2.2, 95%CI: 1.2-4.0), hospital stay > two weeks (OR=5.2, 95%CI: 2.3-11.1) and having diabetes mellitus (OR=2.2, 95%CI: 1.1-4.7) were factors significantly associated with SSIs.
Conclusion: This study shows a significant proportion of SSIs among patients in Sana'a, Yemen. Being a female, having a dirty surgical wound, amputation, excision, long hospital stays, diabetes mellitus, and emergency surgery appears to be the major factors associated with SSIs. The most common SSI bacterial etiology is *S. aureus*, sensitive to vancomycin and rifampicin.
Keywords: antibiotics, associated factors, bacterial etiologies, drug resistance, post operative infections, Sana'a City, surgical site infections, Yemen.

INTRODUCTION

Surgical wound infections complicate surgical wound healing and are commonly detected. Most infections appear in the first 30 days after surgery. Surgical wounds can become infected with bacteria, in spite of whether the bacteria are previously on the patient's skin or if the bacteria are spread over the patient through contact with infected individuals or from the hospital environment. Wound infections can be external (skin), deep (muscle and tissue), or extend to the organ or location of the the surgery[1]. Recent studies have demonstrated that postoperative infection can occur many years after surgery, and these infection rates are not registered as a result of loss of patient follow-up, difficulty in accessing a history of prior surgery, visiting a new surgeon, be deficient in requirements from national records and other reasons[2,3,4].

SSIs classified by CDC into three types: superficial infections, deep wound infections, and infections concerning organs or body spaces. The grade of contamination of the surgical site at the time of surgery influences the possibility of an SSI. Based on the occurrence and level of contamination; wounds are classified such as clean, contaminated, dirty or infected[5]. SSI epidemiological studies are problematic due to the various nature of this surgical infection. Prevalence varies greatly between surgeries, hospitals, patients, and surgeons[6].

The SSI may be varied by either internal or external microorganisms. Most SSIs are caused by endogenous bacteria that exist on the skin of the patient when the incision of the surgical is made. Gram-positive bacteria, for example, *Staphylococcus aureus* are the most common causative skin-dwelling bacteria. SSIs are likely to be caused by microorganisms inside the patient's body that are exposed in the course of the surgery. Pathogens depend on the site of the surgery; for instance, the risk of developing SSI from Gram-negative intestinal microorganisms increases with surgery in the gastrointestinal tract[7]. Considering risk factors of contracting SSI, numerous associated factors have been acknowledged in the research text on the contrary studies are not reproducible. Regardless of this fact, a variety of authors have frequently recognized that advanced age, male sex, and considerable blood loss were risk factors of SSI[8-11]. Additional risk factors for SSI are usually divided into procedure related (peri-operative), patient-related (preoperative) and postoperative categories. In general, patient-related risk factors for developing SSI can be classified as either modifiable or non-modifiable. Variable patient-related risk factors include poor diabetes control, use of immunosuppressive medications, obesity, tobacco use and duration of preoperative hospitalization. Risk factors associated with the procedure include wound category, shaving of hair in the operation site, hypoxia, length of surgery and hypothermia. Not modifiable or modifiable, such as age and gender[12]. Although previous research was conducted on bacterial features, antibiotic sensitivity and risk factors for urinary tract infection in postoperative patients in specialized hospitals in Sana'a, Yemen[13], there is no information regarding SSI in Yemen.

Therefore, this study aimed to determine the prevalence and distribution of bacterial pathogens isolated of SSI associated with postoperative wounds and their antimicrobial susceptibility profiles in selected hospitals in Sana'a City, Yemen.

SUBJECTS AND METHODS

Study area and period

The study was conducted in several public hospitals in Sana'a city the capital of Yemen. In the region, there are 4 public hospitals, one Police hospital, one army hospital, several 12 private general hospitals. Currently, these hospitals provide health-care services to more than 5 million people in Sana'a and around Sana'a neighboring regions. The hospitals were selected based on provision of major surgical service in the Sana'a city.

Study design and population

A cross-sectional study was conducted among 309 postoperative patients who underwent elective or emergency surgical procedure between January 2019 and January 2020 at selected hospitals in Sana'a.

Sample size determination and sampling technique

The minimum sample size of 309 was estimated using the singular population ratio formula with the assumption of an SSI prevalence of 75.0% from a previous studies in Ethiopia[14,15], a 4.83% margin of error, a standard normal deviate of 1.96 at 95% confidence level, and a non-response rate of 10%. The patients who met the inclusion criteria and consent to participate were consecutively recruited into the study.

Data collection methods

Patients physical examination were carried out by a rained master's student of medical microbiology for presence of SSIs based on one or more of the following criteria: pain, tenderness, localized swelling, redness, heat or purulent discharge, evidence of an abscess or fever >38ºC in deep incisions.

Sample collection

Wound swab or aspirates were collected aseptically from the surgical sites of the patients who came for medical checkup. This was carried out before the wound is treated with antiseptic solution. The samples were then placed in 5ml Stuart transport media and transferred to the Bacteriology Department of the National Center for Public Health Laboratories for bacteriological examination.

Bacterial Isolation and Identification

Test procedures were performed on the samples following standard bacteriological techniques for swabs and aspirates[16]. The samples were inoculated into blood agar, Mannitol salt agar, and MacConkey agar (Oxoid) using standard streak plate technique. The plates were incubated in an anaerobic atmosphere at 37°C for 24-48h. Bacterial growth on media was confirmed based on their colony shape, pigment production; blood hemolysis as beta hemolysis, alpha hemolysis, gamma hemolysis; tests of biochemical as fermentation of lactose, mannitol, glucose, sucrose; and testing of motility properties.

Bacteria grown on both blood agar and mannitol salt agar are suspected to be Gram-positive bacteria for the reason that mannitol salt agar is a selective medium for *Staphylococcus*. Subsequently, a *catalase* test was performed to distinguish *streptococcus* from *staphylococci*, where *catalase* negative results excluded *streptococcal* species. Moreover, a coagulase enzyme test was carried out to distinguish *S. aureus* from other species of the *Staphylococcus* genus, where they are negative for *coagulase*. Bacteria grown on MacConkey agar and blood agar are suspected to be Gram-negative bacteria because Mac-Conkey agar is Gram-negative bacteria selective media. Colonies on MacConkey agar were charac-terized based on their character of lactose fermentation. The pink color characters the lactose fermenters while the colorless colonies were the lactose-non-fermenters.

Gram-negative bacteria were further tested for their motility and characterized using arrays of biochemical tests including indole, urea, Triple Sugar Iron agar (TSI), Simmon's Citrate agar, and Lysine Decarboxylase (LDC). Colonies that produced pigment on blood agar and non-lactose fermenter on MacConkey agar were tested using oxidase to confirm *P. aeruginosa*, which is oxidase-positive bacterium. Gram-negative bacteria were also investigated for their motility and differentiate using combinations of bio-chemical assays including triglyceride iron agar (TSI), indole, urea, Simmon's Citrate agar and Lysine Decarboxylase (LDC). Colonies that formed dye on blood agar and non-lactose fermented on MacConkey agar were tested with oxidase to confirm *P. aeruginosa* (oxidase-positive bacteria).

Antimicrobial Susceptibility Testing

The antimicrobial susceptibility patterns of the isolates were tested with the Kirby-Bauer diffusion technique using Mueller-Hilton agar (Oxoid). Four to five bacterial colonies of the same morphology were selected and suspending in 5ml nutrient broth. The turbidity of the suspension was then adjusted to 0.5 McFarland to obtain a colony count of approximately 10^7 or 10^8 colony-forming units per milliliter. A sterile swab was then inserted into the suspension, removed the excess by pressing it against the sides of the tube, inoculated directly at the center of the Mueller-Hilton agar plate and then spread evenly to obtain confluent growth. To test for *streptococci* susceptibility, 5% defibrinated sterile blood was aseptically added to the Mueller-Hilton agar[16]. After the inoculated plates were left to dry for 3-5 minutes, the appropriate anti-microbial susceptibility discs were aseptically placed and pressed gently against the medium for total surface contact using a sterile forceps. To avoid the area of inhibition from overlapping, the discs were spaced equally at a distance of approximately 24 mm from each other and 15 mm from the edge of the plate. The plates were incubated aerobically in the incubator at 37ºC for 18-24 hours[17]. The diameter of the zone of inhibition for each antibiotic was measured to the nearest millimeter using digital caliper, (Market lab, UK). The diameter of the inhibition zone of tested bacteria around the disc was measured to the nearest millimeter, and then classified as sensitive and resistant according to Cheesbrough[16] and the Clinical Laboratory Standard Institute guidelines of 2015[17].

The antimicrobial susceptibility discs (Oxoid, Ltd, UK) includes; Amikacin (30 µg), Clarithromycin (30 µg), Amoxicillin-clavulanic acid (30 µg), Ampicillin (10 µg) Penicillin (30 µg), Erythromycin (15 µg), Ceftriaxone (30 µg), Cefixime (30 µg), Ceftazidime (30 µg), Cefotaxime (30 µg), Cefepime (30 µg), Gentamicin (10 µg), Ciprofloxacin (5 µg), Norfloxacin (10 µg), and Cotrimoxazole (25 µg) Imipenem (30 µg), Aztreonam (30 µg), Rifampicin (30 µg), and Vancomycin (30 µg).

Data analysis

The data were analyzed with Epi Info version 6 (CDC, Atlanta, USA). The continuous variable (age) was summarized with mean and standard deviation while the categorical variables were summarized with frequencies and proportions and presented as tables. Bivariate analysis was conducted to determine association between the dependent variable (SSIs) and the independent variables (demographic and clinical information) with a 95% confidence level.

Ethical Consideration: Ethical approval for this study, No: 12 dated December 1, 2018 was obtained from the Medical Ethics and Research Committee of the Faculty of Medicine and Health Sciences, Sana'a University. All procedures were according to the ethical guidelines of the review committee. Also, from all participants, consents were taken and participants were informed that participation is voluntary and that they can reject this exclusive of stating any reason.

Table 1: Characteristics of the patients, N=309.

Characteristics	N (%)	Characteristics	N (%)
Mean age ± SD	34.0 ± 18.3year	**Weight**	
Age group(years)		Underweight	61(19.7)
<15	57(18.4)	Normal weight	183(59.2)
15-24	54(17.5)	Overweight/obese	65(21)
25-34	93(30.1)	**Health condition**	
35-44	39(12.6)	Diabetes mellitus	31(10)
≥45	66(21.4)	Hypertension	29(9.4)
Gender		**Surgical site infection**	
Male	204(66.02)	Present	98(31.7)
Female	105(33.8)	Absent	211(68.3)

RESULTS

Of 309 postoperative patients with mean age of 34.0±18.3 (SD) years, 93 (30.1%) were of the age group 25-34 years, while females were 105 (33.8%). The prevalence of SSIs was 31.7%, Table 1. The odds of SSIs among females (39.1%), with an odds ratio (OR) of 1.6, 95%CI: 1.1-2.7) was higher than the males (27.9%). Also, presence of drainage at the operation site (OR=3.6, 95%CI=2.1-6.2), having post-operative antibiotics (OR=7.0, 95%CI: 4.1-12.0), dirty surgical wound (OR=10.5, 95%CI: 5.0-21.9), emergency surgery (OR=3.1, 95%CI: 1.8-5.1), amputation (OR= 2.5, 95%CI: 1.1-5.7), excision (OR=2.2, 95%CI: 1.2-4.0), hospital stay > two weeks (OR=5.2, 95%CI: 2.3-11.1), being underweight (OR=1.9, 95% CI=1.1-3.5 and having diabetes mellitus (OR=2.2, 95%CI: 1.1-4.7) were factors significantly associated with SSIs, Table 2.

Table 2: Relationship between risk factors and surgical site infection among post-operative patients, N=309.

Risk factors	Total N (%)	Surgical site infection N (%)	Bivariate analysis OR (95%CI)
Gender			
Male	204(66)	57(27.9)	0.6(0.36-0.9)
Female	105(34)	41(39.05)	1.6(1.1-2.7)
Age group(years)			
<15	57(18.4)	15(26.3)	0.32(0.18-0.5)
15-24	54(17.5)	17(31.5)	0.98(0.5-1.8)
25-34	93(30.1)	35(37.6)	0.98(0.5-1.8)
35-44	39(12.6)	14(35.9)	1.2(0.6-2.4)
≥45	66(21.4)	17(25.6)	0.7(0.3-1.2)
Weight			
Normal	183(59.2)	40(21.8)	0.32(0.18-0.5)
Underweight	61(19.7)	27(44.2)	1.97(1.1-3.5)
Overweight/obese	65(21)	31(47.7)	1.03(0.57-1.8)
Health condition			
Diabetes mellitus	31(10)	15(48.4)	2.2(1.1-4.66)
Hypertension	29(9.4)	12(41.4)	1.6(0.72-3.4)
Wound location			
Abdomen	262(84.8)	76(29)	0.48(0.24-0.8)
Thighs	13(4.2)	6(46.2)	1.9(0.6-5.8)
Extremities	19(6.1)	9(47.4)	2(0.79-5.1)
Head/face/jaws/mouth	15(4.9)	7(46.7)	1.9(0.75-5.5)
Wound discharge			
Yes	76(24.6)	41(54)	3.6(2.1-6.2)
No	233(75.4)	57(24.5)	0.27(0.16-0.47)
Post-operative antibiotics			
Yes	101(32.7)	61(60.4)	7(4.1-12)
No	208(67.3)	37(17.8)	0.14(0.08-0.2)
Wound type			
Clean	179(57.9)	21(11.7)	0.09(0.05-0.1)
Contaminated	83(26.9)	41(49.4)	2.8(1.7-4.8)
Dirty	47(15.2)	36(76.6)	10.5(5-21.9)
Surgery type			
Elective	216(69.9)	52(24.1)	0.3(0.1-0.5)
Emergency	93(30.1)	46(49.5)	3.1(1.8-5.1)
Amputation	25(8.1)	13(52)	25(1.1- 5.7)
Excision	51(16.5)	24(47.1)	2.2(1.2- 4)
Others	233(75.4)	61(26.2)	0.37(0.2-0.6)
Length of hospital stay			
≤2 weeks	279(90.3)	78(28)	0.19(0.08- 0.4)
>2 weeks	30(9.7)	20(66.7)	5.2(2.3-11.1)

OR=odds ratio, *CI*=confidence interval 95%, X^2=Chi squire, *p*=*p* value *independence is generally defined in a statistical sense: a variable is called an independent risk factor if it has a significant contribution to an outcome in a statistical model that includes established risk factors. *Elective surgery is done to correct a non-life-threatening condition, and is carried out at the person's request.

* Emergency surgery is surgery which must be done promptly to save life, limb, or functional capacity.

Independence is generally defined in a statistical sense: a variable is called an independent risk factor if it has a significant contribution to an outcome in a statistical model that includes established risk factors.

The most common Gram-negative bacteria isolated (57.1%) were *E. coli* (34.7%), *Klebsiella spp.* (11.2%) and *P. aeruginosa* (11.2%) Table 3. Double microbial infections constituted 26.5% of the bacterial infections (Table 3). Among the Gram-positive bacteria isolated (42.9%), *S. aureus* 48 (37.8%) and the coagulase negative *Staphylococci* 5 (5.1%) were the most resistant (100%) to penicillin, Table 5.

DISCUSSION

This study assessed the prevalence of SSIs, associated factors and antimicrobial susceptibility patterns of the bacterial isolates among postoperative patients in Sana'a. The prevalence of SSIs in this study was similar to the 24.6% reported in Hawassa[20] and the 29.8% observed in Mekele[15], all in Ethiopia. However, this finding was dissimilar from previous studies in Ethiopia[14,10] Rwanda[18], and Uganda[19]. Also, the SSI occurrence in this study was lower than the 67.6% reported by Zahran and colleagues in Egypt[11], but is higher than the 2.5% presented by Ramirez and co-workers from 13,000 surgeries performed in three cities in Peru[21] and the 2.2% from a meta-analysis in Saudi Arabia[22]. This difference may be linked to difference in hygienic practices and environments as improper wound care after surgery, failure to maintain sterility during surgical procedures, lack of portable water, overcrowding and inadequate infection control measures are known risk factors for SSIs. The high prevalence of SSIs reported in this study may be attributed to the absence of modern surgical techniques, well-equipped operation rooms, and inadequately trained healthcare professionals in Yemen compared to middle and high-income countries. In this study, being female was significantly associated with SSI. It is different from the studies: by Deribe *et al*.,[20] in Hawassa, Ethiopia, by Shakir *et al*., in Ethiopia in the Harare region[14], and by Zahran *et al*., In Egypt[11], the prevalence of SSI was nearly the same in both sexes. In the current study, there was no significant association between any age group with SSI. It is different from the study by Deribe *et al*.,[14] in Hawassa, Ethiopia and Shakir *et al*.,[20] in Ethiopia in the Harare region, where the prevalence of SSI was found to be higher in the older age groups.

Table 3: Frequency of bacterial isolates from post-operative wounds of patients who had developed Surgical site infections (SSIs) at selected hospitals in Sana'a, Yemen.

Organisms	Number (%)
Gram-positive	42(42.9)
S. aureus	37(37.8)
CoNS	5(5.1)
Gram-negative	56(57.1)
E. coli	34(34.7)
Klebsiella species	11(11.2)
P. aeruginosa	11(11.2)
Double-microbial infections	26(26.5)
S. aureus and *Klebsiella* species	7(7.1)
E. coli and *P. aeruginosa*.	7(7.1)
S. aureus and *E. coli*	8(8.2)
E. coli and CoNS	4(4.1)
Total	98(100)

On the contrary, a study by Asres *et al*., in Addis Ababa in Ethiopia contradicts this finding as infection was mostly observed in the <10 year age group[8]. In this regard, the prevalence of SSI has varied between age group in previous studies, and may be related to participants' immune status as well[14]. In this study, the prevalence of SSI was higher in patients who had discharge at the operating site than in those who did not. This result is in line with the report of Shakir *et al*., in Ethiopia[14] and Zahran *et al*., in Egypt[11]. One possible explanation is that it is one of the physical diagnostic criteria for SSIs without the need for laboratory testing. The current study found that the prevalence of SSI was higher in patients with the dirty wound type than in patients with clean wounds. This result is consistent with the reports of Shaker *et al*.,[14], Lubega *et al*.,[19] by Deribe *et al*.,[20] and Mengesha *et al*.,[15].

Table 4: Antimicrobial susceptibility pattern of the isolated Gram-negative bacteria.

Antimicrobial agents	Sensitive N(%)	Resistance N(%)
Amikacin (10 µg)	55(98.2)	1(1.8)
Amoxicillin-clavulanic acid (30 µg)	38(67.8)	18(32.2)
Ampicillin (10 µg)	4(7.1)	52(92.9)
Ciprofloxacin (5 µg)	49(87.5)	7(12.5)
Clarithromycin (30 µg)	28(50)	28(50)
Cotrimoxazole (25 µg)	26(46.4)	30(53.6)
Ceftriaxone (30 µg)	19(33.9)	28(66.1)
Cefixime (30 µg)	43(76.8)	13(23.2)
Ceftazidime (30 µg)	41(73.2)	15(26.8)
Cefotaxime (30 µg)	49(87.5)	7(12.5)
Cefepime (30 µg)	41(73.2)	15(26.8)
Gentamicin (10 µg)	49(87.5)	7(12.5)
Imipenem (30 µg)	55(98.2)	1(1.8)

The significant effect of internal contamination during the operation or external contamination during the wound care procedure may be scientifically justified. According to this study, being diabetic was associated with a higher risk of SSI, compared to non-diabetics. This may be because deficiency of vasoactive neuropeptides in patients with neuropathy might impair normal soft tissues resulting in delayed wound healing in diabetic patients. In the current study also, the presence of antibiotics after surgery, was a factor significantly associated with anti-SSI. This is similar to studies conducted previously in Ethiopia[8,14,23] and in Egypt[11]. Emergency surgery was a factor significantly associated with SSIs in the current study. This is similar to the study by Makdad *et al*.,[13] where emergency surgery has been independently associated with postoperative infection. Regarding postoperative patients in other surgical specialties, the investigation reveals that the appreciable postoperative incidence is not limited to the type of surgeries[24]. This study revealed that 57.1% of the isolates are Gram-negative bacteria, which is in agreement with the previous study from Ethiopia[14,25,26], while the study conducted in Egypt[11] contradicts this result where Gram-positive bacteria were more dominant. This difference may be attributed to the habitats of the bacterial aetiology and infection prevention practices in different healthcare settings. This research indicates that the most frequently isolated species was *S. aureus* (37.8%). The finding is in line with studies done in Ethiopia (33.3%)[8], and (26.2%)[10] whereas the study conducted in Uganda revealed that of the most prevalent isolate was *K. pneumonia* with a 50% rate[19]. This difference in the distribution of bacterial species might be due to variation in common hospital-acquired pathogens, and infection prevention and control policies and guidelines across countries.

Table 5: Antimicrobial susceptibility pattern of the isolated Gram-positive bacteria.

Antimicrobial agents	Sensitive N (%)	Resistant N (%)
Amoxicillin(30 µg)	9(21.4)	33(78.6)
Aztreonam(30 µg)	40(95.2)	2(4.8)
Augmentin(30 µg)	35(83.3)	7(16.7)
Gentamycin(10 µg)	36(85.7)	6(14.3)
Ciprofloxacin(5 µg)	39(92.8)	3(7.2)
Cefixime(30 µg)	32(76.2)	10(23.8)
Ceftazidime(30 µg)	30(71.4)	12(28.4)
Cefotaxime(30 µg)	36(85.7)	6(14.3)
Cefepime(30 µg)	32(76.2)	10(23.8)
Co-trimoxazole(25 µg)	23(54.7)	19(45.3)
Penicillin(30 µg)	0(0)	42(100)
Erythromycin(15 µg)	6(14.2)	36(85.8)
Norfloxacin((30 µg)	25(59.5)	17(40.5)
Rifampicin(30 µg)	42(100)	0(0)
Vancomycin(30 µg)	42(100)	0(0)

In this study, Ciprofloxacin, Cefotaxime, Cefepime, Gentamicin and Imipenem were relatively effective drugs in treating SSIs caused by Gram-negative bacteria which is consistent with a previously reported study in Yemen by Al-Makdad *et al.*,[13] and in Ethiopia by Gelaw *et al.*,[27]. On the contrary, the study by Al-Shami *et al*. reported reduced efficacy of these drugs (33%, 51%, 12%, and 10%, respectively)[28]. Perhaps the rise in antibiotic resistance due to irrational use of anti-infective drugs combined with inadequate measures to control the spread of infections, variation in common hospital-acquired pathogens, and acquisition of antimicrobial-resistant organisms is then related to hosting risk factors as well as to the amount of time spent in an environment where they are exposed to these microorganisms. The current study also indicated that Aztreonam, Augmentin, Gentamicin, Ciprofloxacin, and Cefotaxime were effective drugs for SSI inhibitors caused by Gram-positive organisms in more than 80% of isolates and were almost similar to those reported previously in Yemen[13,29-42]. The present study confirms the alarming rate of resistance of Gram-positive bacteria to the polyclonal antimicrobials penicillin (100%), erythromycin (85.8%) and amoxicillin (78.6%) which was similar compared to previous studies conducted in Yemen before[29-42]. This may be because the experimental treatment of isolates and/or the random and repeated use of these antibiotics by unskilled practitioners along with the lack of guidelines for antibiotic use participate a fundamental role in the emergence and spread of resistance[13,28,41].

Limitations

This study did not address anaerobic bacteria pathogens due to limited laboratory facilities. The study of the cross section made it difficult to establish causation (the chronology of cause and effects could not be explored).

CONCLUSIONS

This study shows a significant proportion of SSIs among post-operative patients in Sana'a, Yemen. Being a female, having dirty surgical wound, amputation, excision, long hospital stays, diabetes mellitus, and emergency surgery appears to be the major factors associated with SSIs. The most common bacterial etiology is *S. aureus* and sensitive to vancomycin and rifampicin. Since the clinical benefits of these risk factors are unproven, further research such as prospective cohort study should be conducted to operative management in Yemen.

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AUTHOR'S CONTRIBUTION

Alhadi YAA: writing original draft, literature survey. **Al-Kibsi TAM:** investigation, data interpretation. **Al-Shamahy HA:** methodology, conceptualization. **Aldeen YAAS:** formal analysis, review. The final manuscript was read and approved by all authors.

CONFLICT OF INTEREST

None to declare.

REFERENCES

1. Alhlale MF, Humaid A, Saleh AH, Alsweedi KS, Edrees WH. Effect of most common antibiotics against bacteria isolated from surgical wounds in Aden Governorate hospitals, Yemen. Universal J Pharm Res 2020; 5(1): 21-24. *https://doi.org/10.22270/ujpr.v5i1.358*

2. Agarwal A, Kelkar A, Agarwal AG, Jayaswal D, Schultz C, Jayaswal A, *et al*. implant retention or removal for management of surgical site infection after spinal surgery. Global Spine J 2020; 10 (5): 640–646. *https://doi.org/10.1177/2192568219869330*
3. The Hardest Decision Any Spine Surgeon Has to Make | Orthopedics This Week". ryortho.com. Retrieved 2022-05-24.
4. World Health Organization (WHO). Global guidelines for the prevention of surgical site infection; 2016. https:// pubmed.ncbi.nlm.nih.gov/28139389/. Accessed May 14, 2022.
5. Centers for Disease Control and Prevention (CDC). Procedure- Associated Module: Surgical Site Infection (SSI) Event. Atlanta, GA: Centers for Disease Control and Prevention; 2017
6. Berrios-Torres SI, Umscheid CA, Bratzler DW, *et al*. Centers for disease control and prevention guideline for the prevention of surgical site infection. JAMA Surg 2017; 152(8):784–791. *https://doi.org/10.1001/jamasurg.2017.0904*
7. Naderi HR, Ebrahim ZM. Evaluation of postoperative infections in patients undergoing abdominal surgery: a systematic review. Patient Saf Qual Improv 2015; 3(4):300–303.
8. Asres GS, Legese MH, Woldearegay GM. Prevalence of multidrug resistant bacteria in postoperative wound infections at Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia. Arch Med 2017;9(4):12.
9. Moghadamyeghaneh Z, Hwang GS, Hanna MH. Risk factors for prolonged ileus following colon surgery. Surg Endosc 2016; 30:603–609. *https://doi.org/10.1007/s00464-015-4247-1*
10. Mulu W, Kibru G, Beyene G, Damtie H. Associated risk factors for postoperative nosocomial infections among patients admitted at Felege Hiwot Referral Hospital, Bahir Dar, Northwest Ethiopia. Clin Med Res 2013; 2(6):140–147. *https://doi.org/10.11648/j.cmr.20130206.15*
11. Zahran WA, Zein-Eldeen AA, Hamam SS, *et al*. Surgical site infections: problem of multidrug-resistant bacteria. Menoufia Med J 2017; 30(4):1005–1013. *https://doi.org/0.4103/mmj.mmj_119_17*
12. Anderson DJ, Moehring RW, Sloane R, *et al*. Bloodstream infections in community hospitals in the 21st century: a Multicenter Cohort Study. PLoS One 2014; 9:e91713. *https://doi.org/10.1371/journal.pone.0091713*
13. Al Makdad ASM, Al-Haifi AY, Salah MK, Al-Shamahy HA, Al-Falahi TH. Urinary tract infections in post operative patients: prevalence rate, bacterial profile, antibiotic sensitivity and specific risk factors. Universal J Pharm Res 2020; 5(3):21-26. *https://doi.org/10.22270/ujpr.v5i3.329*
14. Shakir A, Abate D, Tebeje F, Weledegebreal F. Magnitude of Surgical Site Infections, Bacterial Etiologies, Associated Factors and Antimicrobial Susceptibility Patterns of Isolates Among Post-Operative Patients in Harari Region Public Hospitals, Harar, Eastern Ethiopia. Infect Drug Resist 2021; 14:4629-4639. *https://doi.org/10.2147/IDR.S329721*
15. Mengesha RE, Kasa BG-S, Saravanan M, *et al*. Aerobic bacteria in post-surgical wound infections and pattern of their antimicrobial susceptibility in Ayder Teaching and Referral Hospital, Ethiopia. BMC Res Notes. 2014;7(1):575. *https://doi.org/10.1186/ 1756-0500-7-575*
16. Cheesbrough M. District Laboratory Practice in Tropical Countries. 2nd ed. New York 106. Cambridge, UK: Cambridge University Press; 2006.
17. Clinical and Laboratory Standard Institute. Performance Standards for Antimicrobial Disk Susceptibility Tests. 25th ed. CLSI document M100-S25. Wayne, United State; 2015.
18. Mukagendaneza MJ, Munyaneza E, Muhawenayo E, *et al*. Incidence, root causes, and outcomes of surgical site infections in a tertiary care hospital in Rwanda: A prospective observational cohort study. Patient Saf Surg 2019; 13(1):1–8. *https://doi.org/10.1186/s13037-019-0190-8*
19. Lubega A, Joel B, Justina Lucy N. Incidence and etiology of surgical site infections among emergency postoperative patients in mbarara regional referral hospital, South Western Uganda. Surg Res Pract. 2017; 2017:1–6. *https://doi.org/10.1155/2017/6365172*
20. Deribe B, Jemebere W, Bekele G. Surgical site infection prevalence and associated factors in Hawassa University comprehensive specialized hospital, Southern Ethiopia; 2019. *https://doi.org/10.21203/rs.2.15549/v1*
21. Ramirez-Wong FM, Atencio-Espinoza T, Rosenthal VD, *et al*. Surgical site infections rates in more than 13,000 surgical procedures in three cities in Peru: findings of the international nosocomial infection control consortium. Surg Infect 2015; 16(5):572–576. *https://doi.org/10.1089/sur.2014.201*
22. Al-Mulhim FA, Baragbah MA, Sadat-Ali M, *et al*. Prevalence of surgical site infection in orthopedic surgery: a 5-year analysis. Int Surg 2014; 99(3):264–268. *https://doi.org/10.9738/ INTSURG-D-13-00251.1*
23. Amare B, Abdurrahman Z, Moges B, *et al*. Postoperative surgical site bacterial infections and drug susceptibility patterns at Gondar University Teaching Hospital, Northwest Ethiopia. J Bacteriol Parasitol 2011; 2:126. *https://doi.org/10.4172/2155-9597.1000126*
24. Peersman G, Laskin R, Davis J, Peterson M. Infection in total knee replacement: a retrospective review of 6489 total knee replacements. Clin Orth Relat Res 2001; (392):15-23. PMID: 11716377
25. Tesfaye S, Esseye S, Beyene G, Ali S. 2016 Patterns of bacteria isolated from admitted patients with signs of infection at Jimma University specialized hospital, Jimma, Ethiopia. Int J Trop Dis Health 2011; 17(4):1–12.
26. Dessalegn L, Shimelis T, Tadesse E, Gebre-selassie S. Aerobic bacterial isolates from post-surgical wound and their antimicrobial susceptibility pattern: a hospital based cross-sectional study. J Med Res 2014; 3(2):18–23.
27. Gelaw A, Gebre-Selassie S, Tiruneh M, Mathios E, Yifru S. Isolation of bacterial pathogens from patients with postoperative surgical site infections and possible sources of infections at the University of Gondar Hospital, Northwest Ethiopia. J Environ Occup Health 2014; 3(2):103-108.
28. Al-Shami HZ, Al-Haimi MA, Al-Shamahy HA, *et al*. Patterns of antimicrobial resistance among major bacterial pathogens isolated from clinical samples in two tertiary's hospitals, in Sana'a, Yemen. Universal J Pharm Res 2021; 6(5):60-67. *https://doi.org/10.22270/ujpr.v6i5.674*
29. Abbas AM, Al-Kibsi TAM, Al-Shamahy HA, *et al*. Characterization and antibiotic sensitivity of bacteria in orofacial abscesses of odontogenic origin. Universal J Pharm Res 2020; 5(6):36-42. *https://doi.org/10.22270/ujpr.v5i6.510*
30. Al-Akwa AA, Zabara A, Al-Shamahy HA. Prevalence of *Staphylococcus aureus* in dental infections and the occurrence of MRSA in isolates. Universal J Pharm Res 2020; 5(2):1-6. *https://doi.org/10.22270/ujpr.v5i2.384*
31. Shogaa Al-Deen SH, Al-Ankoshy AAM, Al-Najhi MMA, Al-Shamahy HA, *et al*. Porphyromonas gingivalis: biofilm formation, antimicrobial susceptibility of isolates from cases of Localized Aggressive Periodontitis (LAP). Universal J Pharm Res 2021; 6 (4): 1-6. *https://doi.org/10.22270/ujpr.v6i4.633*
32. Al-Eryani SA, Alshamahi EYA, Al-Shamahy HA, Alfalahi GHA, Al-Rafiq AA. Bacterial conjunctivitis of adults: causes and ophthalmic antibiotic resistance patterns for the common bacterial isolates. Universal J Pharm Res 2021; 6: (1). *https://doi.org/10.22270/ujpr.v6i1.535*
33. AL-Haddad KA, Ali Al-Najhi MM, Al-Akwa AAY, *et al*. Antimicrobial susceptibility of Aggregatibacter actinomyce-temcomitans isolated from Localized Aggressive Periodon-titis (LAP) Cases. J Dent Ora Heal Ad Re 2007; 103. *https://doi.org/10.1111/j.1600-0463.2007.apm_630.x*

34. Al-Haddad KA, Al-Najhi MMA, Al-Shamahy HA, *et al*. Clinical features, age and sex distributions, risk factors and the type of bacteria isolated in periodontitis patients in Sana'a, Yemen. Universal J Pharm Res 2021; 6(1):1-8. *https://doi.org/10.22270/ujpr.v6i1.532*
35. Alhasani AH, Ishag RA, Al Shamahy HA, *et al*. Association between the *Streptococcus mutans* biofilm formation and dental caries experience and antibiotics resistance in adult females. Universal J Pharm Res 2020; 5(6):1-3. *https://doi.org/10.22270/ujpr.v5i5.478*
36. AL-Magrami RTF, Al-Shamahy HA. *Pseudomonas aeruginosa* skin-nasopharyngeal colonization in the in-patients: prevalence, risk factors and antibiotic resistance in tertiary hospitals in Sana'a city-Yemen. Universal J Pharm Res 2019; 3(6). *https://doi.org/10.22270/ujpr.v3i6.219*
37. Al-Safani AA, Al-Shamahy H, Al-Moyed K. Prevalence, antimicrobial susceptibility pattern and risk factors of MRSA isolated from clinical specimens among military patients at 48 medical compounds in Sana'a city-Yemen. Universal J Pharm Res 2018; 3(3):40-44. *https://doi.org/10.22270/ujpr.v3i3.165*
38. Alshamahi EYA, Al-Shamahy HA, Musawa YA, Al-Shami HZ. Bacterial causes and antimicrobial sensitivity pattern of external ocular infections in selected ophthalmology clinics in Sana'a city. Universal J Pharm Res 2020; 5(3), July 2020. *https://doi.org/10.22270/ujpr.v5i3.409*
39. Al-Shamahy HA, Abbas AMA, Mahdie Mohammed AM, Alsameai AM. Bacterial and fungal oral infections among patients attending dental clinics in Sana'a City-Yemen. On J Dent Oral Health 2018; 1(1): 1-6. *https://doi.org/10.33552/OJDOH.2018.01.000504*
40. Gylan EMA, Muharram BA, Al-Shamahy HA, *et al*. *In vitro* evaluation of the antimicrobial activity of five herbal extracts against *Streptococcus mutans*. Universal J Pharm Res 2022; 7(1):1-6. *https://doi.org/10.22270/ujpr.v7i1.721*
41. Ishak AA, Alhadi AM, Al-Moyed KAA, Al-Shamahy HA. Childhood urinary tract infection: clinical signs, bacterial causes and antibiotic susceptibility. Universal J Pharm Res 2021; 6(4). *https://doi.org/10.22270/ujpr.v6i4.643*
42. Saleh AAM, Al-Shamahy HA, Al-Hrazi RMA, *et al*.. Biofilm formation and antibiotic susceptibility of uropathogens in patients with catheter associated urinary tract infections in Ibb city-Yemen. Universal J Pharm Res 2020; 4(6). *https://doi.org/10.22270/ujpr.v4i6.329*