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Incidence of surgical site infection, bacterial isolate, and their antimicrobial susceptibility pattern among patients who underwent surgery at Dessie Comprehensive Specialized Hospital, Northeast Ethiopia

Abdurrahman Ali[1], Daniel Gebretsadik[1] and Kassu Desta[2]

Abstract

Objective: Surgical site infection is the most common postoperative complication worldwide, representing a major burden for patients and health systems. The aim of the study is to determine the incidence and bacterial profile that cause surgical site infection among patients who underwent surgery in parts of Northeast Ethiopia.

Methods: A health facility-based cross-sectional study was conducted in Dessie Comprehensive Specialized Hospital from July 22 to October 25, 2016. A total of 338 patients from the obstetrics and gynecology and general surgical wards were included, through consecutive sampling technique. The specimens were collected aseptically on the first day when the patients had presented with clinical evidence of infection and then sent to the microbiology laboratory. The data were entered and analyzed by SPSS version 20, and the results were explained by frequency distribution in tables and figures.

Results: The majority of participants were female (74.3%) and more than half (61.2%) of the surgeries were performed in the gynecology and obstetrics ward. Clinically, 49 patients (14.5%) were diagnosed as developing surgical site infection, and wound swabs were taken for bacteriological study. About 41 (83.7%) swabs showed bacterial growth, indicating 12.13% overall prevalence of bacterial surgical site infection. Out of 48 bacterial isolates, more than half (56.25%) of them were Gram negative. The most frequent isolate was *Staphylococcus aureus*, 14 (66.67%), followed by *Escherichia coli*, 9 (33.33%). Out of the total bacterial isolates, 38 (79.2%) isolates were found to be multidrug resistant, and the rate of multidrug resistant was higher among Gram-negative isolates.

Conclusion: An average rate of surgical site infection was found to be reported and significant numbers of bacterial isolates were also detected. The highest rate of surgical site infection was reported in prostate surgery, followed by small bowel, vaginal hysterectomy, and exploratory laparotomy surgical procedures. Periodic surveillance on the incidence rate and bacterial profile along with the determination of their antibiotic susceptibility should be performed.

Keywords

Incidence, surgical site infection, bacteria, antimicrobial resistance, Ethiopia

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Introduction

Surgical site infection (SSI) is an infection that occurs after surgery in the part of the body where the surgery took place due to contamination during the time of the operation.[1,2] It is the most common postoperative complication worldwide, representing a major burden for patients and health systems.[3] The infection causes a significant amount of morbidity and mortality among patients, particularly those who live in low resource areas.[4] SSIs occur within 30 days after the operative

[1]Department of Medical Laboratory Science, College of Medicine and Health Sciences, Wollo University, Dessie, Ethiopia
[2]Department of Medical Laboratory Sciences, School of Allied Health Sciences, College of Health Science, Addis Ababa University, Addis Ababa, Oromia, Ethiopia

Corresponding author:
Daniel Gebretsadik, Department of Medical Laboratory Science, College of Medicine and Health Sciences, Wollo University, P.O. Box 1145, Dessie, 1145, Ethiopia.
Email: gebretsadikd@gmail.com

procedure (except in the case of added implants, when the duration extends to 1 year from the operation).[2,5] In order to minimize the chance of occurrence of SSI, the patient, the healthcare providers, and other stakeholders should be aware of and implement the different preventive measures before and after the surgical procedures.[2,6]

In different parts of the world, varied proportions of SSI have been reported so far. A global, multicenter study across 66 countries including low-income, middle-income, and high-income countries indicated that the overall incidence of SSI was 12.3%.[7] Among study participants in Sierra Leone, the incidence of SSI reported was 11.5%.[8] A systematic review and meta-analysis in sub-Saharan Africa indicated that the pooled incidence of SSI was 14.8%.[9] A relatively low incidence rate of SSI was revealed in a study conducted in China.[10] In Ethiopia, a similar study revealed the overall incidence of SSI to be 21.1%.[11] The incidence of SSI in these studies showed that the problem is still worsening in developing countries compared to developed countries. A study conducted in low- and middle-income countries showed another rationale for the increasing burden of SSI in wide areas of those regions as well as globally.[12] In different parts of the world, either elective or emergent types of surgery have been performed at various points in time. In each of these surgery types, various surgical procedures have been accomplished successfully. But the bad scenario is that patients who undergo these surgical procedures are highly vulnerable to SSI.[13–15] These SSIs can be reduced while we comply with infection prevention practices; this was demonstrated by the reduction of SSIs during COVID-19, which included compliance with hand hygiene, universal mask usage, and social distancing practices.[16,17]

In many studies in various locations, a variety of different bacterial pathogens are responsible for causing infection in the surgical area. The majority of studies concluded that Gram-negative pathogens are the primary cause of infection.[8,11,18–20] The frequently isolated Gram-negative bacterial pathogens are *Escherichia coli*, *Klebsiella* species, *Pseudomonas* species, and *Proteus* species.[11,19] Although Gram-positive bacterial pathogens are not the dominant isolates in general, but specifically some species like *Staphylococcus aureus*, coagulase-negative *Staphylococcus* (CoNS), and *Streptococcus* species were considered as the cause of devastating effect on the patients.[11,19,21] These pathogens are exhibiting a prominent level of antibiogram resistance against the tested drugs.[22,23]

In Ethiopia, limited studies have been conducted on SSI and different outputs have also been forwarded about the different aspects of the problem.[11,24–26] But still, there is a paucity of research on SSI in the country, particularly in the northeastern part of Ethiopia. As a result, the current study was carried out to fill this research gap by determining the prevalence of bacterial infection with their antibiograms in the country's northeastern region. The study provided the bacterial profile that can cause infection at surgical wards in the health facility. It also provided the health facility's stakeholders and physicians the spectrum of the problem. The result of the current study rings an alarm for the antimicrobial stewardship activities in all cases of bacterial infection in the health facilities.

Methods

Study area, period, and design

From July 22 to October 25, 2016, a hospital-based cross-sectional study was conducted at Dessie Comprehensive Specialized Hospital (DCSH). The hospital is situated in South Wollo Zone, Amhara Region, Northeast Ethiopia, and it is the only referral hospital in Wollo Province, which serves about 8 million people including the neighboring regions. The hospital has more than 200 beds and offers different specialized services, including pediatrics, surgery, obstetrics and gynecology, orthopedics, and internal medicine. On average, about 10 major operations are performed per day.

Population

All patients who underwent surgery at the hospital were considered as the source population. All patients from obstetrics and gynecology and general surgical wards who underwent clean and clean contaminated surgeries during the study period were taken as the study population. Patients who were admitted to obstetrics and gynecology and general surgical wards for surgery and underwent clean or clean contaminated surgeries and/or those who were willing to give informed consent to participate in this study were included. Patients with infection occurring 30 days after the operation if no implant was in place, infection on the episiotomy, contaminated wounds, procedures in which healthy skin was not incised, such as opening abscesses, pediatrics below the age of 15 years, and orthopedic surgeries were not included in this study.

Sample size and sampling technique

In this study, a total of 338 patients from the obstetrics and gynecology and general surgical wards who fulfilled the inclusion criteria during the study period were included. A consecutive sampling technique was employed to select the study subjects.

We have considered 95% confidence interval, 11.4% previous prevalence,[27] and 4% margin of error (d)

$$n = \frac{\left(Z_{\alpha/2}\right)^2 \times p\ (1-p)}{d^2}$$

$$n = \frac{(1.96)^2 \times 0.114(1-0.114)}{[0.04]^2}$$

$n = 243$

By adding 10% contingency, the final minimum calculated sample size became 268. In order to increase the representativeness of the study, we enrolled 338 study subjects that had visited the hospital during the study period.

Data collection

Data regarding the study participants were collected through the reviewing of the patient's card and through microbiological techniques. The reviewed data were collected by the physician from the patient card, and the data collectors were requesting the patients themselves for confirmation. The microbiological data (information) were obtained via the laboratory analysis of a swab from the wound site.

Specimen collection

The specimens were collected aseptically on the first day when the patients presented with clinical evidence of infection (purulent drainage from the incision or drain) before the wound was cleaned with antiseptic. SSI cases were defined by surgical and obstetrics and gynecology residents who had provided adequate information regarding the CDC SSI criteria. The samples were collected by experienced nurses, from the depth of the wound with strict aseptic precautions with the help of sterile cotton swab sticks moistened with sterile saline for bacteriological examination. Two swabs from each sample were obtained, one for the direct smear study and the other for an aerobic culture, which was immediately sent (with a maximum delay of 20 mins) to the Amhara Public Health Institute (APHI)—Dessie branch in a separate sterile test tube for investigation.

Laboratory investigation

First direct microscopic examination was done via Gram staining technique to look for pus cells and the bacteria. The first swab was used for making a smear by rolling the swab stick on a clean glass slide, which was then alcohol fixed and stained by the Gram staining technique following the standard operating procedure (SOP). The Gram-stained smear was examined under a microscope and the bacteria were broadly classified into cocci and bacilli, Gram positive or Gram negative. This report was then correlated with the growth on the culture plates after 24–48 h. The second swab was inoculated on sheep blood agar and MacConkey agar as well as Mannitol salt agar and incubated at 37°C for 24–48 h under aerobic conditions. The culture media were prepared by following the manufacturer's instructions as well as inputs from SOPs.[28] Then, identification of the growth was performed by studying the morphology of the colonies; smear from pure colonies were prepared and stained with Gram stain; and a microscopic examination was performed to aid the identification process. When there was a mixed growth, colonies of different morphological characteristics were subcultured on appropriate media in order to obtain a pure colony. The isolated bacteria were further microbiologically identified by using the relevant biochemical tests. The test for antibiotic susceptibility was performed by using the Kirby–Bauer disc diffusion method on Mueller–Hinton agar using antibiotics according to the Clinical and Laboratory Standards Institute (CLSI) guideline.[29] The Mueller–Hinton agar was enriched with 5% sheep blood in the case of fastidious bacteria like *Streptococcus* species. Several isolated colonies of similar morphology were taken carefully and suspended in sterile nutrient broth and/or sterile normal saline. The suspension was then gently agitated to get a uniform suspension and the turbidity of the suspension was matched with the McFarland 0.5% barium sulfate opacity standard. A sterile swab was dipped into the suspension of the isolate, squeezed against the side of the tube to remove excess fluid and spread over the Mueller–Hinton agar plate following the SOP. Sensitivity discs for appropriate drugs were placed on the media and incubated at 37°C for 24 h.[9] The final identification of the bacteria was made by taking into account the results of the various biochemical tests. Antibiotic susceptibility patterns were reported by measuring the zone of inhibition on a millimeter scale. The antibiotic discs were reported as susceptible, intermediate, susceptible-dose dependent, and resistant, based on the criteria provided by CLSI document M100-S24. We have used two 150 mm antimicrobial susceptibility testing (AST) plates for each of the Gram-positive bacterial isolate.

Methicillin resistance for *S. aureus* and CoNS was determined by a disc diffusion test using a cefoxitin (30 µg) disc on Mueller–Hinton agar. Plates were incubated and maintained at 33–35°C for 24 h. Results were interpreted according to CLSI guidelines, that is, for *S. aureus* and CoNS, zone diameters $\leqslant$21 and $\leqslant$24 mm, respectively, were considered resistant to methicillin. Extended Spectrum Beta-Lactamases (ESBL) production was screened on Mueller–Hinton agar with a 30 µg ceftriaxone disc, and isolates with zone diameters of $\leqslant$25 mm were considered positive for ESBL screening according to CLSI guidelines and confirmed using the double disc approximation method. Discs containing ceftazidime (30 µg) and cefotaxime (30 µg) were placed 20 mm center-to-center with the amoxicillin/clavulanate (20/10 µg) disc. The plate was then incubated at 37°C for 18–20 h. An enhanced zone of inhibition toward the amoxicillin/clavulanate (20/10 µg) disc was considered positive for ESBL production.[30] Multidrug-resistant (MDR) bacteria were identified based on the ECDC definition, in which a bacterium is classified as MDR when the isolate is non-susceptible to at least one agent in three or more antimicrobial categories.[31] For Gram-positive organisms, susceptibility was tested against penicillin (10 units), ampicillin (10 µg), ceftriaxone (30 µg), vancomycin (30 µg), gentamicin (10 µg), erythromycin (15 µg), tetracycline (30 µg), ciprofloxacin (5 µg), clindamycin (2 µg), trimethoprim/sulfamethoxazole (1.25/23.75 µg), tetracycline (30 µg), cefoxitin (30 µg), cefepime (30 µg), and chloramphenicol (30 µg). Gram-negative

organisms were tested against ampicillin (10 μg), amoxicillin/clavulanate (20/10 μg), ceftriaxone (30 μg), ceftazidime (30 μg), gentamicin (10 μg), ciprofloxacin (5 μg), trimethoprim/sulfamethoxazole (1.25/23.75 μg), piperacillin (100 μg), cefepime (30 μg), cefoxitin (30 μg), and amikacin (30 μg).

Quality control

The reliability of the laboratory test results was ensured by implementing quality control measures throughout the whole processes of the laboratory work. All materials, equipment, and procedures were adequately controlled. Aseptic techniques were followed in all the steps of specimen collection and inoculation onto culture media to minimize contamination. All the culture media were prepared according to the manufacturer's instruction. SOPs for sample collection, transport, culture, and susceptibility testing of the isolated organisms were followed to ensure procedural quality. International control bacterial strains were used in controlling the tests carried out in this study. Qualities of the culture media, antibiotic discs, as well as personal performance, were controlled by reference strains, such as *E. coli* American Type Culture Collection (ATCC) 25922, *S. aureus* ATCC 25923, and *Pseudomonas aeruginosa* ATCC 27853.

Statistical analysis. The data were entered and analyzed by SPSS version 20 and the results were explained by frequency distribution in tables and different figures. Descriptive analysis like simple frequency and cross tabulation were performed in order to obtain the distribution of data.

Ethical considerations

Ethical clearance was obtained from the Ethical Review Committee of Addis Ababa University, College of Health Science, Department of Medical Laboratory Sciences. Written permission to conduct the study in DCSH and APHI, Dessie Branch, was requested from the administrators of both institutions. Written informed consent was obtained from the subjects and legally authorized representative of the minor subjects for participation in the study. Information about the study was given to the participants to ensure they had the necessary information to provide informed consent. Appropriate counseling and assurance of confidentiality were given to participants with worries and anxiety about the study. The study participants' laboratory results were communicated to the attending physician for use in guiding patients' management.

Results

Sociodemographic characteristic of the study participants

Overall, a total of 338 patients who fulfilled the inclusion criteria were enrolled in this study and the majority of them were female (74.3%). More than half (61.2%) of the surgeries were performed in the gynecology and obstetrics ward, while the rest 38.8 % were in general surgery. Participants in the study ranged in age from 16 to 76 years old, with a mean age of 35.25 ± 15.07 years. The majority of study participants (42.6%) were between the ages of 25 and 34 years (Table 1).

Table 1. Sociodemographic characteristics of the study participants in DCSH, from July 22 to October 25, 2016.

Variables	No	%
Sex of the participant		
Male	87	25.7
Female	251	74.3
Ward type		
General surgery	131	38.8
Gynecology and obstetrics	207	61.2
Residence		
Rural	164	48.5
Urban	174	51.5
Age in years		
15–24	74	21.9
25–34	144	42.6
35–44	34	10.1
45–54	28	8.3
55–64	38	11.2
⩾65	20	5.9
Mean ± SD	35.25 ± 15.07	
Median	28	
Range	16–76	

Culture results

Forty-nine (14.5%) of the total study subjects were clinically diagnosed with SSI, and wound swabs were collected from these patients for bacteriological testing. Bacterial growth was detected in 41 (83.7%) of the 49 wound swabs, resulting in a 12.13% overall prevalence of bacterial SSI. Single bacteria were isolated from 34 (82.9%) of the samples with bacterial growth, whereas the remaining seven (17.1%) of the samples showed mixed bacterial growth. Out of 48 bacterial isolates, more than half (56.25%) of them were Gram negative (Table 2).

The rate and distribution of SSI

The rate of SSI was 16.8% and 9.2% in the general surgical ward and the obstetrics and gynecology ward, respectively. Among the procedures, the highest rate of SSI was found in prostate surgery (PRST), followed by small bowel (SB), vaginal hysterectomy (VHYS), and exploratory laparotomy (XLAP) with their respective rates of 22.2%, 21.1%, 20%, and 18.8% (Table 3).

Bacterial etiology of SSI

The most predominant isolate among Gram-positive bacteria was *S. aureus* ($n = 14$; 66.67%), followed by *CoNS* ($n = 4$;

Table 2. Culture results of samples taken from the study participants suspected to develop SSI in DCSH, July 22 to October 25, 2016.

	Number	Percent
Culture result N = 49		
Growth	41	83.7
No growth	8	16.3
Single bacterial growth	34	82.9
Mixed bacterial growth	7	17.1
The bacteria isolated N = 48		
Gram-negative rods	27	56.25
Gram-positive cocci	21	43.75

Table 3. Distribution of SSI by surgical procedure in DCSH, July 22 to October 25, 2016.

Surgical procedure	Total number of procedures	Total number of SSI	Rate of SSI (%)
APPY	28	3	10.70
COLO	34	6	17.60
CSEC	166	12	7.20
HER	15	1	6.70
HYST	27	5	18.50
PRST	18	4	22.20
SB	19	4	21.10
VHYS	10	2	20.00
XLAP	16	3	18.80
Others	5	1	20.00
Total	338	41	12.13

APPY: appendix surgery; COLO: colon surgery; CSEC: cesarean section; HER: herniorraphy; HYST: abdominal hysterectomy; PRST: prostate surgery; SB: small bowel surgery; VHYS: vaginal hysterectomy; XLAP: exploratory laparotomy.

19.05%). The principal organisms isolated as Gram-negative rods were *E. coli* (9, 33.33%), *Klebsiella* species (7, 25.93%), and *Citrobacter freundii* (3, 11.11%) (Figure 1).

The majority of the isolates were from cesarean sections, accounting for 15/48 (31.25%). Among these, *S. aureus* was the most prevalent organism, which was detected in 6/15 (40%) samples, followed by *Streptococci*, *Klebsiella* species, and *C. freundii. E. coli was* the most common organism isolated from colon and prostate surgery specimens, which were isolated from 3/7 (42.9%) and 2/5 (33.3%) specimens, respectively (Table 4).

Antibiotic susceptibility pattern

As presented in Table 5, 100% of the *Staphylococcus* species were resistant to penicillin, whereas a moderate resistance was observed for the rest of the antibiotics tested, including cotrimoxazole (55.6%), cefoxitin (55.6%), and tetracycline (38.9%). But all the *Staphylococcus* species were sensitive to chloramphenicol and 77.8% of them were also found to be sensitive to ciprofloxacin and clindamycin. About 66.67% of *E. coli* and two of the *K. pneumoniae* species were found to be *ESBL*-producing strains. Out of 14 *S. aureus* species, 6 (42.86%) were found to be methicillin-resistant *Staphylococcus aureus* (MRSA), whereas all 4 CoNS species were found to be Methicillin-Resistant Coagulase negative *Staphylococcus* (MRCoNS). All *Enterobacteriaceae* isolates showed a high degree of resistance to multiple antimicrobial agents tested: 91.3% for ampicillin, 87% for augmentin, and 73.9% for cotrimoxazole and ceftriaxone. A moderate degree of resistance was observed for ciprofloxacin, cefepime, and gentamicin (52.2%, 47.8%, and 34.8%, respectively). But 95.7% of the *Enterobacteriaceae* isolates were found to be sensitive to amikacin (Table 5).

Out of the total bacterial isolates, 38 (79.2%) isolates were found to be MDR and the rate of MDR was higher among Gram-negative isolates. While considering specific bacterial species, the predominant rate of MDR was indicated in *S. aureus*, followed by *E. coli* and *Klebsiella* species (Table 6).

Only two bacterial isolates, one from the Gram positive and one from the Gram negative, were fully susceptible to the tested antibiotics, whereas only two isolates from the Gram-positive category were found to be resistant to the seven tested antibiotics. The trends in the number of antibiotic-resistant isolates revealed that Gram-negative isolates were resistant to the most antibiotic classes (Figure 2).

Discussion

Our study had focused on the determination of the prevalence of SSIs, identification of the bacterial isolate responsible for SSIs, and investigation of the drug susceptibility pattern of the isolate. This information was communicated with the physician and the physician took appropriate action for the better management of the health of their patients.

In this study, the rate of clinical SSI (14.5%) was slightly higher than that in similar studies done in Addis Ababa, Ethiopia (9.8%),[32] and Alexandria, Egypt (2.3%),[33] but it was lower than that in other studies performed in the Harari region, Mekelle, and Jimma, Ethiopia.[11,23,25,34] It was also lower than a pooled prevalence report that was conducted in Ethiopia.[35] This difference across studies could be due to the fact that the rate of SSIs varies widely across study periods, between hospitals and between surgeons, suggesting that working practices play a critical role in the prevention of these infections.[36]

The overall culture-confirmed SSI rate in the present study was 12.1% (41/338). This is in agreement with studies performed in Addis Ababa, Bahir Dar, and Mekelle, Ethiopia, as well as other studies conducted in India, which reported 10.9%–17.7%.[25,26,37–39] Whereas it was higher than that in studies conducted in two European countries, Italy and

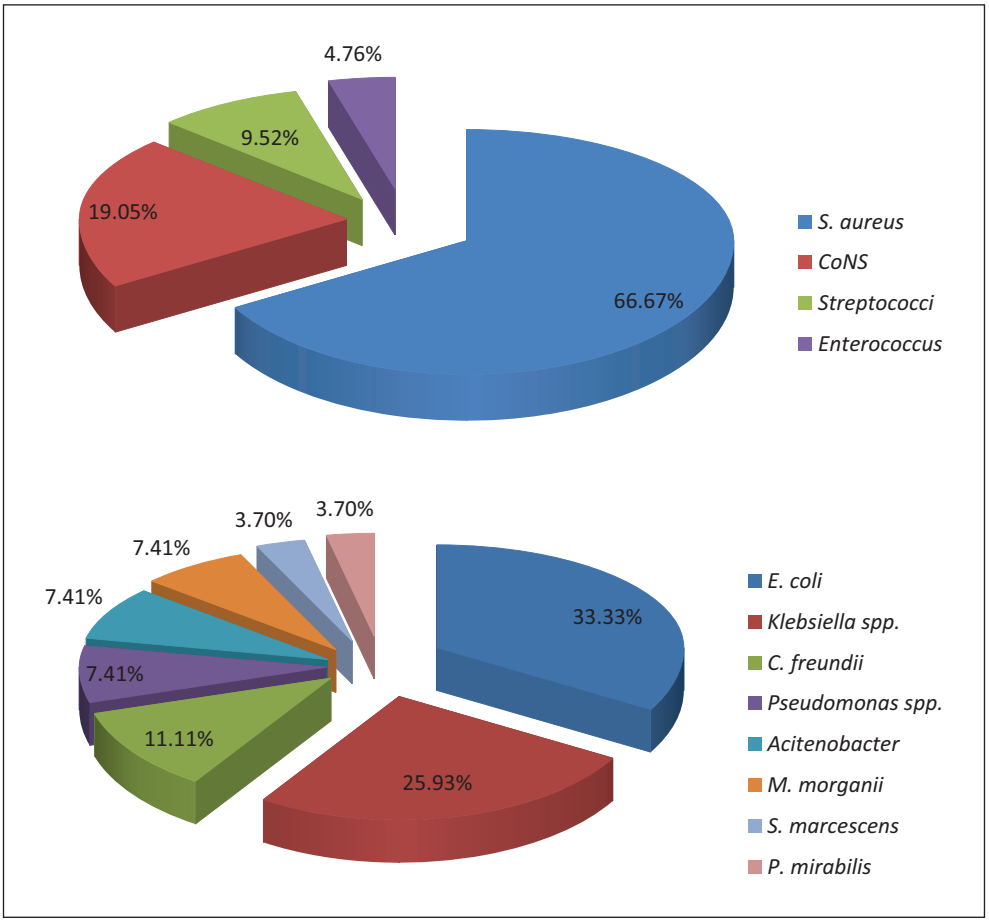

Figure 1. Distribution of pathogenic bacteria isolated from the study participants with SSI in DCSH, July 22 to October 25, 2016.
SSI: surgical site infection; DCSH: Dessie Comprehensive Specialized Hospital.

Table 4. Distribution of pathogenic bacterial isolate in relation to type of surgical procedure in DCSH, July 22 to October 25, 2016.

Bacterial isolate	Surgical procedure									
	APPY *N*=4	COLO *N*=7	CSEC *N*=15	HER *N*=1	HYST *N*=5	PRST *N*=6	SB *N*=4	VHYS *N*=2	XLAP *N*=3	OTHERS *N*=1
Staphylococcus aureus no	1	1	6	1	1	1	1	1	1	0
CoNS no	0	1	0	0	1	1	0	0	1	0
Enterococcus no	0	0	0	0	0	1	0	0	0	0
Streptococci no	0	0	2	0	0	0	0	0	0	0
Escherichia coli no	1	3	1	0	1	2	0	0	1	0
Pseudomonas sp. no	0	1	0	0	0	0	0	0	0	1
Proteus mirabilis no	0	0	0	0	0	0	0	1	0	0
Klebsiella sp. no	2	1	2	0	1	0	1	0	0	0
Citrobacter freundii no	0	0	2	0	0	0	1	0	0	0
Serratia marcescens no	0	0	1	0	0	0	0	0	0	0
Acinetobacter no	0	0	1	0	0	0	1	0	0	0
Morganella morganii no	0	0	0	0	1	1	0	0	0	0

APPY: appendix surgery; COLO: colon surgery; CSEC: cesarean section; HER: herniorraphy; HYST: abdominal hysterectomy; PRST: prostate surgery; SB: small bowel surgery; VHYS: vaginal hysterectomy; XLAP: exploratory laparotomy.

Table 5. Antibiotic resistance pattern of SSI bacterial isolates in DCSH, July 22 to October 25, 2016.

Antibiotics	Isolated bacteria											
	Staphylococcus aureus	*CoNS*	*Enterococcus*	*Streptococcus* sp.	*Escherichia coli*	*Pseudomonas* sp.	*Proteus mirabilis*	*Klebsiellas* sp.	*Citrobacter freundii*	*Serratia marcescens*	*Acinetobacter* sp.	*Morganella morganii*
ERY												
Sensitive	10	1	0	1								
Intermediate	2	0	0	0								
Resistance	2	3	1	1								
PEN												
Resistance	14	4	1	2								
CPR												
Sensitive	12	2			1		1	3	2	0	0	1
Intermediate	1	0			1		0	1	1	0	0	0
Resistance	1	2			7		0	3	0	1	2	1
DA												
Sensitive	11	3		2								
Intermediate	0	0		0								
Resistance	3	1		0								
TET												
Sensitive	7	2										
Intermediate	2	0										
Resistance	5	2										
CAF												
Sensitive	14	4	0									
Intermediate	0	0	0									
Resistance	0	0	1									
COT												
Sensitive	6	1			3		1	0	0	0		0
Intermediate	0	1			0		0	1	0	0		1
Resistance	8	2			6		0	6	3	1		1
CN												
Sensitive	12	4			6	1	1	4	1	0	0	2
Intermediate	2	0			1	0	0	0	0	0	0	0
Resistance	0	0			2	1	0	3	2	1	2	0
CXT												
Sensitive	8	0			7		1	5	1	0		2
Intermediate	0	0			1		0	0	0	0		0
Resistance	6	4			1		0	2	2	1		0
CTR												
Sensitive						0					0	
Intermediate						0					0	
Resistance						2					2	

(Continued)

Table 5. (Continued)

Antibiotics	Isolated bacteria											
	Staphylococcus aureus	*CoNS*	*Enterococcus*	*Streptococcus* sp.	*Escherichia coli*	*Pseudomonas* sp.	*Proteus mirabilis*	*Klebsiellas* sp.	*Citrobacter freundii*	*Serratia marcescens*	*Acinetobacter* sp.	*Morganella morganii*
PIPC												
Sensitive						0					0	
Intermediate						0					0	
Resistance						2					2	
AMK												
Sensitive					9	2	1	6	3	1	2	2
Intermediate					0	0	0	0	0	0	0	0
Resistance					0	0	0	1	0	0	0	0
FEP												
Sensitive				1	2		1	3	1	0	0	1
SDD				0	1		0	1	1	1	0	0
Resistance				1	6		0	3	1	0	2	1
AMP												
Sensitive			1		0		1	1	0	0		0
Intermediate			0		0		0	0	0	0		0
Resistance			0		9		0	6	3	1		2
AUG												
Sensitive					0		1	2	0	0		0
Intermediate					0		0	0	0	0		0
Resistance					9		0	5	3	1		2
CTR												
Sensitive				1	1		1	2	0	0	0	1
Intermediate				1	0		0	1	0	0	0	0
Resistance				0	8		0	4	3	1	2	1
Vancomycin												
Sensitive			1	2								
Intermediate			0	0								
Resistance			0	0								
ESBL												
Positive					6			2				
Negative					3			0				

ERY: erythromycin; PEN: penicillin; CPR: ciprofloxacin; DA: clindamycin; TET: tetracycline; CAF: chloramphenicol; COT: cotrimoxazole; CN: gentamicin; CXT: cefoxitin; FEP: cefepime; AMP: ampicillin; AUG: augmentin; CTR: ceftriaxone; PIPC: piperacillin; AMK: amikacin; CN: gentamicin.

Table 6. Frequency of multidrug-resistant bacteria in Gram-positive and Gram-negative bacteria isolated from SSI in DCSH, July 22 to October 25, 2016.

Group of the isolate	MDR			
	Yes		No	
	Number	%	Number	%
Staphylococcus aureus	9	18.8	5	10.4
CoNS	3	6.2	1	2.1
Enterococcus	1	2.1	0	0
Streptococcus sp.	1	2.1	1	2.1
Escherichia coli	8	16.7	1	2.1
Pseudomonas sp.	1	2.1	1	2.1
Proteus mirabilis	0	0	1	2.1
Klebsiella sp.	7	14.6	0	0
Citrobacter freundii	3	6.2	0	0
Serratia marcescens	1	2.1	0	0
Acinetobacter sp.	2	4.2	0	0
Morganella morganii	2	4.2	0	0
Total (*N* = 48)	38	79.2	10	20.8
Gram positive (*N* = 21)	14	66.7	7	33.3
Gram negative (*N* = 27)	24	88.9	3	11.1

Turkey, which reported 2.6% and 4.3%, respectively.[40,41] This might be due to the fact that these studies were conducted at a national level on a large and diverse group of people as well as the availability of advanced infection control practices including advanced surgical techniques, improved operating room ventilation, sterilization methods, barriers, patient care, and safety. The poor state of infrastructure and equipment, unreliable supplies and quality of medications, shortcomings in organizational management and infection control, difficulties in the supply and training of personnel, and severe underfinancing in the developing world contribute to the difficulties in surgical safety and patient care.[42]

More than half of the pathogenic bacteria isolated from post-surgical wound infection in the present study were Gram-negative rods (56.25%) and the rest were Gram-positive cocci (43.75%). This finding was in line with other studies conducted in Bahir Dar, Addis Ababa, Hawassa, and Mekelle, Ethiopia, as well as studies in Nigeria and India.[22,25,26,32,43,44] A prospective cohort study conducted in Sierra Leone indicates more than 83% of bacterial isolates were Gram negative, and another study conducted in Ethiopia also showed about 80% of the isolates were Gram-negative bacteria, which demonstrates that Gram-negative bacteria are still significant isolates in causing SSIs.[8,11] On the contrary, other similar studies reported Gram-positive cocci as a predominant isolate over Gram-negative rods.[5,39,45] The predominance of Gram-negative rods in this study can be justified by the fact that, as Jnaneshwara et al.[28] explain, there has been an increase in postoperative wound infections caused by Gram-negative organisms in recent years. One source of variation in the bacterial isolates could be the variation in the wards in which the surgery procedures are performed.

The predominant isolates among the 21 Gram-positive isolates in this study were *S. aureus* 14 (66.67%), followed by *CoNS* (19.05%), *Streptococcus* species (9.52%), and *Enterococcus* species (4.76%). Among the 27 Gram-negative isolates, *E. coli* accounted for the highest proportion (33.33%), followed by *Klebsiella* species (25.93%) and *C. freundii* (11.11%). Overall, *S. aureus* was the predominant isolate (29.2%), followed by *E. coli* (18.6%), *Klebsiella* species (14.6%), and *CoNS* (8.3%). Similar to the findings of the present study, a study conducted in the Harari region of Ethiopia indicated *S. aureus* and *E. coli* were the two most predominant isolates among the Gram-positive and Gram-negative categories.[23] In contrast to the current study, another similar study conducted in Ethiopia and Spain found *E. coli* to be the most common bacterial isolate rather than *S. aureus*.[11,46] Even though we did not differentiate the specific species of the genus Streptococcus in the isolates in this study, there were two isolates from the cesarean section. Similarly, Group B Streptococcus is a major cause of cesarean section SSI around the world.[21]

The bacterial profile in different surgical procedures was variable in this study. The bacteria isolated in appendix surgery were two *Klebsiella* species, *S. aureus*, and *E. coli* (one each). Two independent previous studies also isolated these organisms in appendix surgery, even though, there was little variation in the number between studies and additional isolates that were reported.[47,48] In colon surgery, the most dominant isolate was *E. coli* (three), followed by *S. aureus*, *CoNS*, *Pseudomonas* species, and *Klebsiella* species (one each). *S. aureus* was the predominant isolate (six) in cesarean sections, followed by *Streptococcus* species, *Klebsiella* species, and *C. freundii* (two each) and *E. coli*, *S. marcescens*, and *Acinetobacter* species (one each). *S. aureus* was also the predominant isolates in cesarean section, as it was reported by previous studies from Uganda and Nigeria, but the pattern in the distribution of the entire isolates was different.[47,48]

In this study, the highest resistance which is exhibited by Enterobacteriaceae isolates was for ampicillin (91.3%), followed by augmentin (87%), cotrimoxazole (82.6%), and ceftriaxone (78.3). The resistance of Enterobacteriaceae isolates to ampicillin in this study was in line with previous studies conducted in Bahir Dar, Mekelle, Addis Ababa, and Hawassa, Ethiopia, as well as Uganda, which reported 88.2%–96.5%.[25,26,32,44,48] This study's cotrimoxazole resistance by Enterobacteriaceae isolates was consistent with an Indian report (88.3%), but it was slightly higher than reports from Bahir Dar (64.7%) and Hawassa (58.6%).[25,44,49] Ceftriaxone resistance by Enterobacteriaceae isolates in the present study was in harmony with previous findings from Bahir Dar, Mekelle, and Addis Ababa.[25,26,32] This high rate of resistance for ampicillin, augmentin, cotrimoxazole, and ceftriaxone could be attributed to the fact that they are relatively cheap and/or widely prescribed in the empirical treatment of

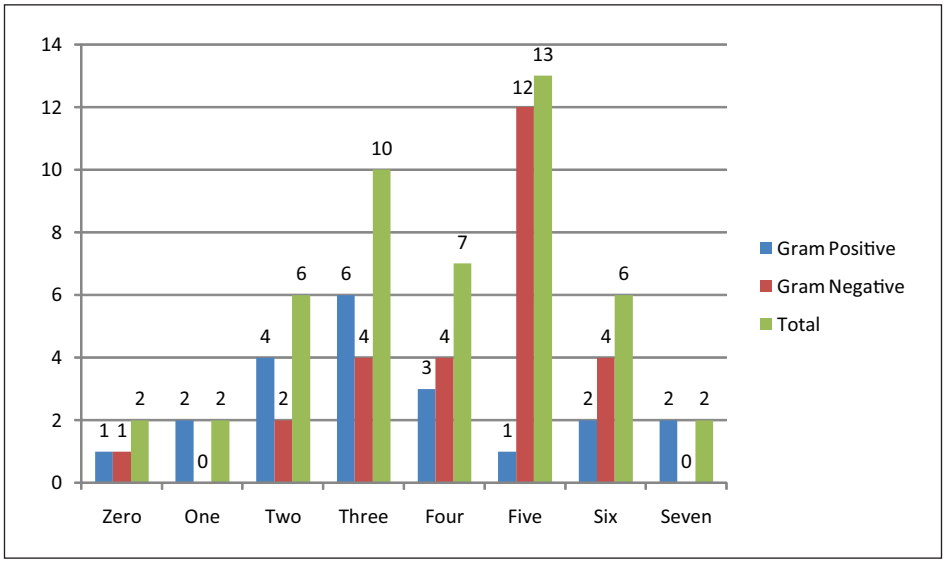

Figure 2. Distribution of Gram-positive and Gram-negative bacteria based on their resistance for different number of classes of antibiotics in DCSH, July 22 to October 25, 2016.

various bacterial infections. This can be justified by the fact that in this study, ampicillin and ceftriaxone (alone or together with metronidazole) were the antibiotics given to 97.1% of the patients who had received preoperative antibiotic prophylaxis. The rate of cefoxitin resistance in the present study was lower than that of a previous report from Addis Ababa, which reported 72.1%.[32] Only 1 (4.3%) out of the 23 Enterobacteriaceae isolates showed resistance to amikacin in this study. In contrast to this study, a study from India reported a resistance rate of 25.9% for amikacin.[49] The lowest resistance for amikacin in the present study could be due to the unavailability of this drug in the study setting.

In the present study, around 80% of all the isolates were found to be MDR, which is higher than a study conducted in Egypt, which showed only 13% of the total isolates were MDR.[33] The MDR rates for Gram-negative and Gram-positive isolates were 88.9% and 66.7%, respectively. The overall MDR rate in this study was slightly lower than that of the previous reports from Bahir Dar and Hawassa, Ethiopia, which reported 97.6% and 93.2%, respectively.[26,44] The rate of MDR among Gram-negative isolates in this study was also relatively lower as compared to that of previous reports from Bahir Dar and Addis Ababa, Ethiopia.[26,32] The reason for the relatively lower rate of MDR in the present study could be due to differences in defining MDR; in the aforementioned previous studies, isolates not susceptible to at least two drugs were considered to be MDR.

In this study, most of the Gram-positive isolates (6 out of 21) showed resistance to three classes of antibiotics, whereas 2 out of the 21 Gram-positive isolates showed a resistance pattern for seven classes of antibiotics. Concerning Gram-negative isolates, most (12 out of 27) of them were resistant to five classes of antibiotics. A maximum of six classes of antibiotics were resisted by four of the Gram-negative isolates. Although the rate of MDR in the present study was relatively lower than that of the reports from Bahir Dar and Addis Ababa, Ethiopia, due to differences in defining MDR, it was still alarmingly high. This coincides with the fact that the problem of MDR continues to grow, especially in developing countries, as a result of antimicrobial drug overuse, overdosing, drug prescription with an improper susceptibility test, unethical drug promotion, self-medication, and a long duration of hospitalization.[50]

Limitation of the study

The study was conducted in a health facility that serves a huge number of clients and also provides referral health services for outlying catchment areas. The current study was conducted in a single institution, but it would be more representative if it was conducted in several health facilities. We have done the study only in general surgery and gynecology and obstetrics wards, but it would be good if we included other wards in the study area. Because of a lack of microbiology laboratory facilities, we could not isolate anaerobic bacterial pathogens from the study participants.

Conclusion

In the present study, an average rate of SSI was found to be reported and significant numbers of bacterial isolates were also detected. The rate of SSI was high in the general surgical ward in comparison with that in the obstetrics and gynecology ward. The highest rate of SSI was reported in PRST,

followed by SB, VHYS, and XLAP surgical procedures. The number and percentage of Gram-negative rod isolates were found to be relatively high. The predominant Gram-negative and Gram-positive isolates were *E. coli* and *S. aureus*, respectively. Among the various surgical procedures, the cesarean section was found to have the highest rate of bacterial infection. *S. aureus* was the most prevalent organism in this surgical procedure and *E. coli* was the most common organism isolated from colon and PRST. Different patterns of antibiotic resistance had been observed among various bacterial isolates and the rate of MDR was found to be higher, particularly among Gram-negative isolates. Periodic surveillance of the incidence rate and bacterial profile, as well as antibiotic susceptibility testing, should be carried out.

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Author contributions

All authors were involved in proposal writing, designed the study, and participated in all implementation stages of the project. We were all involved in laboratory work, analyzing the data and finalizing the manuscript. The authors were responsible for the critical revision of the manuscript. All authors reviewed and approved the final manuscript.

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Ethics approval

Ethical approval for this study was obtained from Ethical Review Committee of Addis Ababa University, College of Health Science, Department of Medical Laboratory Sciences (DRERC/196/15/MLS)*.

Informed consent

Written informed consent was obtained from the subjects and legally authorized representative of the minor subjects.

Data availability

The authors confirm that all data underlying the findings are fully available without restriction. All relevant data are within the manuscript.

ORCID iD

Daniel Gebretsadik https://orcid.org/0000-0001-5032-5143

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